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Analysis of Japanese-U.S. Nuclear Power Plant Maintenance

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ABSTRACT

This report is an update of a report of the same title dated June 1984 and presents the results of a project designed to compare and contrast Japanese and United States nuclear power plant operating experience, preventive maintenance/surveillance requirements, and organization and management practices relating to maintenance. Findings are based on information obtained on the November-December 1983 and November 1984 visits to Japan by the NRC and representatives of Battelle's Pacific Northwest Division, and on various documents obtained from the Japanese (primarily the Ministry of International Trade and Industry--MITI) during and subsequent to the visits. U.S. data sources included NUREG-0020 (Greybook) and plant technical specifications. The study shows that Japanese plants experienced far fewer manual shutdowns, manual scrams, automatic scrams, and reduced loads than U.S. plants and that their mean-time-between-event (MTBE), even when adjusted for differences in average plant availability, was approximately 10 times greater than the U.S. MTBE. The report also points out significant differences in the Japanese approach to preventive maintenance, and in the Japanese regulatory approach to maintenance, their management and organizational context for maintenance, and other socioeconomic factors that may affect the performance of maintenance.

EXECUTIVE SUMMARY

PURPOSE

The purpose of this report is to present the results of work on a project entitled "Analysis of Japanese-U.S. Nuclear Power Plant Maintenance." This report is an updated version of the June 1984 report of the same title. It contains information obtained from the Japanese as part of the Bilateral Information Exchange program between the NRC and The Ministry of International Trade and Industry (MITI), including the 1983 Japanese operating experience.

BACKGROUND

The Deputy Director, Division of Human Factors Safety, Office of Nuclear Reactor Regulation (DHFS/NRR), accompanied by representatives from Battelle's Pacific Northwest Laboratory (PNL), and Human Affairs Research Centers (HARC), visited Japan between November 28 and December 11, 1983, to examine Japanese maintenance practices, focusing particularly on preventive maintenance. The trip resulted in the acquisition of numerous documents on preventive maintenance and other aspects of Japanese maintenance practices, including the 10-year work plans for annual inspections for the Genkai (Kyushu Electric Power Company) and Fukushima Daini (No. 2) (Tokyo Electric Power Company) Nuclear Power Plants, as well as the results of previous inspections at these plants. As a result of the visit to Japan, contacts were established with government agencies and industry organizations. A delegation of government and industry representatives from Japan visited the U.S. in February 1984 and met with the NRC staff and representatives of utilities, an NSSS vendor, Sandia National Laboratory and Battelle.

In November 1984 the Deputy Director, Division of Human Factors Safety, again visited Japan to participate in the Bilateral information Exchange meetings. A member of the Battelle project team also participated in two of the meetings. In preparation for the meetings, a number of questions were formulated to fill in gaps in information about the Japanese maintenance system. These questions were submitted to MITI prior to the meetings, and much of the information incorporated in this revision of the report was received from MITI in response to these questions. Included in the information from MITI was the 1983 operating experience of Japanese reactors.

The Japanese documents were analyzed and compared with U.S. information to determine the differences in the approaches to the regulation and practice of nuclear power plant maintenance.

PROJECT OBJECTIVE

The objective of this project is to assess the degree to which differing Japanese and U.S. approaches to the regulation and practice of nuclear power plant (NPP) maintenance may explain the difference in reactor trips and safety

equipment availability between U.S. and Japanese plants, and to assist in the continuing dialogue with the Japanese.

PROJECT ORGANIZATION

This project consisted of three primary tasks: 1) assessing the difference in Japanese-U.S. NPP operating experience, 2) assessing Japanese maintenance organizational and management practices, and 3) comparing and contrasting Japanese preventive maintenance practices with U.S. surveillance practices.

Task 1. Assess the Difference in U.S. and Japanese NPP Operating Experience

This task involved an assessment of the U.S. and Japanese NPP operating experience for 1981-1983 in order to draw some preliminary conclusions about factors that may be influencing the significant differences found in such indicators as number of automatic trips, forced outages, and capability/availability factors.

Task 2. Assess Japanese NPP Maintenance Organization and Management Practices

This task involved assessment of Japanese maintenance organizations, management personnel, and other factors within the context of Japanese cultural, economic, and government systems. The results of this task, along with the results of Task 1, were used in conjunction with Task 3 results to assess factors influencing differences in Japanese and U.S. operating experience.

Task 3. Compare and Contrast Japanese and U.S. NPP Preventive Maintenance Requirements

This task involved a review of the Japanese documents concerning preventive maintenance (PM) regulatory requirements and a comparison of these requirements with U.S. PM requirements, in order to contrast the two countries' approaches. Plant technical specifications from four U.S. plants known to be comparable to the Japanese plants Genkai 1 and Fukushima-Daini 1, were reviewed to determine NRC-mandated PM requirements. Findings from Tasks 1 and 2 of the project were incorporated in Task 3 in order to assess factors that may be influencing the differences in Japanese and U.S. operating experiences.

SUMMARY OF MAJOR PROJECT FINDINGS

- The Japanese reactors experience significantly fewer trips than U.S. reactors. This is true even when the data are normalized for number of plants operating, total megawatts produced per year and similar factors. Nor are the differences due to differences

in trip set points or technical specifications since Japanese requirements are very similar and in many cases identical to those in the U.S.

- A significant percentage of trips (both manual and automatic) are caused by balance of plant (BOP) problems. This is true for both Japan and the U.S. The absolute number of trips in Japan is far smaller than in the U.S.

- Japanese reactors had a mean-time-between-event (MTBE) for automatic scrams that was approximately 10 times greater than their U.S. counterparts.

- U.S. plants had a significantly higher rate of repetitive trips than their Japanese counterparts.

- The average availability of U.S. plants decreased steadily from 1981 to 1983, while Japanese plant availability increased over the same period.

- The overall capacity factors for the U.S. for 1981, 1982, and 1983 were 57%, 60% and 58%, respectively. For Japan the overall capacity factors for 1981, 1982 and 1983 were 58%, 66% and 69%, respectively.

- In the U.S. plants, almost all technical specifications-mandated surveillances consist of ensuring the operability of safety-related equipment through functional, administrative or visual verification. In Japan, on the other hand, the emphasis is on an extensive preventive maintenance program on both safety-related and BOP equipment. To a large extent, Japanese preventive maintenance consists of the disassembly and inspection of individual components.

- The Japanese maintenance program is based on a legal requirement to conduct an annual inspection of every nuclear power plant.

- The Japanese have in place a structured, industry-wide program of preventive maintenance. Their program consists of four fundamental elements: 1) a statutory annual inspection; 2) a voluntary internal inspection (conducted concurrently with the statutory annual inspection); 3) special work, including back fitting and corrective maintenance; and 4) routine inspection. The first three elements are conducted annually during a maintenance outage. The last element, "routine inspection," is conducted during plant operation.

- The MITI involves itself to a great extent in the preventive maintenance program by witnessing a significant number of maintenance activities during each plant's annual outage. Selection of maintenance activities to be witnessed is based in part on the

safety significance of the equipment but MITI also witnesses maintenance of BOP components. MITI uses a contractor as well as its own staff to witness maintenance activities.

- In general, the numbers and types of components subject to inspection are much greater than current technical specification requirements in the U.S. In addition, the inspection frequently goes beyond visual inspection to include disassembly and measurement for wear. The annual inspection takes approximately three months.

- The central role of nuclear power in the Japanese plan of energy self-sufficiency greatly influences its regulatory structure.

- The group orientation of the Japanese society to an important extent determines the form and practice of management and its organizational structure within the nuclear industry.

- Maintenance in Japanese plants is often done by teams of workers cross-trained so that jobs are rotated. Teams are responsible for the quality of the workers' performance.

- The group orientation of the Japanese society in combination with the Japanese system of labor relations impacts the way maintenance activities are structured and carried out.

- The use of subcontract organizations to perform maintenance is a very common practice in the nuclear industry in Japan. During the scheduled maintenance outages, most of the work is conducted either by personnel supplied by the vendors or by subcontractor organizations.

- The Japanese nuclear industry is characterized by close, stable relationships between the utilities, vendors and subcontractors. The implications of plant maintenance are significant, with vendors providing continuing maintenance and maintenance training for the utilities. Maintenance subcontractors provide a stable maintenance work force for scheduled maintenance activities. These patterns appear to allow the utilities to have a highly reliable maintenance program and work force.

ACKNOWLEDGMENTS

There are a number of people who were not primary authors of this report but whose contributions were essential to the success of the project and the report.

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1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this report is to present the results of a study to assess the degree to which differing Japanese and U.S. approaches to the regulation and practice of nuclear power plant maintenance may explain the difference in reactor trips and safety equipment availability between U.S. and Japanese plants.

1.2 BACKGROUND

In July 1983, the U.S. Nuclear Regulatory Commission (NRC) requested the NRC staff to provide information on why Japanese nuclear power plants have fewer automatic scrams than American plants. The staff provided preliminary data that showed that the frequency of reactor trips in Japan in 1982 was about 18 times less than in the U.S. The staff further indicated that the reported differences in scram frequency between Japan and the U.S. plants appeared to be real, and not due to differences in nomenclature, definitions, or reporting requirements (NRC 1983).

The staff continued to explore the issue, and later that year, the Deputy Director, Division of Human Factors Safety, Office of Nuclear Reactor Regulation (DHFS/NRR), accompanied by representatives from the Pacific Northwest Laboratory (PNL), and the Human Affairs Research Centers (HARC), visited Japan (between November 28 and December 11, 1983) to examine Japanese maintenance practices. Preventive maintenance was a particular focus during this trip. The trip resulted in the acquisition of numerous documents on preventive maintenance and other aspects of Japanese maintenance practices, including the 10-year work plans for annual inspections at the Genkai (Kyushu Electric Power Company) and Fukushima Daini (No. 2) (Tokyo Electric Power Company) Nuclear Power Plants, as well as the results of previous inspections at these plants. As a result of the visit to Japan, contacts were established with government agencies and industry organizations. A delegation of government and industry representatives from Japan visited the U.S. in February 1984 and met with the NRC staff and representatives of utilities, an NSSS vendor, Sandia National Laboratory and PNL.

In November 1984 the Deputy Director, Division of Human Factors Safety, again visited Japan to participate in the Bilateral Information Exchange meetings. A member of the PNL project team also participated in two of the meetings. In preparation for the meetings, a number of questions were formulated to fill in some of the information gaps about the Japanese maintenance system. These questions were submitted to MITI prior to the meetings, and much of the information incorporated in this report was received from MITI in response to the questions posed. Included in the information from MITI was the 1983 operating experience of Japanese reactors.

1.3 PROBLEM

A number of factors appear to be involved in the difference between U.S. and Japanese nuclear power plant performance. The NRC determined that there was a need to more systematically and completely describe the difference between U.S. and Japanese plant operating experience, and then explore the factors that may influence that difference. A number of questions were addressed in the resultant assessment presented in this report:

- What are the differences between U.S. and Japanese plant operating experience, and what has the recent trend been in these differences?
- Are the differences a "true" comparison of U.S.-Japanese plant performance, or can they be attributed to different reporting requirements, set-points, nomenclature, or the like?
- Is it possible that differences in the way the Japanese regulate and practice plant maintenance, especially preventive maintenance, may account for the differences in operating experience?
- What is the potential impact of Japanese management, organizational, and socioeconomic factors on the difference in U.S. and Japanese operating experience?

1.4 APPROACH

In February 1984, the NRC contracted with the Pacific Northwest Laboratory (PNL) to assess the degree to which differing Japanese and U.S. approaches to the regulation and practice of nuclear power plant (NPP) maintenance may explain the difference in reactor trips and safety equipment availability between U.S. and Japanese plants and to assist in the continuing dialogue with the Japanese.

There were three principal tasks in the project:

1. assessing the difference in Japanese-U.S. NPP operating experience
2. comparing and contrasting Japanese preventive maintenance practices with U.S. surveillance practices
3. assessing Japanese maintenance organizational and management practices.

These tasks are described below.

Task 1. Assess the Difference in U.S. and Japanese NPP Operating Experience

This task involved an assessment of the U.S. and Japanese NPP operating experience for 1981-1983 in order to draw preliminary conclusions about factors

that may be influencing the significant differences found in such indicators as number of automatic trips, forced outages, and capability availability factors.

Task 2. Compare and Contrast Japanese and U.S. NPP Preventive Maintenance Requirements

This task involved a review of the Japanese documents concerning preventive maintenance (PM) regulatory requirements and a comparison of these requirements with U.S. PM requirements, in order to contrast the two countries' approaches. Plant technical specifications from four U.S. plants known to be comparable to the Japanese plants Genkai 1 and Fukushima-Daini 1 were reviewed to determine NRC mandated PM requirements. Findings from Tasks 1 and 2 of the project were incorporated in Task 3 in order to assess factors that may be influencing the differences in Japanese and U.S. operating experience.

Task 3. Assess Japanese NPP Maintenance Organization and Management Practices

This task involved assessment of Japanese maintenance organizations, management personnel, and other factors within the context of Japanese cultural, economic, and government systems. The results of this task, along with the results of Task 1, were used in conjunction with Task 3 results to assess factors influencing differences in Japanese and U.S. operating experience.

1.5 ORGANIZATION OF THIS REPORT

This report is organized into five sections. Section 1.0 is the Introduction and Section 2.0 is a brief summary of major project findings. Sections 3.0, 4.0 and 5.0 correspond to the three project tasks. Section 3.0 of the report deals with the identification of the differences in U.S. and Japanese operating experience. Section 4.0 is a comparison of Japanese and U.S. nuclear power plant maintenance programs. Section 5.0 is an assessment of Japanese nuclear power plant organization and management practices.

1.6 SOURCES OF DATA

The information and data about the Japanese commercial nuclear industry that represent the basis of this report come for the most part directly from Japanese sources through the kind cooperation of Japanese government agencies and industry groups involved in regulation and operation of commercial nuclear power plants in Japan. Sources of information and data about the U.S. commercial nuclear power industry come from both published reports and data sources like the "greybook" and as a result of the extensive work PNL has done for the NRC in the areas of safety technology, licensing of new plants and operator licensing examinations.

2.0 SUMMARY OF MAJOR PROJECT FINDINGS

This report addresses three principal areas of nuclear power plant operation and maintenance. These areas are the operating experience at U.S. and Japanese reactors, the nuclear power plant maintenance programs in each country, and the Japanese nuclear power plant organization and management practices. The following is a summary of the major findings associated with each of these operation and maintenance areas.

2.1 OPERATING EXPERIENCE

The examination of U.S. and Japanese reactor operating experience resulted in the following six major findings:

- Japanese reactors experience significantly fewer trips than U.S. plants. This is true even when the data are normalized for number of plants operating, total megawatts produced per year and similar factors. The differences do not appear to be due to differences in trip set points or technical specifications since Japanese requirements are very similar and in many cases identical to those in the U.S.
- A significant percentage of trips (both manual and automatic) are caused by balance of plant (BOP) problems. This is true in both Japan and the U.S. The absolute number of trips in Japan is far smaller than in the U.S.
- Japanese reactors had a mean-time-between-event (MTBE) for automatic scrams that was approximately 10 times greater than their U.S. counterparts.
- U.S. plants had a significantly higher rate of repetitive trips than their Japanese counterparts.
- The overall capacity factors for the U.S. for 1981, 1982, and 1983 were 57%, 60% and 58%, respectively. For Japan the overall capacity factors for 1981, 1982 and 1983 were 58%, 66% and 69%, respectively.
- The average availability of U.S. plants decreased steadily from 1981 to 1983, while the availability of Japanese plants increased over the same period.

2.2 MAINTENANCE PROGRAMS

The major findings concerning maintenance programs at U.S. and Japanese nuclear power plants are:

- In the U.S. plants, almost all technical specifications mandated surveillances consist of ensuring the operability of safety-related

equipment through functional, administrative or visual verification. In Japan, on the other hand, the emphasis is on an extensive preventive maintenance program on both safety-related and balance of plant (BOP) equipment. To a large extent, Japanese preventive maintenance consists of the disassembly and inspection of individual components.

- The Japanese maintenance program is based on a legal requirement to conduct an annual inspection of every nuclear power plant.

- The Japanese have in place a structured, industry-wide program of preventive maintenance. Their program consists of four fundamental elements: 1) a statutory annual inspection, 2) a voluntary internal inspection (conducted concurrently with the statutory annual inspection), 3) special work, including back fitting and corrective maintenance, and 4) routine inspection. The first three elements are conducted annually during a maintenance outage. The last element, "routine inspection," is conducted during plant operation.

- The Japanese Ministry of International Trade and Industry (MITI) involves itself to a great extent in the preventive maintenance program by witnessing a significant number of maintenance activities during each plant's annual outage. Selection of maintenance activities to be witnessed is based in part on the safety significance of the equipment but MITI also witnesses maintenance of BOP components. MITI uses a contractor as well as its own staff to witness maintenance activities.

- In general, the numbers and types of components subject to inspection are much greater than current technical specification requirements in the U.S. In addition, the inspection frequently goes beyond visual inspection to include disassembly and measurement for wear. The annual inspection takes approximately three months.

2.3 ORGANIZATION AND MANAGEMENT PRACTICES

An assessment of the Japanese nuclear power plant organization and management practices indicated that:

- The central role of nuclear power in the Japanese plan of energy self-sufficiency greatly influences its regulatory structure.

- The group orientation of the Japanese society to an important extent determines the form and practice of management and its organizational structure within the nuclear industry.

- Maintenance in Japanese plants is often done by teams of cross-trained workers so that jobs are rotated. Teams are responsible for the quality of the workers' performance.

- The group orientation of the Japanese society in combination with the Japanese system of labor relations impacts the way maintenance activities are structured and carried out.

- The use of subcontract organizations to perform maintenance is a very common practice in the nuclear industry in Japan. During the scheduled maintenance outages, most of the work is conducted either by personnel supplied by the vendors or by subcontractor organizations.

- The Japanese nuclear industry is characterized by close, stable relationships between the utilities, vendors and subcontractors. The implications for plant maintenance are significant, with vendors providing continuing maintenance and maintenance training for the utilities. Maintenance subcontractors provide a stable maintenance work force for scheduled maintenance activities. These patterns appear to allow the utilities to have a highly reliable maintenance program and work force.

3.0 COMPARISON OF JAPANESE-U.S. NUCLEAR POWER PLANT OPERATING EXPERIENCE

The comparative assessment of U.S. and Japanese nuclear power plant operational event data is based on the information supplied by the plant operators/owners to the NRC and MITI. The principal sources used in this effort were the NRC Report entitled, Licensed Operating Reactors - Status Summary Report (NUREG-0020) (NRC 1981, 1982, 1983) and the Japanese Ministry of International Trade and Industry (MITI) Plant Operation Yearbook (MITI 1981, 1982, 1983). Also, the International Atomic Energy Agency's (IAEA 1981, 1982, 1983) Operating Experience with Nuclear Power Stations in Member States and the journal Atoms in Japan were used to obtain additional Japanese event and availability data.

This assessment focuses on the years 1981, 1982 and 1983. Babcock and Wilcox and Combustion Engineering plants were not included because they have no direct counterpart among Japanese plants. Therefore, the assessment examines U.S. General Electric BWR and Westinghouse PWR plants and all Japanese BWR and PWR plants. Only full-year operational units are included in the analysis of event data (Sections 3.3 through 3.6). Plants that commenced operation after the first of the year were not included in that year's count.

Section 3.2 discusses the differences between the reactor trip set points used for U.S. and Japanese power plants. Section 3.3 analyzes reactor event data by the type of reactor trip. The event data in this and in following sections is generally presented on a per-plant, per-year basis. Section 3.4 summarizes power plant availabilities in the two nations, while Section 3.5 incorporates the event and availability data to provide event rates and mean times between events. Using a subset of the overall data, Section 3.6 compares four groups of U.S.-Japanese "sister" plants divided by reactor type. The purpose of the sister plant comparison was to determine if there were event-related differences in the operational performance of the four types of reactors. The final discussion, Section 3.7, analyzes automatic reactor trips for 1981-1983.

The following section summarizes the findings of Sections 3.2 through 3.7.

3.1 SUMMARY OF FINDINGS

The first part of this analysis compared generic Westinghouse and General Electric reactor trip set points. Only four of the set points differed significantly between the two countries. The United States was more conservative than Japan with respect to the steam generator level--low low set point for PWRs, and more conservative with respect to BWR main steam isolation valve (MSIV) closure, main steam line radiation high, and turbine stop valve closure limits. However, these set point differences did not seem to be a significant factor in the large difference in the number of reactor trips between the two countries.

The availability factors compared favorably between the two countries although U.S. plant availability is trending down, while Japanese plant availability is trending up. For 1981, 1982 and 1983, the U.S. had 69%, 68% and 65% respectively, and Japan had 58%, 68% and 72% respectively.

The overall capacity factors for the U.S. for 1981, 1982, and 1983 were 57% and 60% and 58% respectively. For Japan the overall capacity factors for the same years were 58%, 66% and 69%.

Table 3.1 shows the high and low individual plant availability/capacity/mean time between auto scram events (MTBE).

TABLE 3.1. High and Low Individual Plant Availability/Capacity/MTBE Factors

		1981		1982		1983	
		U.S.	Japan	U.S.	Japan	U.S.	Japan
Availability	High	98.5%	85.0%	97.3%	92.2%	96.3%	99.9%
	Low	15.8%	22.6%	15.7%	5.2%	12.0%	37.2%
Capacity	High	84.9%	84.9%	92.8%	87.9%	92.8%	99.3%
	Low	3.9%	22.4%	13.5%	3.4%	4.4%	34.7%
MTBE (days)	High	325	*	349	*	352	*
	Low	20	80	18	121	5	152

*No events reported.

In comparing availability factors, it should be noted that there is a possible difference in the way availability factors are calculated. The United States calculation considers the sum of unit reserve shutdown hours plus hours on line whereas Japan's availability calculation appears to consider only hours on line.

Another measure used in this comparative analysis was the MTBE. For the G.E. and Westinghouse reactors, it was found that;

- MTBE for Japanese reactors was 7 times greater in 1981 than in the U.S. for automatic scrams
- MTBE for Japanese reactors was 11 times greater in 1982 than in the U.S. for automatic scrams
- MTBE for Japanese reactors was about 10 times greater in 1983 than in the U.S. for automatic scrams
- Smaller reactors in both countries performed better than the larger reactors with respect to MTBE for automatic scrams.

Based on an analysis of the actual trips as reported in NUREG-0020, and the MITI supplied information, it was found that about 75% of all automatic trips in both countries were equipment related. Of that number, about 60% were caused by balance of plant (BOP) related equipment. The other 25% of the automatic trips were due to personnel error. In the United States, of the personnel error related trips, 17% of all automatic trips were due to maintenance. It should be noted that the equipment related trips do not include those reactor trips caused by personnel error. These are equipment failure related trips specifically. The personnel error related trips are largely due to procedural errors. Proportionately, Japanese reactors had similar problems. They did, however, have significantly fewer events per reactor.

An insight into why Japan had significantly fewer events was gained by a closer look at the reactor trip descriptions. From that analysis, it was found that the U.S. incurs significantly more repetitive trip events than does Japan. In fact, it was found that Japan had only one such occurrence for the three years studied. A repetitive event is defined as several reactor trips in a short period of time for the same identical problem.

Many of the trips which occurred in U.S. plants between 1981 and 1983 appear to have resulted from relatively easy-to-avoid incidents, such as scaffolding hitting against pressure transmitters, impact wrenches vibrating sensitive trip instrumentation, and the like. There was little evidence that pre-maintenance reviews (PMRs) were being conducted routinely in U.S. plants to mitigate against such incidents. It is not known at this time if the Japanese have such a mechanism in place, but they do require more detailed and comprehensive follow-up and sign-off procedures for maintenance than is typical in U.S. plants.

3.2. REACTOR TRIP SETPOINTS

A review of generic Westinghouse and General Electric reactor trip setpoints was performed to identify any noticeable difference between U.S. and Japanese reactors. In general, there is not a great deal of variance between the setpoints. A significant variance was found, however, between the U.S. and Japanese values for the four specific setpoints shown in Table 3.2.

As shown, the U.S. is more conservative than Japan with respect to steam generator level (low low) and more conservative with respect to MSIV closure, high radiation in the main steam line and closure of turbine stop valves. The U.S. experienced one automatic trip for high steam line radiation and closure of turbine stop valves in 1982. Two turbine stop valve closure trips were reported in 1981. With respect to inadvertent MSIV closures resulting in reactor trips, there were sixteen instances in 1981 and 2 occurrences in 1982 in the U.S. Without further investigation, it is not known at this time whether these MSIV related trips would have occurred if the U.S. setpoint was 10% of closure as in Japan, instead of 6%. There were no reported MSIV related automatic trips for Japan in 1981, 1982 or 1983. The Japanese had one turbine stop valve closure related trip in 1981, none for 1982 and two in 1983.

It does not appear therefore, that the differences in trip set points shown in Table 3.2 are a significant factor in the differences that exist between the number of trips per reactor for U.S. and Japan. To better understand the differences in the number of automatic trips experienced by each country, an analysis was performed on the types of trips that occurred in 1981, 1982 and 1983.

TABLE 3.2. Trip Set-Point Comparisons

	PWR	
	U.S.	Japan
S/G Level -- Low Low	≥10% narrow range instrument span	>5% narrow range instrument span
	BWR	
MSIV Closure	≤6% closed	≤10% closed
Main Steam Line Radiation - High	≤2.5 times full power background	10 times full power background
Turbine Stop Valve Closure	≤5% closed	10% closed

3.3 ANALYSIS OF EVENT DATA

In the U.S. there were 49 General Electric (G.E.) and Westinghouse reactors in commercial operation for 1981. By the end of 1982 this had increased to 53 reactors. An additional Westinghouse reactor came on line in 1982 and brought the count to 54 full-year commercial units by the end of 1983. In total these plants experienced 965 events in 1981, 1095 events in 1982 and 1213 events in 1983. These totals are based on the information presented in the monthly reports entitled, Licensed Operating Reactors - Status Summary Report (NUREG-0020) (NRC 1981, 1982, 1983). In these monthly reports the events are categorized as either a manual shutdown, a manual scram, an auto-scram, a reduction in load, or an "other" activity. A manual shutdown refers to a controlled power descent and a manual scram is defined as an operator initiated error. Figure 3.1 shows a breakdown of the number of events per reactor in the first four categories for 1981 to 1983.

Included in Figure 3.1 is the breakdown of events per reactor for Japanese nuclear power plants in 1981, 1982 and 1983. This information was obtained from the Ministry of International Trade and Industry annual reports for 1981, 1982, and 1983 entitled, Plant Operating Yearbook (MITI 1981, 1982, 1983). The

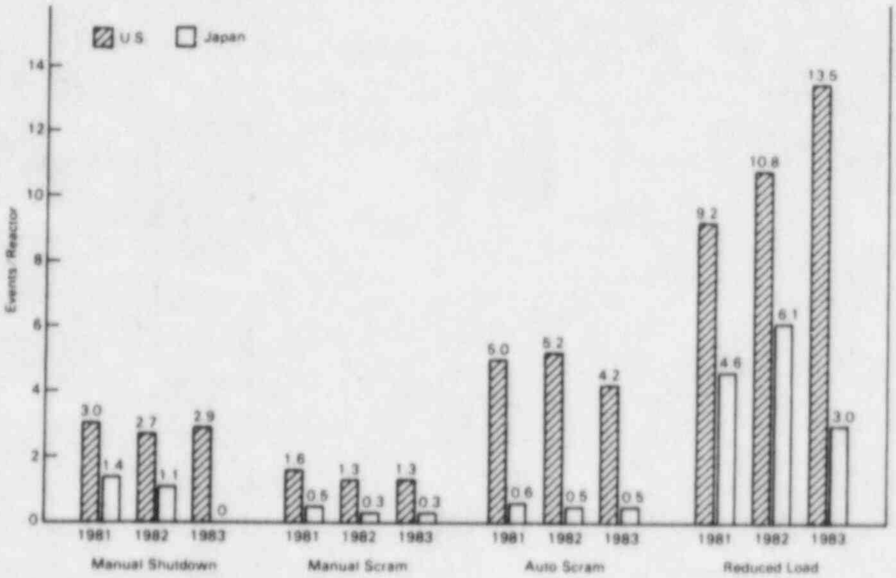

FIGURE 3.1. Average Number of Events Per Full-Year Commercial Operating Reactors for 1981-1983: U.S. (G.E. and Westinghouse Reactors) - Japan (BWR and PWR Reactors)

20 Japanese reactors commercially operating for all of 1981 experienced 139 events. This increased to 168 events in 1982 for the 21 full-year commercial reactors, and to 87 events in 1983 for 23 full-year commercial reactors.

As can be noted, the Japanese reactors have a significantly lower per-plant count in each category than was experienced by the U.S. plants. This is particularly true in the area of automatic scrams where the U.S. reactors experienced on the order of ten times more events than the Japanese.

An item to note is that the reduced load category in Figure 3.1 includes all reported reductions. This is due to the inability to identify, with the time and resources available, which U.S. power reductions were greater than 20%. In the case of Japanese reactors, if all reductions of less than 20% are excluded from the count the per reactor counts fall from 4.6 to 3.0 and 6.1 to 3.3 in 1981 and 1982, respectively.

3.4 POWER PLANT AVAILABILITY

The average availability of U.S. G.E. and Westinghouse units was almost 69% in 1981, 68% in 1982 and 65% in 1983. This compares with Japanese plant availabilities of 58%, 68% and 72% in 1981, 1982 and 1983 , respectively, as shown in Figure 3.2. In 1981 the U.S. plants averaged 99 days down per refueling.

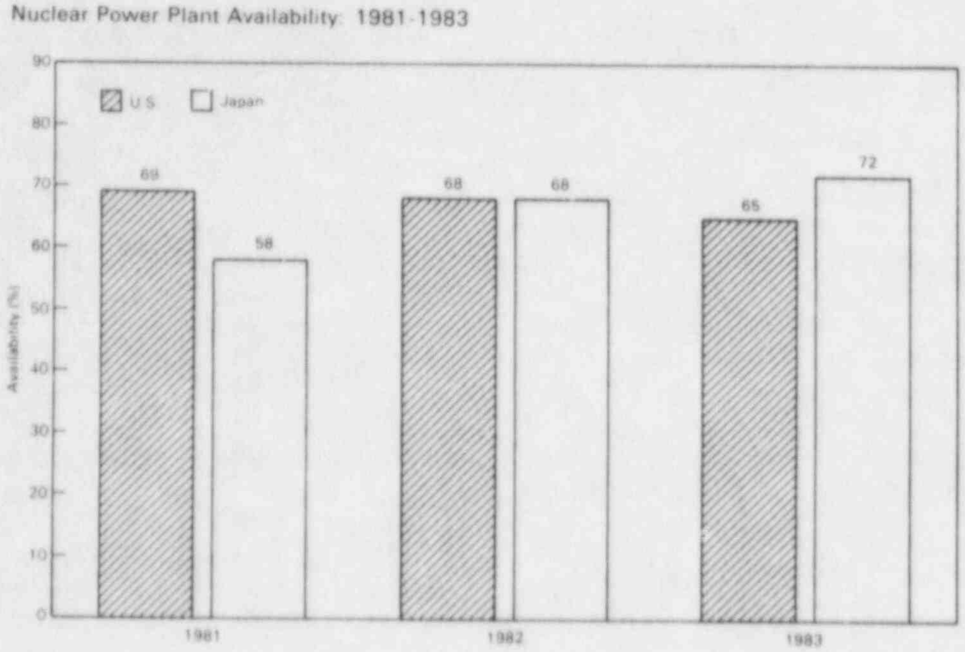

FIGURE 3.2. Average Nuclear Power Plant Availability 1981-1983: U.S. (G.E. and Westinghouse Reactors) - Japan (BWR and PWR Reactors)

The Japanese plants required an average of 140 days for their annual inspection and refueling. This does not include the time Japanese plants require for "mid-term inspection." Furthermore, Japanese reactors take longer to get to rated power (100%) and synchronize to the power grid than U.S. reactors. This appears to be a MITI requirement since this is characteristic of all Japanese reactors. The additional time spent in getting to full power consists of extensive testing of plant systems. Once full power is achieved and the reactor is synchronized to the grid, the amount of surveillance and testing performed by the Japanese appears to be less than that performed in the U.S. The time down per shutdown-scram event by Japanese plants is significantly longer than that experienced at U.S. plants. In fact, at several U.S. plants two and even three shutdowns-scrams per day were noted. In our review of the Japanese data this situation never occurred.

3.5 EVENT RATES AND MEAN TIME BETWEEN EVENTS

In order to place the U.S. and Japanese reactors on a comparable basis the event data as presented in Figure 3.1 was normalized by dividing the average counts by the availability factor for the respective year. This normalization effort adjusts for those years where low availability may have led to a low event count. This normalized event data is graphically presented in Figure A.1 Appendix A.

Although the unit counts increased, the difference between the Japanese and U.S. plants remained relatively the same. In all methods of shutdown, scram, or power reduction, the Japanese plants have from two to ten times fewer events per reactor.

Another way to view the event counts experienced by the Japanese and U.S. reactors in 1981, 1982, and 1983 is to identify the number of days the reactors operate between event occurrences. This period of time is referred to as the mean time between events (MTBE). It is obtained by dividing the number of days per year by the normalized event counts. For example, in 1982 the U.S. G.E. and Westinghouse reactors experienced on the average 29 adjusted events per reactor. This translates into approximately 13 days between events. This mean time between event fell to 12 days in 1982 and to 11 days in 1983 for the U.S. reactors. The Japanese reactors on the average experienced an event once every 31 days in 1981 and in 1982. With the reduced number of events experienced in 1983 and the increased average availability factor, the average MTBE for Japanese plants in 1983 increased to almost 70 days. A graphic breakdown of the mean time between event information for the two nations is presented in Figure 3.3.

As shown in Figure 3.3, the Japanese reactor average mean time between reported auto scram was 355 days in 1981, 497 days in 1982, and 502 days in

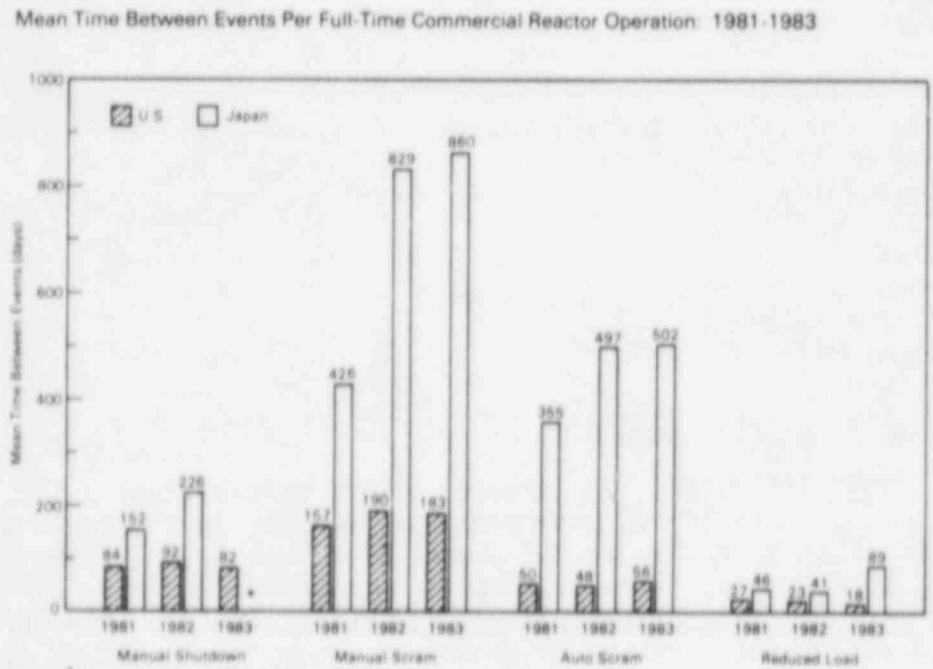

FIGURE 3.3. Mean Time Between Event Per Full-Year Commercial Operating Reactor for 1981-1983: U.S. (G.E. and Westinghouse Reactors) - Japan (BWR and PWR Reactors)

1983. On the average each Japanese reactor experiences an auto scram approximately once every 1.25 years. In contrast, U.S. reactors operated approximately 0.14 years (51 days) between auto scram events.

3.6 U.S.- JAPANESE SISTER PLANTS

In order to identify possible differences in operational performance between various types of reactors, four sister plant groups were selected for comparative assessment. The four groups included plants of similar age, size and reactor type. The BWR plants LaSalle and Fukushima Daini-1 (2-1) examined in Section 4 of this report were not included in the comparative assessment because of their limited operating histories.

The four groups of plants are:

- G.E. BWR II plants
  - Tsuruga (Japan)
  - Oyster Creek
  - Nine Mile Point 1
- G.E. BWR III plants
  - Fukushima Daiichi-1 (I-1) (Japan)
  - Dresden 2
  - Dresden 3
- G.E. BWR IV plants
  - Fukushima Daiichi-2 (I-2) (Japan)
  - Vermont Yankee
  - Brown Ferry 1
- PWR plants
  - Genkai 1 (Japan)
  - Prairie Island 2
  - Turkey Point 4.

3.6.1 Event Data - Sister Plants

For the years 1981-1983, the Japanese sister plants experienced fewer manual shutdowns than their U.S. counterparts. Of the Japanese plants, only Tsuruga, a BWR II unit, had a greater number of manual scrams than the U.S. sister plant counterparts. With respect to auto scrams and reduced loads, all BWR II facilities had significantly fewer events in the 1981-1983 period than their respective national average as shown in Figure 3.4. The BWR III Dresden 2 and 3 facilities had approximately the same number of auto scrams in 1981-1983 as the U.S. average. The Browns Ferry 1 plant in the BWR IV category had higher counts in three of the four event categories than the U.S. average. Of the PWR group, the Genkai 1 plant is below the Japanese 81-83 average for all scram and shutdown categories.

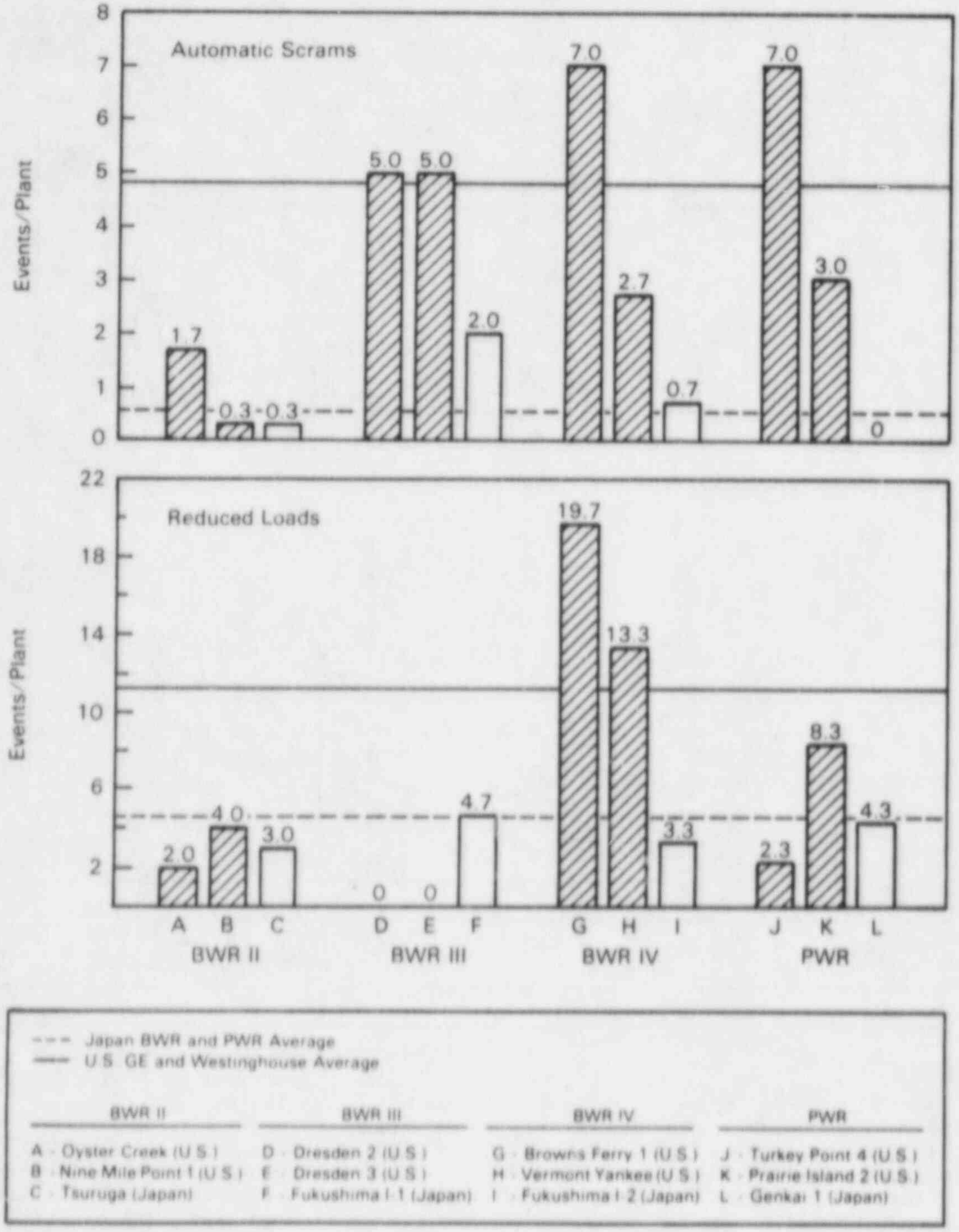

FIGURE 3.4. Average Events Per U.S. and Japanese Sister Plants for 1981-1983

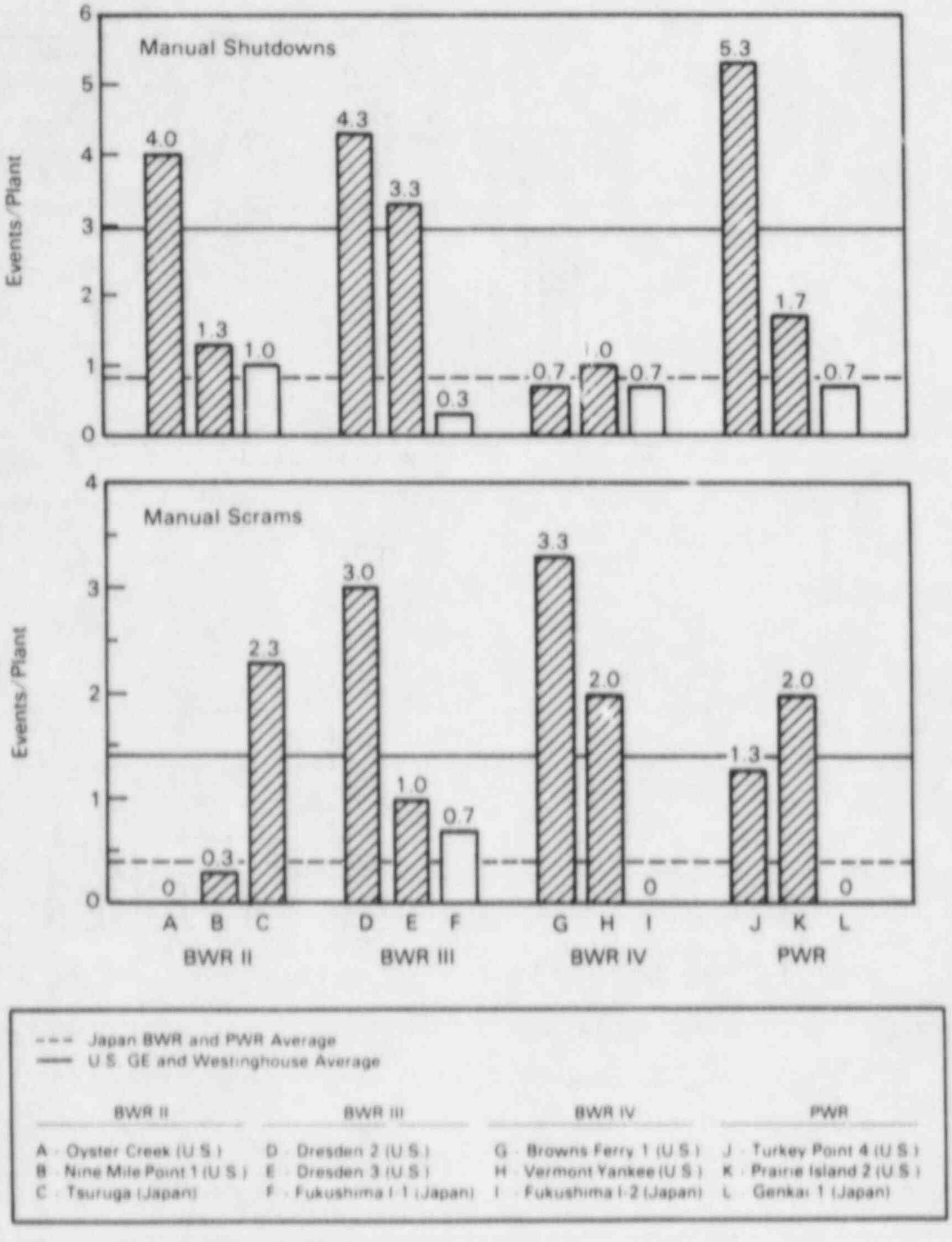

FIGURE 3.4. (contd)

3.6.2 Availability - Sister Plants

As shown in Figure 3.5, the availability of the BWR II facilities for Japan and the U.S. is below their respective national averages. For BWR IIIs U.S. plants are above the national average whereas the Japanese plant is below the national average.

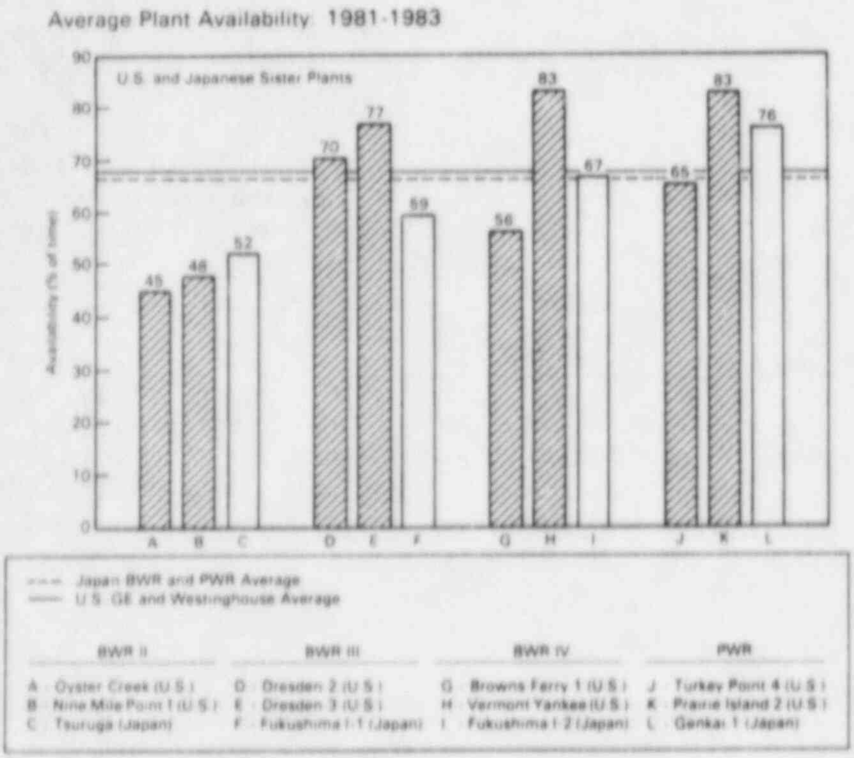

FIGURE 3.5. Avai ability of U.S. and Japanese Sister Plants for 1981-1983

3.6.3 Event Rate and Mean Time Between Events - Sister Plants

Adjusting the plants' event counts by their respective three-year average availability factor modifies the relative number of events per reactor year between sister plants. This is done to account for those plants where a low availability may have led to a low event count. A breakdown of the adjusted event data for the sister plants is presented in Figure A.2 of Appendix A. Oyster Creek, Tsuruga and Nine Mile Point 1 have the greatest relative increase due to their low average two-year availabilities.

The Japanese plants have fewer normalized events of any kind per plant than their U.S. counterparts, with only two exceptions: 1) the Japanese BWRs had significantly more manual scrams than either of its U.S. counterparts, and 2) The Japanese BWR III had an average of 7.9 load reductions, whereas U.S. BWR IIIs had none.

The mean time between event (MTBE) is obtained by dividing the number of days per year by the adjusted event count data. This MTBE information for the sister plants is presented in Figure 3.6. As can be noted in the figure, the three BWR IV plants as a group had the longest period of time between manual shutdown events. All but one of the BWR II and III plants had significantly shorter periods between manual shutdowns than was experienced by the BWR IV plants. With respect to manual scrams only U.S. BWR IIs exceeded the Japanese plant MTBE. The Japanese units had either no manual scrams or, in the case of Fukushima I-1 and Tsuruga, fell far below the Japanese average of 705 days. For auto scrams the Japanese units, other than Tsuruga and Genkai, also fell below the Japanese three-year BWR-PWR average of 451 days, but still exceeded their U.S. counterparts. The five U.S. reactors operated for a longer period than the national average before experiencing an automatic scram. In the case of reduced loads, U.S. reactors compared favorably with their counterparts in Japan. Only the BWR IVs had lower MTBE's than the Japanese BWR IV reactor. Of the four Japanese sister plants, all but one (Fukushima I-1) were above the national average for reduced load events.

3.7 ANALYSIS OF AUTOMATIC REACTOR TRIPS

An analysis of automatic reactor trips was performed for the years 1981 and 1982 and 1983 using NUREG-0020 and information supplied by MITI. This analysis excluded those reactors that were not commercially operational and included those reactors that operated all or part of a specific year. Hence the number of operational reactors reported in the following sections will differ slightly from previous Sections 3.3 through 3.6.

3.7.1 Automatic Trips in 1981

For 1981 there were 54 G.E. and Westinghouse operating reactors in the U.S. These reactors experienced 237 automatic trips, or 4.4 trips per reactor. Based upon the descriptions of each trip event as reported in NUREG-0020, 77% (182 trips) were equipment related and 23% (55 trips) were due to personnel error.

An analysis was then performed to see if these two categories, equipment and personnel error, could be broken down any further. With respect to the equipment category, it was found that about 57% of the reported trips (135 trips) were due to BOP related equipment or 2.5 trips/reactor. Following (Table 3.3) is a breakdown of the specific systems that were responsible for these automatic trips at U.S. reactors.

This shows that almost 75% of the BOP related automatic trips were due to two systems, main feed and turbine-generator. With respect to the main feed system the components causing the most difficulty were main feed regulation valves/bypass regulation valves and main feed pumps. With respect to the turbine generator, most of the difficulties were with the voltage regulator and the electro-hydraulic controls (EHC).

For the personnel error category, the results were as follows (Table 3.4).

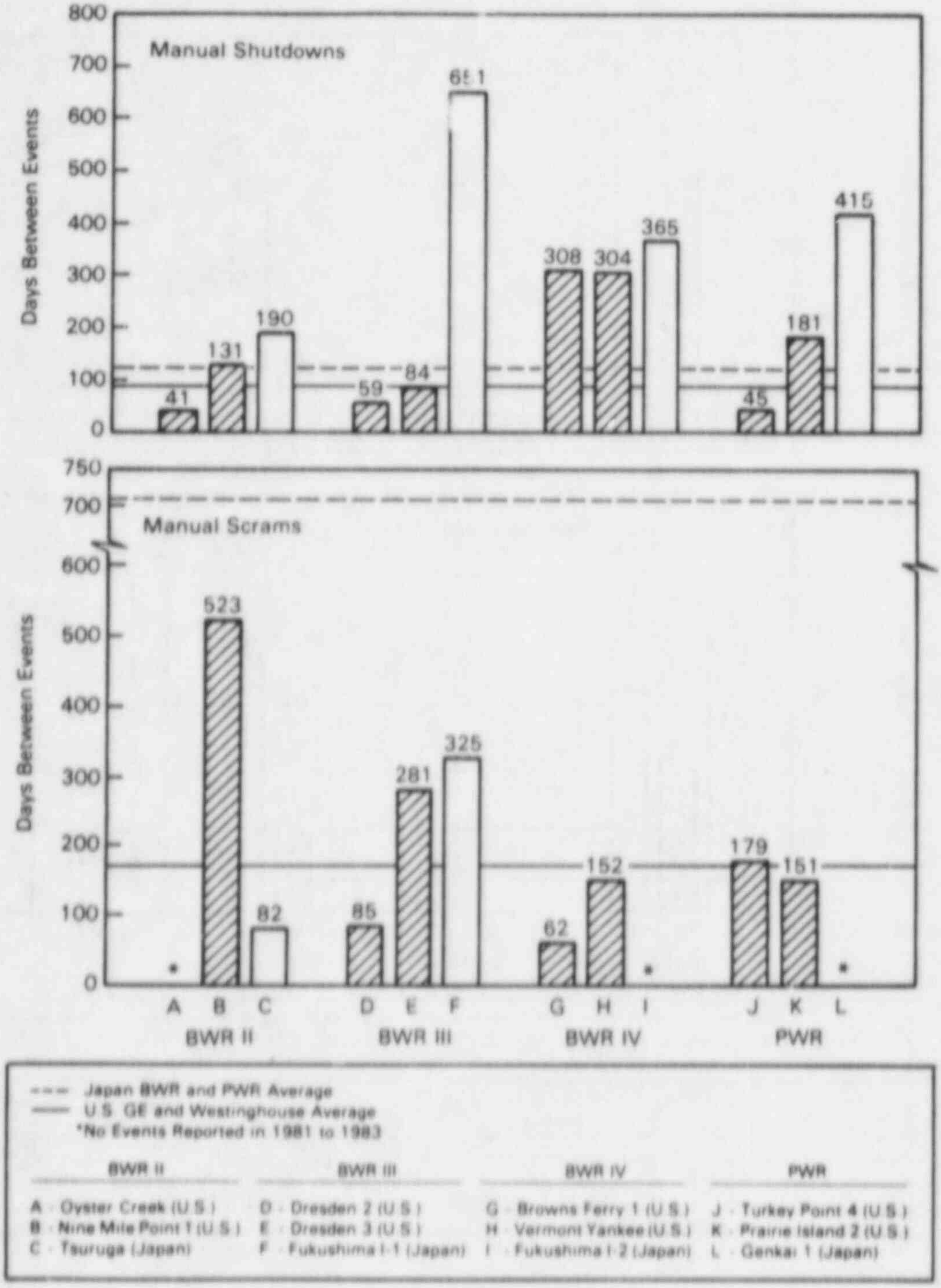

FIGURE 3.6. Mean Time Between Event Per U.S. and Japanese Sister Plants for 1981-1983

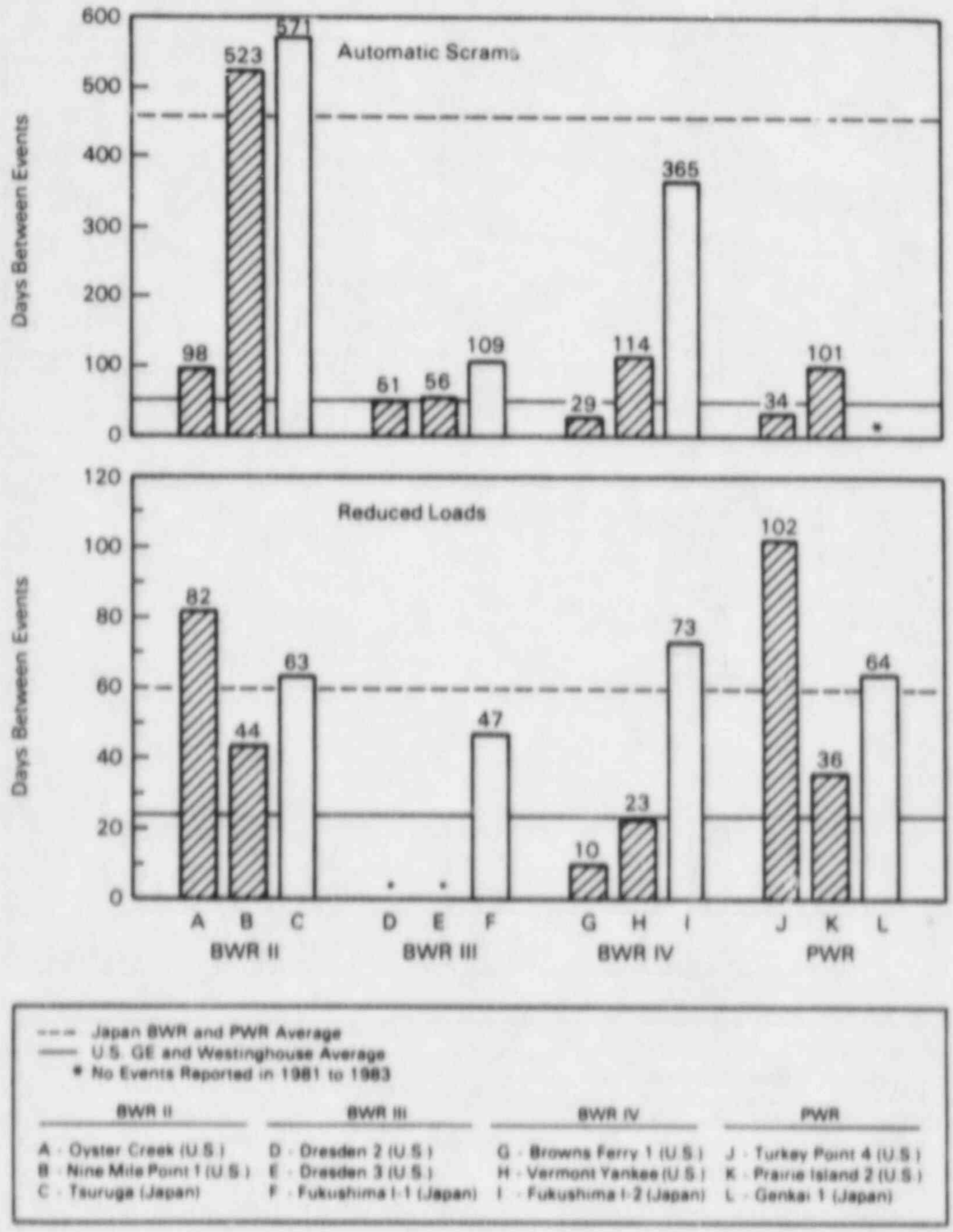

FIGURE 3.6. (contd)

TABLE 3.3. 1981 BOP Equipment-Related Auto Trips at U.S. Reactors

	Trips	% of Subtotal
Turbine-Generator	56	42%
Main Feed System	45	33%
Condensate System	19	14%
Other	15	11%
Subtotal	135	100%

TABLE 3.4. 1981 Personnel Error-Related Auto Trips at U.S. Reactors

	Trips	% of Subtotal
Maintenance Error Involving Safety Related Equipment	12	22%
Maintenance Error Involving Balance of Plant (BOP) Equipment	29	53%
Operator Error Involving Safety Related Equipment	8	14%
Operator Error Involving Balance of Plant (BOP) Equipment	6	11%
	55	100%

The results of the analysis show that in 1981, about 75% of the personnel errors that directly resulted in an automatic trip were from the maintenance department. This means that roughly 17% of the automatic trips in 1981 were related to maintenance. The personnel-error cost of replacement power associated with the downtime from the maintenance related trips was approximately $\$100 \times 10^6$.

For Japan in 1981, there were nine automatic trips or 0.4 trips per reactor. Seventy-eight percent (7 trips) were equipment related and 22% (2 trips) were due to personnel error.

With respect to the equipment category, 66% of the automatic trips at Japanese reactors were due to BOP equipment. The following specific systems (Table 3.5) were responsible for these trips.

TABLE 3.5. 1981 BOP Equipment-Related Auto Trips at Japanese Reactors

	Trips	% of Subtotal
Main Feed System	3	50%
Turbine Generator	3	50%
Subtotal	6	100%

Again, as with the U.S., the same two systems, main feed and turbine generator, are largely responsible for the BOP related automatic trips. The problems appear to be similar, even though the Japanese reactors experience significantly fewer trips than U.S. reactors. With respect to the personnel error category, two automatic trips occurred in Japan. One was due to operator error involving safety related equipment and one was due to maintenance error involving safety related equipment.

3.7.2 Automatic Trips in 1982

For 1982 there were 55 G.E. and Westinghouse commercially operating reactors in the U.S. These reactors experienced 283 automatic trips or 5.2 trips per reactor. Seventy-three percent (207 trips) were equipment related and 27% (76 trips) were due to personnel error.

With respect to the equipment category, 58% (164 trips) of the reported automatic trips were BOP related equipment. This is consistent with the 1981 findings of 58%. The specific BOP systems that were responsible for these trips are shown in Table 3.6.

TABLE 3.6. 1982 BOP Equipment-Related Auto Trips at U.S. Reactors

	Trips	% of Subtotal
Main Feed System	65	40%
Turbine-Generator	45	27%
Condensate System	20	12%
Other	34	21%
Subtotal	164	100%

As with 1981, this information shows that the largest contributors to automatic trips for BOP related equipment are the main feed system (MFS) and

turbine generator. With respect to the MFS, the main feed regulation valve/bypass regulation valve and main feed pumps were the largest problems. For the turbine generator, the voltage regulator and EHC system were the main contributors to automatic trips.

For the personnel category, the breakdown is presented in Table 3.7.

TABLE 3.7. 1982 Personnel Error-Related Auto Trips at U.S. Reactors

	Trips	% of Subtotal
Maintenance Error Involving Safety Related Equipment	15	20%
Maintenance Error Involving Balance of Plant Equipment	38	50%
Operating Error Involving Safety Related Equipment	10	13%
Operator Error Involving Balance of Plant Equipment	8	11%
Other	5	6%
Subtotal	76	100%

These results show that about 70% of the personnel errors in 1982 that directly resulted in an automatic trip were from the maintenance department. This is approximately 19% of all automatic reactor trips. The cost of replacement power associated with the downtime from the maintenance related trips was approximately $\$100 \times 10^6$.

For Japan in 1982, there were seven automatic trips or 0.3 trips per reactor. Forty-three percent (3 trips) were equipment related and 57% (4 trips) were due to personnel error.

With respect to the equipment category all of the automatic trips were due to BOP equipment. The following specific systems were responsible for these trips (Table 3.8).

Four of the seven automatic trips were due to personnel error. Following is a breakdown of these four events (Table 3.9).

TABLE 3.8. 1982 BOP Equipment-Related Auto Trips at Japanese Reactors

	Trips	% of Subtotal
Main Feed System	2	67%
Turbine Generator	1	33%
Subtotal	3	100%

TABLE 3.9. 1982 Personnel Error-Related Auto Trips at Japanese Reactors

	Trips	% of Subtotal
Operator Error Involving Balance of Plant Equipment	1	25%
Maintenance Error Involving Balance of Plant Equipment	3	75%
Subtotal	4	100%

3.7.3 Automatic Trips in 1983

For 1983, there were 54 G.E. and Westinghouse commercially operating reactors in the U.S. These reactors experienced 228 automatic trips or 4.2 trips per reactor. Seventy-six percent (174 trips) were equipment related and 24% (54 trips) were due to personnel error.

With respect to the equipment category, 42% of the reported automatic trips were BOP related equipment. This is less than the 1981 and 1982 reported BOP related trips. It should be noted here, that the Salem automatic trip without scram (ATWS) occurred in early 1983, after which it was a requirement that utilities perform a post-trip analysis. The specific BOP systems that were responsible for these trips are summarized in Table 3.10.

As with 1981 and 1982, the largest contributors to automatic trips for BOP related equipment are the main feed system and turbine generator. With respect to the MFS, the main feed regulation valve/bypass regulation valve and main feed pumps were the largest problems. For the turbine generator, the voltage regulator and EHC System were the main contributors to automatic trips.

TABLE 3.10. 1983 BOP Equipment-Related Auto Trips at U.S. Reactors

	Trips	% of Subtotal
Main Feed System	33	35%
Turbine/Generator	30	32%
Condensate System	10	11%
Other	22	22%
Subtotal	95	100%

For the personnel error category, the breakdown is shown in Table 3.11.

TABLE 3.11. 1983 Personnel Error-Related Auto Trips at U.S. Reactors

	Trips	% of Subtotal
Maintenance Error Involving Safety Related Equipment	10	19%
Maintenance Error Involving Balance of Plant Equipment	25	45%
Operator Error Involving Safety Related Equipment	9	17%
Operator Error Involving Balance of Plant Equipment	10	19%
Subtotal	54	100%

These results show that about 65% of the personnel errors in 1983 that directly resulted in an automatic trip were from the maintenance department. This amounts to 15% of all automatic trips, which is roughly a 2% reduction from 1981 and 4% from 1982.

For Japan in 1983, there were twelve automatic trips or 0.5 trips per reactor. Eighty-three percent (10 trips) were equipment related and 17% (2 trips) were due to personnel error.

With respect to the equipment category, 42% (5 Trips) were due directly to BOP equipment. Three trips were due to lightning striking balance of plant equipment. The specific systems responsible for these trips are described in Table 3.12.

TABLE 3.12. 1983 BOP Equipment-Related Auto Trips at Japanese Reactors

	Trips	% of Subtotal
Turbine/Generator	4	50%
Condensate System	1	13%
Other (Lightning)	3	37%
Subtotal	8	100%

Two of the twelve automatic trips in 1983 were due to personnel error. Both trips were due to maintenance personnel error.

Table 3.13 and 3.14 summarize the results of this analysis. The reactor trip data presented in NUREG-0020 was not of sufficient detail to differentiate, in all cases, between those reactor trips that initiated safety injection (SI) and those that did not. This is another area that should be investigated more thoroughly as it could indicate which automatic trips were direct challenges to reactor safety systems.

Another aspect of automatic trips that was considered was an analysis of the type of operational or maintenance activity occurring at the time of reactor trip. Table 3.15 summarizes the type of activity occurring at the time of trip for the three years analyzed. Represented are the percentage of total automatic trips occurring during the listed activity.

From this analysis it appears that roughly twice as many trips occur during surveillance and testing than any of the other activities. Further analyses must be performed to determine why more trips are occurring during surveillance and testing and provide recommendations to mitigate these occurrences.

For the three years analyzed, most Japanese reactor trips occur during equilibrium or "rated" power operations. A large fraction of the surveillance and testing in Japan takes place during the testing phase that occurs just prior to commercial power production. In 1981, however, Japanese reactors experienced four automatic trips during surveillance and testing activities.

Most of the equipment related automatic trips experienced by both countries were BOP related. The actual number of automatic trips experienced by Japan is significantly less, however. This suggests that the U.S. could significantly reduce the number of automatic trips due to equipment by giving more attention to the operation and maintenance of BOP equipment. A more in-depth study should also be performed to evaluate the type and quality of Japan's BOP maintenance program.

TABLE 3.13. Breakdown of Automatic Trips at U.S. Reactors--1981, 1982 and 1983

	1981		1982		1983	
	Trips	% of Total	Trips	% of Total	Trips	% of Total
EQUIPMENT RELATED						
Balance of Plant Equipment						
• Main Feed System	45	19%	65	23%	33	14%
• Condensate System	19	8%	20	7%	10	4%
• Turbine Generator	56	24%	45	16%	30	13%
• Other	15	6%	34	12%	22	11%
Balance of Plant Subtotal	135	57%	164	58%	95	42%
Safety Related Equipment	47	20%	43	15%	79	34%
Equipment Subtotal	182	77%	207	73%	174	76%
PERSONNEL ERROR						
Maintenance Error Involving Safety Related Equipment	12	5%	15	5%	10	4%
Maintenance Error Involving Balance of Plant Equipment	29	12%	38	13%	25	12%
Operator Error Involving Safety Related Equipment	8	3%	10	4%	9	4%
Operator Error Involving Balance of Plant Equipment	6	3%	8	3%	10	4%
Other	--	--	5	2%	--	--
Personnel Error Subtotal	55	23%	76	27%	54	24%
TOTAL	237	100%	283	100%	228	100%

TABLE 3.14. Breakdown of Automatic Trips at Japanese Reactors--1981, 1982 and 1983

	1981		1982		1983	
	Trips	% of Total	Trips	% of Total	Trips	% of Total
EQUIPMENT RELATED						
Balance of Plant Equipment						
• Main Feed System	3	33%	2	29%	--	--
• Condensate System	--	--	--	--	1	8%
• Turbine Generator	3	33%	1	14%	4	33%
• Other	--	--	--	--	3	--
Balance of Plant Subtotal	6	67%	3	43%	8	66%
Safety Related Equipment	1	11%	--	--	2	17%
Equipment Subtotal	7	78%	3	43%	10	83%
PERSONNEL ERROR						
Maintenance Error Involving Safety Related Equipment	1	11%	--	--	2	17%
Maintenance Error Involving Balance of Plant Equipment	--	--	3	43%	--	--
Operator Error Involving Safety Related Equipment	1	11%	--	--	--	--
Operator Error Involving Balance of Plant Equipment	--	--	1	14%	--	--
Other	--	--	--	--	--	--
Personnel Error Subtotal	2	22%	4	57%	2	17%
TOTAL	9	100%	7	100%	12	100%

TABLE 3.15. Activity Occurring at the Time of Reactor Trip

	1981	1982	1983
Power Ascension	3%	3%	7%
Power Descent	3%	2%	2%
Maintenance In Progress	9%	8%	7%
Surveillance and Testing	13%	11%	17%

The following five examples of automatic trips taken from NUREG-0020 are representative of repetitive trips at individual reactors. Example 6 consists of events that occurred at three different reactors.

- Example 1

  09/01/81 Mechanical problem in circuitry of turbine stop valves
  09/21/81 Mechanical problem in circuitry of turbine stop valves
  09/26/81 Mechanical problem in circuitry of turbine stop valves
  10/18/81 Mechanical problem in circuitry of turbine stop valves

- Example 2

  07/21/82 Reactor scram on low condenser vacuum
  07/21/82 Reactor scram on low condenser vacuum

- Example 3

  09/11/82 Slow response time of Bypass Feed control valve in IC S/G
  09/11/82 Slow response time in Bypass Feed Control control valve in IC S/G
  07/18/82 Control Problems with Bypass flow control valves

- Example 4

  10/01/81 Reactor scram due to MSIV Fast Closure
  11/04/81 Reactor scram due to MSIV Fast Closure
  03/17/81 Reactor scram due to MSIV Fast Closure
  09/09/81 Reactor scram due to MSIV Fast Closure

The analysis of Japanese trip data indicated that when an automatic trip occurred, the plant would correct the problem such that it would not occur again. There was only one instance where a Japanese reactor tripped automatically more than once for the exact same problem. The above examples occurred prior to the Salem ATWS event in 1983. Following the Salem event, all U.S. reactors were required to perform a post-trip analysis prior to startup. This is to insure that the facility understands the exact nature and cause of a trip

and has taken the proper action to correct the problem. This type of analysis was not practiced on a regular basis as evidenced by the following example.

- Example 5

05/15/82 Reactor trip caused by loss of power to the control rods due to problem with control rod drive M/G sets. Problem still being evaluated.

05/20/82 Reactor trip caused by loss of power to the control rods due to problems with the control rod drive M/G sets. Problem still being evaluated.

In 1981 24% (54 trips) of the auto trips at U.S. reactors were repetitive trips. In 1982 and 1983, 20% (57 trips) and 14% (34 trips) of auto trips were repetitive respectively. It appears that the post trip analysis requirement following the ATWS event at Salem has been a factor in reducing the number of repetitive trips in the U.S. An analysis of 1984 data should be performed to see if this trend continues.

Finally, the type of work to be performed, the area within the plant where the work is to occur, and the procedures to be used should be reviewed by knowledgeable individuals prior to sign-off by the Shift Supervisor. This pre-maintenance review (PMR) could eliminate most trips illustrated by the following examples.

- Example 6

08/24/82 Mechanics working near the steam header pressure transmitter with an impact wrench jarred the transmitter causing a spurious safety injection, reactor trip.

01/26/82 Contractor dropped scaffolding by reactor pressure transmitter giving pressure spike causing scram.

05/30/81 Trip occurred while filling west Feed Pump turbine lube oil filter. A drop in lube oil pressure tripped the Feed Pump followed by reactor trip.

A preliminary analysis was also performed on the number of trips as a function of reactor size. The measure used was MTBE for automatic trips. This identifies the number of days of reactor operation before experiencing an automatic trip. Table 3.17 summarizes that analysis.

This indicates that the smaller facilities have better operating records than the larger facilities. Also, Japanese three-loop PWRs had MTBE's that were 25 times larger than those for U.S. three-loop PWRs in 1982. An analysis as to why this is so was beyond the scope of this study.

TABLE 3.16. Comparison of MTBE as a Function of Reactor Size

	1981		1982		1983	
	U.S.	Japan	U.S.	Japan	U.S.	Japan
PWR						
2 Loop	208	1190	124	1344	134	1829
3 Loop	31	380	28	706	46	375
4 Loop	36	--(a)	31	563	34	192
BWR						
55-700 MWe	140	651	71	906	77	517
800-1200 MWe	38	283	29	416	46	972

(a) No reported auto scrams for 1981.

4.0 JAPANESE PREVENTIVE MAINTENANCE PRACTICES

The Japanese have a structured, industry-wide program of preventive maintenance. Their program has four basic elements: 1) statutory annual inspection, 2) voluntary internal inspection (concurrent with the statutory annual inspection), 3) special work, including backfitting and corrective maintenance, and 4) routine inspection. The first three elements are conducted annually during a maintenance outage. The last element, routine inspection, is conducted during plant operation.

This chapter describes the Japanese preventive maintenance program. Extensive use is made of tables and figures to illustrate the Japanese program. Because of this, all of the tables and figures have been located sequentially at the end of this section. The information supplied in this chapter was taken from material supplied by the Japanese during two visits. The first visit was conducted by the NRC and representatives from PNL in November 1983. During that visit PNL was supplied with a copy of a long-range inspection schedule for a typical boiling water reactor (BWR). Additionally, a copy of the inspection report for the first annual inspection of a typical BWR was supplied. Material describing the preventive maintenance program at a Japanese pressurized water reactor (PWR) was also provided. The second visit was conducted to participate in a bilateral exchange meeting with the Japanese. During that meeting the Japanese supplied PNL with several tables and figures describing their preventive maintenance program. The materials provided during the first trip are documented in a trip report dated May 1984 prepared by R. V. Badalamente, M. H. Morgenstern, and W. T. Russell and entitled, "Trip Report: Review of Japanese Nuclear Power Plant Maintenance, Regulation and Practice," (NRC 1984). Additional information came from the NRC transcript of discussions held during the second meeting on nuclear regulatory matters between the U.S. and Japan dated November 7, 1984.

The supplied material describing the preventive maintenance program at a Japanese PWR was not as clearly detailed as the material describing the program at a BWR. Because of this most of the details presented in this section are taken from the material describing preventive maintenance at a Japanese BWR facility. Our review of the PWR material does indicate that the preventive maintenance at PWRs is of similar scope to that conducted at BWRs.

4.1 ANNUAL INSPECTION OUTAGE

Article 47 of the Electric Utility Industry Law in Japan specifies that power plant structures important for securing a safe and smooth supply of electric power will be inspected at prescribed intervals. The regulation specifies that the following systems or components will be inspected:

"Steam turbine, nuclear reactor and its incidental facilities (main body of nuclear reactor, reactor cooling system, instrumentation control system, fuel system, radiation control system, waste disposal system, reactor container, auxiliary boiler, and emergency power [stand by] generating system)"

The law states further that these components will be inspected every two years (± one month) for the steam turbine and every year (± one month) for the nuclear reactor and its incidental facilities. The inspection period is defined to start when the station is separated from the grid during shutdown for inspection. It is defined to end on the date of the final full-load inspection.

4.1.1 Description of the Inspection Process

In practice the Japanese utilities develop long-range (10-year) inspection schedules meeting the requirements of Electric Utility Law. These long-range schedules are comprehensive and formal, but are considered to be flexible. Utilities may make changes to the schedule as necessary to accommodate short-term goals, such as responding to issues resulting from recent industry events. A detailed inspection schedule for a specific annual outage is drafted using the long-range schedule. Pragmatic concerns such as known mechanical problems are factored in, along with the plans for responding to recent industry events. The result is a specific inspection plan, detailed to the component level, to be used for a specific annual inspection.

The annual inspection includes both a voluntary component and a statutory component. Those inspections designated as statutory are formally designated as such in both the long-range inspection schedule and the inspection plan for a specific inspection. Statutory inspection items are observed by a government inspector. The details of the government role in the preventive maintenance process is discussed in the next subsection.

The specific inspection plan developed for a specific inspection outage at a given power plant details those items that will be inspected on a component by component basis. The statutory and voluntary portions of the annual inspection include items such as those listed below.

- Visual, volumetric, and surface inservice inspection of piping on a rotating basis in a manner similar to the ASME Code Section XI (ASME 1983).

- Disassembly and inspection (overhaul) of designated equipment (such as pumps, valves, and motors). The piece of equipment is completely dismantled and closely inspected. Where necessary, equipment is entirely replaced. Instrumentation and controls are inspected, and replaced if necessary.

- Simple inspection (mechanical seal inspection) of designated equipment. Partial dismantling of equipment to allow for inspection (and replacement if necessary) of bearings, safety seals, or valve packing materials. Inspecting, testing, and replacing instrumentation and control components.

- General inspection (appearance inspection) of designated equipment. Includes such items as measuring insulation resistance of motors, checking oil sump inventories, visually inspecting the exterior of pipes and equipment, and checking and adjusting control equipment.

The long-range inspection schedule specifies what type of inspection is to be given to a given component. Also the schedule specifies the frequency to which specific components are exposed to individual types of inspections. The main rationale for determining how often individual components are inspected includes: 1) importance to safety, 2) whether or not a stand-by component exists, 3) importance to generating power, 4) operational trouble and historical difficulty, 5) vendor technical manuals and recommendations, 6) equipment revolutions per minute, and 7) operational environment, e.g., sea water.

The bulk of the items in a facility's long-range inspection schedule are voluntary and include both balance of plant (BOP) and safety related equipment. Table 4.1 is a list of statutory inspection items and their individual frequencies, taken from an actual long-range inspection schedule for a Japanese BWR.

Table 4.2 gives an example of the types of inspection items performed during an actual annual inspection at a Japanese BWR. The actual inspection from which this material was summarized was the first annual inspection for that particular facility. The statutory items for this particular inspection are marked with an asterisk in Table 4.2, and were observed by a government representative. As can be seen, the statutory items are largely composed of safety related equipment; however, the statutory inspection also included the feedwater pumps and turbines, one of three condensate pumps, and the main turbine.

Each annual inspection includes a category that the Japanese refer to as "Special Work." This work includes corrective maintenance, and response to industry events by either performing special inspections or by backfitting. The scope of the special work performed during the annual inspection varies. For example, in the early 1980s the Japanese took steps to eliminate the possibility of intergranular stress corrosion cracking in their recirculation piping. That project was classified as special work, and was the major effort during the outage in which it was accomplished.

Japanese utilities share information through MITI. They use information describing current industry events to determine what special work should be accomplished to prevent a recurrence at their facility. Table 4.3 is a sample of reactor events and the resultant actions taken as reported to MITI by a Japanese BWR after their first annual inspection. That Japanese BWR reviewed and responded to 85 different events during its first annual inspection.

Historically, the annual inspection periods have lasted about four months, significantly reducing plant availability. As shown below, the length of the inspection period has been decreasing.

Average during FY 1978 - 1979	170 days
Average during FY 1980 - 1981	140 days
Average during FY 1982 - 1983	120 days

The Japanese attribute this decrease to three factors. First, there has been a decreasing tendency for the necessity for corrective maintenance as plants become older and initial problems are worked out. Second, the orchestration and administration of the inspection process has grown more efficient. For example, Main Steam Line nozzle plugs were developed and improved to prevent the MSIV leak rate testing from becoming a critical path item. With the improved plugs, leak rate testing can be performed with the Reactor Vessel (RV) head off, independent of RV water level. Table 4.4 gives examples of modifications of maintenance tooling and systems designed for decreasing the duration of outages. Last, a greater use of automation and remote control designed to reduce overall radiation exposure has also increased efficiency.

During the course of the annual inspection, those systems important to safety and those systems that have been inspected are tested functionally to ensure operability as designed. These functional tests appear to be "full scope" in nature, performed with little or no operational constraints. Table 4.5 is a list of those systems that were functionally tested as part of the statutory inspection at a typical Japanese BWR. Upon completion of the inspection outage, the plant is put through an abbreviated formal startup test program, during which affected systems are verified to be working properly. The startup test sequence takes about one week to complete. The following are the test items performed during the startup test phase for a BWR:

Rod Worth Minimizer Test
Main Steam Isolation Valve open/close
Intercept Stop and Control Valves open/close
Turbine Protection System Test
Turbine Overspeed Trip Test
RCIC Surveillance
HPIC surveillance

Figure 4.1 shows a typical post-inspection startup test sequence for a Boiling Water Reactor.

The results of the periodic inspection are reported to the government upon completion. The inspection report includes: a general overview of the inspection, a list of items included in the inspection, a general itemized summary of the results of both the statutory and the voluntary inspection, a summary of the refueling operation, a summary list of the repair work and modification work accomplished, a summary of radiation control measures taken, a commitment to continue to conduct future inspections in accordance with the long-range inspection schedule, a list of actions taken in response to input provided by consultants, a list of actions taken in response to problems that have occurred within the Japanese industry, and a summary of the pre-inspection performance history of the plant. Also, any problems discovered during the course of the periodic inspection that would have caused a shutdown if the plant were at power are reported to the government. These additional problems are tracked by the government and are ostensibly viewed to be as serious as forced outages.

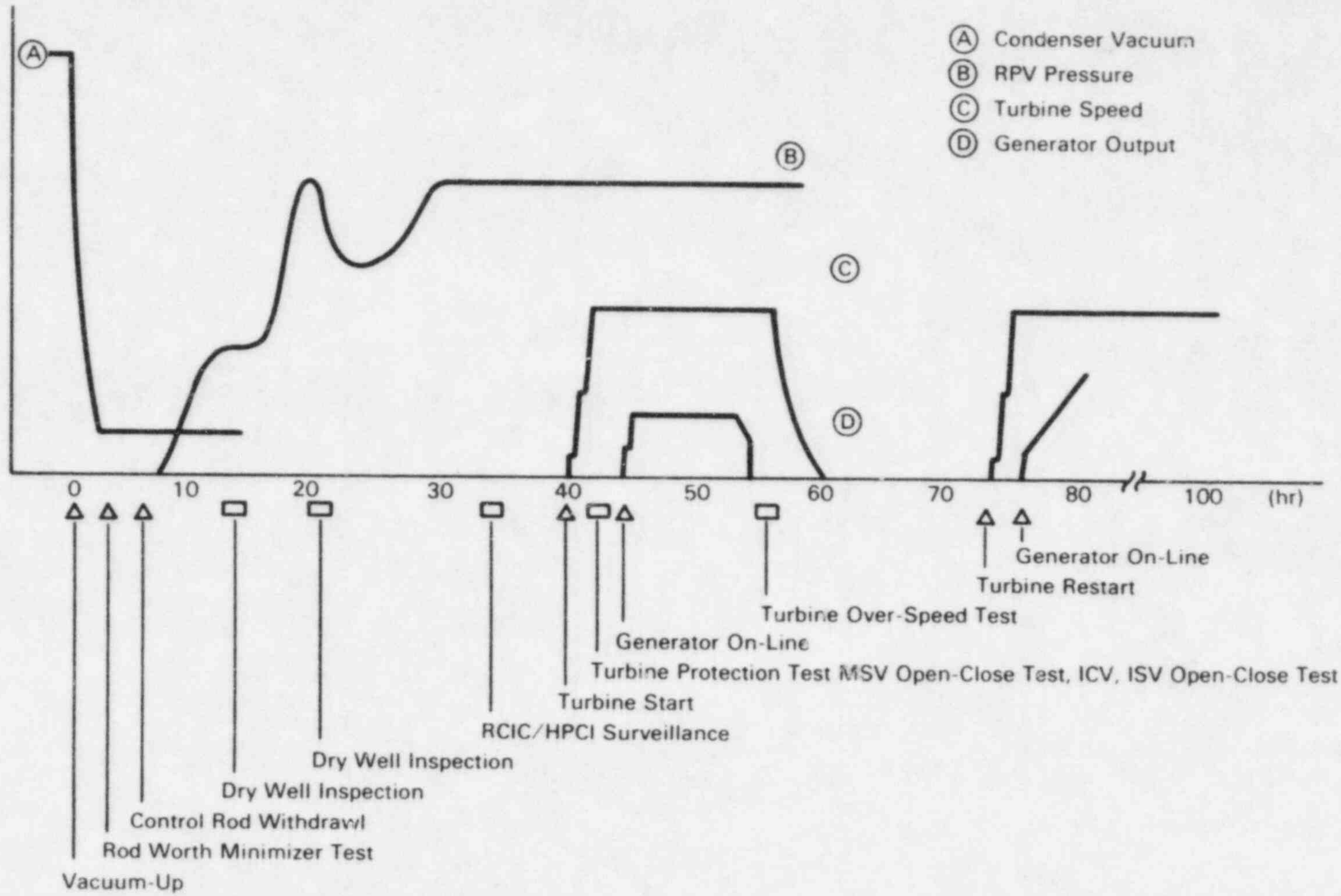

FIGURE 4.1. Example of BWR's Start-up Sequence

Incidents resulting in forced outages in Japan appear to be on the decrease. For instance, the total number of incidents reported to the government during the first half of the fiscal year 1984 were down about 50% over the same period of the previous year. This reduction in incidents (or increase in reliability) is credited by the Japanese to the following factors:

- replacement of vital imported equipment and parts with those domestically produced

- prompt actions taken by utilities based upon occurrences at other facilities

- technical improvements in design, maintenance and repair; and great care in the accomplishment of the annual inspections.

For the latter, the Japanese government gives most of the credit to those inspections observed by a government representative.

4.1.2 The Role of the Japanese Government in Preventive Maintenance

The Ministry of International Trade and Industry (MITI) enforces the legal requirements of the annual statutory inspections by inspecting selected components.

Before October 1, 1980, all statutory inspections were observed by a MITI inspector. Since that date, a substantial portion of the inspections are performed by the Nuclear Power Plant Inspection Center under contract to MITI. This center is staffed by individuals of the Japan Power Plant Inspection Institute. Before 1980, MITI inspectors would typically perform about 60 inspections during an inspection outage at a given plant. Since 1980, MITI inspectors typically have performed about 35 inspections, and contract inspectors have performed about 60 inspections. Although the total number of inspections performed by MITI has been decreasing, the total number of statutory inspections has been increasing.

Typically the government observed inspections are limited to safety related equipment. However, as mentioned in the previous subsection, there are cases of balance of plant (BOP) type equipment being observed. Refer to Table 4.1 and the asterisked items of Table 4.2 for examples of the specific components and systems that are subject to inspection by a representative of the government.

The government inspections provide a final check on the QA of a particular inspection. The utility prepares the equipment for inspection, and one government inspector observes the final measurements, confirmations, and functional tests. The actual inspection process does not require a large manpower commitment from the government, since the utility is given the responsibility for staging of the examination/inspection. At recent inspections conducted at two Japanese power plants, the total man-days expended by MITI inspectors for those outages were 17 and 22 man-days, respectively. Contractors were a little more

committed, as expected, with 40 man-days and 50 man-days, respectively. Typically, a utility will complete its own inspection and verification of operability before the government inspection.

The utility gets immediate feedback on the results of an inspection. In the case of a failure, the inspector and the utility come to agreement on a corrective action.

4.1.3 Radiation Exposure During the Annual Inspection

Considering the level of inspection conducted by the Japanese, it is natural to expect a large accumulated radiation dose. There is very strong public pressure in Japan to minimize radiation exposure. In response, the industry takes great measures to ensure minimum exposure. As noted, the Japanese are making use of automation and remote control systems to lower total exposure. The radiation limit in Japan is 3 rem per three-month period. The Japanese are required to report radiation exposure resulting from the inspection outage to the Japanese government. The details of the facility's radiation protection measures and personnel exposure are included in the post-inspection report to MITI. This information is then made publicly available in monthly reports published by the government.

A recent inspection outage at Fukushima Daini Unit 1 lasted for four months. Table 4.6a shows the total dose received by onsite employees and contractors during this four-month period. Table 4.6b shows the distribution of the dose. Workers are monitored for internal exposure by whole body count. No internal exposure was reported for this inspection.

Table 4.7 lists the duration and total exposure received during annual inspections reported in the Japanese Nuclear Safety Commission Monthly Report for April 1981 (JNSC 1981). The very long duration shutdown for Fukushima Daiichi Unit 1 and Unit 2 and the accompanying large exposure resulted from the major change-out of recirculation system piping to correct intergranular stress corrosion cracking problems. The third column of this table results from dividing the exposure (man-rem) by the duration (months) resulting in an effective monthly rate of exposure.

Table 4.8 gives the yearly exposure values for the entire Japanese industry as presented during the November 1984 bilateral exchange meeting between the U.S. NRC and the Japanese. The average yearly exposure per plant (obtained by dividing the total exposure by the number of units) for Japanese fiscal year 1983 was reported to be 440 man-rem.

These numbers indicate that on the average, the Japanese preventive maintenance program does not appear to be resulting in higher exposure rates than that experienced in the U.S.

4.2 OPERATIONAL SURVEILLANCE TESTING IN JAPAN

The Japanese preventive maintenance program has been described as having four elements: 1) statutory annual inspection, 2) voluntary internal inspection, 3) special work, and 4) routine inspection. The first three elements are conducted during the shutdown inspection outage. The fourth element, "routine inspection", is the analog of surveillance testing in the U.S. Specific testing requirements for a Japanese plant are listed in the facility's Technical Specifications. As in the U.S., Technical Specifications in Japan are generated by the utilities. Technical Specifications are approved by MITI and governed by Article 37 of the Law for Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (JONRE 1982).

Although no translated copies of technical specifications were available for review, we did obtain the table of contents of the Technical Specifications for two Japanese power plants. From the number of pages alone it is apparent that Japanese Technical Specifications are not exact analogs of their U.S. counterparts. The Technical Specifications for a two-loop PWR are only 40 pages long. This includes sections on fuel management, radiation control, emergency planning information, and administration, in addition to a section on maintenance and repair.

Examples of the routine inspections (operational tests) are given in Table 4.9. These examples were taken from the presentation given by the Japanese during the November bilateral exchange meeting. The exact scope of the tests conducted is not clear; however, it is clear that the Japanese focus most of their preventive maintenance resources on the shutdown outages. Our impression is that operational testing is generally de-emphasized.

4.3 U.S. VS JAPANESE PRACTICES

Preventive maintenance requirements in the U.S. are comprised of Technical Specification surveillances and Section XI of the ASME Code for Boilers and Pressure Vessels. Technical Specifications become part of the facility license, and are therefore a legal requirement upon the facility. The Technical Specifications surveillances are largely operational in nature. That is--they are comprised of functional type tests and verifications rather than the inspections conducted by the Japanese. Section XI of the ASME Code (ASME 1983) has been incorporated into 10 CFR 50.55a; therefore, it also is a legal requirement on the facility. This code specifies in-service inspection (e.g., visual, and volumetric) requirements for pressure boundary systems and components.

Technical Specifications for U.S. plants are more substantial than are the Technical Specifications for Japanese plants. Japanese operational testing appears to be targeted at detecting passive failures. Verification of functional operability is apparently relegated to the mechanical inspections and functional tests that are performed during the inspection outage. The U.S. facilities, on the other hand perform a substantial amount of operational verification testing during the operational phase. These tests go beyond simply detecting passive failures, but rather rigorously demonstrate operability.

There appears to be overlap between the U.S. and Japan in the area of in-service inspection. The Japanese indicate that they follow the guidance in the ASME Code Section XI (ASME 1983).

Table 4.10 summarizes a comparison between U.S. and Japanese maintenance requirements for selected safety related components taken from a detailed comparison made between the Technical Specification requirements at two U.S. plants and the long-range inspection schedule for Fukushima Daini Unit 1. The U.S. plants are Susquehanna Unit 1 and La Salle Unit 1, both General Electric Boiling Water Reactors with systems and operating histories similar to Fukushima Daini Unit 1. The first four columns of Table 4.10 are the inspections conducted by the Japanese. The Hydrostatic Test column and the In-service Inspection column are the main inspections performed to ensure structural integrity (ASME Code Section XI). The Full System Functional Test column indicates tests that involve the entire integrated function of the system, with only minimal operational constraints. The Partial System Functional Test column includes less than full scope functional testing, such as test running of pumps on mini-flow recirculation, or cycling selected valves to detect passive failures. Finally the Verification column includes such actions as venting fluid systems to ensure operability, performing a visual flow path verification of component positions, or performing channel checks of actuation instrumentation.

The Japanese dependence upon disassembly and inspection is clearly evident in the Table 4.10 presentation, as is the U.S. dependence upon partial scope functional testing and verification of operability. The overlap in the area of in-service inspection (ASME Code Section XI) (ASME 1983) is also evident. The full scope system functional tests conducted at Japanese plants are similar in scope to those conducted in the U.S., and are conducted at frequencies comparable to the U.S. In order to keep the table more concise, only the most frequent inspections given to the specified component or system have been noted. In many cases multiple tests are performed on a component or system with the same, or less, frequency.

The Japanese disassembly and inspection requirements are actually much broader than that indicated in Table 4.10. For example, the disassembly and inspection of the High-Pressure Core Spray Pump is actually accompanied by a disassembly and inspection of its accompanying component cooling pump and, seal water pump. Additionally, the electric motor for the HPCS pump is disassembled and inspected every 6 years and given a general inspection annually. Furthermore, all system valves are overhauled on a rotating basis.

The Technical Specifications requirements placed upon U.S. plants are limited largely to safety related systems and components. The Japanese also limit most of their statutory inspection to safety related components and systems. Their long-range inspection schedules, however, include non-safety related equipment such as: Reactor Coolant pumps (PWRs), Condenser systems, Condensate system, Feedwater system, Auxiliary boiler, Instrument and Service Air systems, plus the Turbine Generator and associated auxiliaries. The voluntary inspections at Japanese facilities, then, include inspections of these and many

other non-safety related systems. Even though these inspections are non-statutory, they are documented formally in the long-range inspection schedules of the Japanese plants. They do appear to be rather uniformly practiced throughout the Japanese nuclear industry. The Japanese, therefore, appear to have a more structured approach toward maintaining non-safety related and BOP equipment than does the U.S.

4.4 SUMMARY AND GENERAL OBSERVATIONS

The Japanese have a structured, industry wide program of preventive maintenance. Their program relies heavily upon the conduct of annual inspections conducted during an extended outage period. These inspections have their basis in law, however they seem to be administered with considerable flexibility. The result, however, is a formal and uniform program of preventive maintenance that includes non-safety related as well as safety related equipment. The following is an itemization of summary observations taken from the body of this section:

- Japanese preventive maintenance, although flexibly administered, has its basis in law (i.e., Electric Utility Law). Japanese nuclear facilities are required by law to shutdown annually and conduct thorough mechanical inspections.

- There is both a statutory and voluntary component to these annual inspections. Both statutory and voluntary inspections are scheduled ten years in advance.

- The statutory inspections include largely the systems and components included in U.S. Technical Specifications, whereas the voluntary inspections include BOP and other non-safety related systems and equipment.

- Full scope functional testing of important systems is conducted as part of the annual inspection.

- A government representative witnesses the results of statutory inspections and functional tests.

- All facilities are required to submit a report of their annual inspection outages that includes the results of all inspections, both voluntary and statutory. Additionally, they are required to report radiation exposure resulting from the annual inspection.

- Upon completion of the inspection outage, the Japanese facility performs a formal startup program culminating in a formal full power inspection.

- During the operating cycle, the Japanese power plants do perform operational surveillance testing. The testing appears to be targeted at discovering passive failures in components rather than ensuring their operability. Verification of operability appears to be relegated to the shutdown inspection process.

In contrast to the Japanese, the United States does not have a uniform (industry wide) preventive maintenance program. Preventive maintenance in the U.S. appears to be a by-product of Technical Specification operability requirements and ASME Code, Section XI requirements (ASME 1983). The end result appears to be that the U.S Nuclear Regulatory Commission must rely more heavily upon verification of operability during the operational phase then does the Japanese government.

TABLE 4.1. Inspections Scheduled for Statutory Inspection at a Typical Japanese BWR Facility in the Long-Range Schedule

Item	Frequency
Reactor Pressure Boundary (in-service inspection)	ai
Inspection of Fuel Assemblies, and refueling activities	ai
Determination of Reactor SCRAM margin	ai
Recirculation Pump (d&i) (rotating)	5y
Recirculation Pump (simple inspection)	1y
Reactor Coolant Purification System Main Valve (d&i) (one valve)	ai
Safety Relief System/Automatic Depressurization System (d&i)	ai
Main Steam Isolation Valve (d&i)	ai
Low-Pressure Core Injection (LPCI) Pump (d&i) (rotating)	4y
LPCI main valve (d&i)	ai
High-Pressure Core Spray Pump (d&i)	4y
Low-Pressure Core Spray Pump (d&i)	4y
Reactor Core Isolation Cooling Main Valve (d&i)	ai
Control Rod Drive (CRD) mechanisms (d&i) (37/yr)	5y
CRD Pump (d&i)	ai
CRD Control Unit (d&i) (37/yr)	5y
SCRAM Valve (d&i) (37/yr)	10y
Standby Liquid Control (SLC) System Pump (d&i) (both pumps together)	5y
SLC Explosive Rupture Valve (d&i)	ai
SLC Main Valve (d&i)	ai
Primary Containment leak test	ai
Primary Containment electrical penetration leak test	ai
Primary Containment selected isolation valves (d&i)	ai
Combustible Gas Concentration Control Blower (d&i)	4y
Combustible Gas Concentration Control Main Valve (d&i)	ai
Containment Air Regulation System Main Valve (d&i)	ai
Emergency Diesel Generator (EDG) (d&i) (partial rotating)	4y
EDG (simple inspection)	ai
HPCS EDG (d&i)	4y
HPCS EDG (simple inspection)	ai
Selected Cranes	ai
Main Turbine (d&i)	2y
Main Steam Stop and Control Valves (d&i)	ai
Main Steam Intercept Valves (d&i) (6 every 2 yr)	2y
Turbine Bypass Valves (d&i)	5y
Moisture Separator (d&i)	2y
Main Lube oil Pump (d&i)	2y
Specific Instrumentation:	
Selected Main Turbine Controls	
Selected Nuclear Instrumentation	
Selected Radiation Monitoring Instrumentation	
Plant Computer	
Electro-Hydraulic Control System	
High Pressure and Low Pressure Core Spray Instrumentation	

(ai) - annual inspection (d&i) - disassemble and inspect
(y) - year

TABLE 4.2. List of Inspections Performed by a Japanese BWR Facility During an Annual Inspection

Recirculation System

Recirc Pumps (si)*
Recirc Pump Motors (gi)
Variable Frequency Power Supply (Fluid Coupling) - 1 of 2 (si)
Motor/Generator - Motor - 2 of 2 (gi)
Motor/Generator - Generator - 2 of 2 (gi)
Lube Oil Pump - 4 of 8 (d&i)
Lube Oil Pump Motor - 2 of 8 (d&i), 6 of 8 (gi)
Common Valve - one set (d&i-si)

Reactor Water Clean-Up System

Circulating Pumps (d&i)
Holding Pump (d&i)
Precoat Pump (d&i)
Motor for Precoat Pump (d&i)
Regenerative Heat Exchanger - 1 of 5 (o&i)
Filter/Demineralizer (o&i)
Strainers (o&i)
Main Valve - one set (d&i-si)
Common Valve - one set (d&i-si)

Main Steam System

Main Steam Safety Relief Valves - all 18 (d&i)*
Main Steam Isolation Valves - all 8 (d&i)*
Turbine Bypass Valves - all 5 (d&i)*
Main Valve - one set (d&i-si)*
Common Valve - one set (d&i-si)

High-Pressure Core Spray (HPCS)

HPCS Pump (si)
HPCS Pump Motor (gi)
Seal Water Pump (d&i)
Seal Water Pump Motor (d&i)
Main Valve (si)
Common Valve (d&i-si)

Low-Pressure Core Spray (LPCS)

LPCS Pump (d&i)*
LPCS Pump Motor (d&i)
Seal Water Pump (d&i)
Seal Water Pump Motor (d&i)
Main Valve - one set (d&i-si)*
Common Valve - one set (d&i-si)

Component Cooling

First Loop Pump - 1 of 2 (d&i)
First Loop Pump Motor - 1 of 2 (d&i)
First Loop Heat Exchanger - 1 of 2 (o&i)
Second Loop Pump - 2 of 3 (d&i)
Second Loop Pump Motor - 1 of 3 (d&i)
Second Loop Heat Exchanger - 3 of 3 (o&i)
Main Valve - one set (si)
Common Valve - one set (d&i-si)

Residual Heat Removal (Low-Pressure Injection)

Low-Pressure Core Injection LPI Pump - 1 of 3 (d&i)*, 2 of 3 (si)
LPI Pump Motor - 1 of 3 (d&i), 2 of 3 (gi)
Heat Exchanger - 4 of 4 (o&i)
Main Valve - one set (d&i-si)*
Common Valve - one set (d&i-si)

d&i - disassemble and inspect
si - simple inspection
gi - general inspection
o&i - open and inspect
i&a - inspect and adjust
* - observed by a MITI inspector

TABLE 4.2. (contd)

R-sidual Heat Removal Seawater

Seawater Pump - 4 of 4 (d&i)
Seawater Pump Motor - 1 of 4 (d&i), 3 of 4 (gi)
Common Valve - one set (d&i)

Reactor Core Isolation Cooling (RCIC)

RCIC) Pump (d&i)* (Note: Not listed as statutory on the long-range schedule)
RCIC Pump Turbine (d&i)* (Note: Not listed as statutory on the long-range schedule)
Main Valve - one set (d&i)*
Common Valve - one set (d&i)

Reactor Feedwater

Reactor Feedwater Pumps - 2 of 2 (d&i)* (Note: Not listed as statutory on the long-range schedule)
Reactor Feedwater Pump Turbine - 1 of 2 (d&i)* (Note: Not listed as statutory on the long-range schedule)
Motor Driven Feedwater Pump - 2 of 2 (d&i)* (Note: Not listed as statutory on the long-range schedule)
Motor for Motor Driven Feedwater Pump - 1 of 2 (d&i), 1 of 2 (gi)
Feedwater Control Valve - 2 of 2 (d&i)
Feedwater Heaters - 4 of 18 (o&i)
Main Valve - one set (si)
Common Valve - one set (d&i-si)

Condensate

Condensate Pump - 1 of 3 (d&i)*, 2 of 3 (si) (Note: Not listed as statutory on the long-range schedule)
Condensate Pump Motor - 1 of 3 (d&i), 2 of 3 (gi)
Heater Drain Pump - 1 of 3 (d&i), 2 of 3 (si)
Heater Drain Pump Motor - 1 of 3 (d&i) 2 of 3 (gi)
Common Valve - one set (d&i-si)
Hotwell - 3 of 3 (o&i)

Circulating Water

Condenser Water Boxes - 6 of 6 (o&i)
Circ-water Pump - 1 of 3 (d&i)
Circ-water Pump Motor - 1 of 3 (d&i), 2 of 3 (gi)
Continuous Wash (traveling screens) - (d&i)
Water Transport Lines - (o&i)
Common Valves - one set (d&i-si)

Air Extraction

Common Valve - one set (d&i-si)

Condensate Polishing

Demineralizers - 5 of 10 (o&i)
Recirculating Pump - 1 of 2 (d&i)
Motor for Recirculating Pump - 1 of 2 (d&i)
Common Valve - one set (d&i-si)

Control Rod Drive CRD System

CRD Mechanisms - 37 of 185 (d&i), (open and test)*
CRD Water Pump - 2 of 2 (d&i)*
CRD Water Pump Motor - 2 of 2 (gi)
Hydraulic Pressure Control Units - 37 of 185 (d&i)*
Scram Valves - 40 of 370 (d&i)*
Common Valve - one set (d&i)

d&i - disassemble and inspect
si - simple inspection
gi - general inspection
o&i - open and inspect
i&a - inspect and adjust
* - observed by a MITI inspector

TABLE 4.2. (contd)

Stand-By Liquid Control

Rupture Valve - 2 of 2 Test run, replace
Injection Pump - 2 of 2 (si)
Injection Pump Motor - 1 of 2 (d&i), 1 of 2 (gi)
Tank - 2 of 2 (o&i)
Main Valve - one set (si)
Common Valve - one set (d&i)
Measure the Concentration of the Boric Acid

Instruments

Source Range Monitors - Detector Drive Mech (i&a)
Intermediate Range Monitors - same
Power Range - 1 unit (i&a) detector and monitors
Manual Control for Control Rods - one set, (i&a) logic circuit
Control Rod Position Indication - one set, (i&a) detector and circuit
Engineered Safety Features Actuation - one set (i&a)*
Containment Isolation System - one set (i&a)
Reactor Related Instruments - one set (gi)
Turbine Generator and Related Instruments - one set (gi)

Control Air Compressor

Air Compressor - 2 of 2 (d&i)
High-Pressure Air Compressor - 2 of 2 (d&i)

Auxiliary Facilities

Vital AC Power - 2 of 2 (gi)
AC Power for Emergency Shutdown
- Generator - 1 of 2 (d&i), 1 of 2 (gi)
- Motor - 1 of 2 (d&i), 1 of 2 (gi)

Instrumentation for Radiation Control

Area Monitors - one set (i&a)
Process Monitors - one set (i&a)

Stand-By Gas Treatment

Air Ejector - 2 of 2 (d&i)
Train Components - 2 of 2 (gi)

Gas Waste Treatment

Charcoal Holdup Tower - one set (gi)

Liquid Waste Treatment

Liquid Waste Concentrator - 2 of 4 (o&i) (open and test)*
Liquid Waste Sump - 3 of 3 (o&i)
Dry well Sump (o&i)
Instrumentation - one set (gi)
Leak Detection System - one set (gi)

Cooling System for Waste Processing Equipment

Pumps - 2 of 2 (d&i)
Heat Exchanger - 2 of 2 (o&i)
Seawater Pumps - 2 of 2 (d&i)
Seawater Pump Motor - 1 of 2 (gi)

Containment

Containment Isolation Valves - one set (d&i)*

Combustible Gas Concentration Control

d&i - disassemble and inspect
si - simple inspection
gi - general inspection
o&i - open and inspect
i&a - inspect and adjust
* - observed by a MITI inspector

TABLE 4.2. (contd)

Blowers - 2 of 2 (gi)
Main Valves - one set (si)

Drywell Cooling System

Fans - 5 of 5 (d&i)
Supply Fan - 3 of 3 (d&i)
Motors - 8 of 8 (d&i)

Emergency Diesel Generator

Engine - 2 of 2 (d&i)*
Generator - 2 of 2 (gi)

Emergency Equipment Cooling

Pump - 1 of 2 (d&i)
Heat Exchanger - 2 of 2 (o&i)

HPCS Diesel Generator

Engine - (d&i)*
Generator - (gi)

HPSC Cooling Seawater

Seawater Pump - (d&i)

Steam Turbine

Main Unit - (o&i)*
Auxiliary Equipment - (d&i)
Moisture Separators - 2 of 2 (o&i)
Crossover Pipes - one set (o&i)

Turbine Auxiliary Cooling

Pumps - 2 of 3 (d&i), 1 of 3 (si)
Motors for the Pumps 1 of 3 (d&i), 2 of 3 (gi)
Heat Exchangers - 4 of 4 (o&i)

Equipment Cooling Seawater

Seawater Pump - 2 of 3 (d&i)
Seawater Pump Motor - 1 of 3 (d&i), 2 of 3 (gi)

TABLE 4.3. Examples of Corrective Actions Taken During the First Annual Inspection of One Japanese BWR Facility in Response to Industry Events

Description of Event	Results of Inspection
During inspection of a Japanese BWR test of a jet pump beam by volumetric examination revealed an abnormality.	A portion (4 of 20) of the jet pump beams were visually inspected.
A Japanese PWR experienced a reactor trip caused by a faulty transformer relay.	The relay was inspected and overhauled.
A Japanese BWR discovered leaks from the joint between a moisture separator drain tank level control valve and a nearby reducer.	Wall thickness near this joint was measured to confirm soundness.
During startup at a Japanese BWR, a small stream leak was discovered at the reactor recirculating pump flange. The reactor was shut down and the leak repaired.	Soundness of the flange area was confirmed during in-service inspection (leak test).
During operation of a Japanese BWR, the power to the EHC system was lost because of defective information in a relay coil. The result was a turbine/reactor trip.	The relay was replaced with one that was domestically produced. The EHC control circuit was modified.
A Japanese BWR experienced a trip of the reactor protection system channel "B" caused by a failure of the APRM power supply.	The power supply was inspected and overhauled.
During operation of a Japanese BWR, the main steam pressure dropped because the servo valve of the reactor pressure control unit malfunctioned. This resulted in the steam control valve sticking in the open position. The main steam isolation valves closed on low pressure.	The servo value was inspected and overhauled.
During the regular inspection of a Japanese BWR, a portion of the SCRAM valves did not close because of plug-up of the SCRAM valve regulating air system.	Air pipes were blown with air. A SCRAM test was conducted. Cleanliness of the system was safeguarded during maintenance.

TABLE 4.4. Examples of the Modification of Maintenance Tooling and Systems Designed for Decreasing Outage Duration

PWR ITEMS	DESCRIPTION
Bifacial fuel examination device	Device for simultaneously examining two faces of fuel assemblies
Steam generator heat transfer tube high speed ECT device	Device for conducting ECT of heat transfer tubes at high speed
Reactor vessel seal plate	Temporary reactor seal plate to be mounted on the reactor vessel flange after fuel discharge. It is designed to facilitate the simultaneous work of S/G and upper core internals.
Mechanical cavity decontamination device	Mechanization of decontamination work
Equipment transporting device for bringing equipment in and out of c/v	Handling of heavy equipment (e.g., RCP motor) to and from c/v
Portal crane for generator	Crane dedicated for generator work in parallel with steam turbine work
BWR ITEMS	**DESCRIPTION**
Main steam nozzle water sealing plug	To make possible simultaneous fuel exchange and maintenance/inspection of main steam isolation valves and main steam safety valves, via water sealing, by inserting plug in main steam nozzle from inner side of reactor vessel
Reactor well wall decontamination device	Mechanization of decontamination work
Automatic fuel handling machine	To automatically carry out fuel exchange by computer position setting to which fuel assembly is transported.
Modified LPRM exchange device	Device to exchange LPRM using in-core installation guide
CRD automatic exchange	Device to transport removed CRD without reloading and to facilitate simultaneous insertion/removal of CRD mounting bolts
Turbine rotor inspection stand	Stand for rotating turbine rotors at constant speed

TABLE 4.5. List of Systems Tested Functionally and Observed by MITI During the First Annual Inspection of a Japanese BWR Facility

Safety Relief Valves
Turbine Bypass Valves
RCIC system
High-Pressure Core Spray system
Low-pressure Injection (RHR) system (all three pumps)
Low-Pressure Core Spray System
ADS system
Reactor Feedwater system
Control Rod Drive Hydraulic System
Stand-By Liquid Control system
Control Air (instrument air) Compressor
Safety Protection system (calibration)
Reactor Protection system
Nuclear Instrumentation system
"Unified interlock" (Reactor Mode Switch)
Fuel Handling components
Fuel Pool Cooling and Ceanup System
Outdoor Radiation Monitors
Area Radiation Monitors
Process Monitors
Emergency Gas Processing system
Performance Test of the Emergency Gas Processing system filters
Control Room Emergency Ventilation system
Waste Gas Disposal system
Liquid Waste Disposal system
Containment Isolating Valves
Containment Vacuum Breaker
Containment Spray System
Combustible Gas Concentration Control system
Emergency Diesel Generator
In-service Inspection of Reactor Coolant Pressure Boundary
Leak Test of the Reactor Coolant system
SCRAM Margin Test
Leak Test of the Safety Relief Valves
Leak Test of the Main Steam Isolation Valves
Hydrostatic Test of the Liquid Rad-Waste Concentrator (Heat Transfer Tubes)
Examine the status of the solid waste management warehouse
Leak Rate Test of the Reactor Building
Air Tightness Test of the Reactor Building

TABLE 4.6a. Radiation Exposure During the First Annual Inspection at Fukushima Daini, Unit 1

	Number of Workers	Exposure (man-rem)	Average Exposure (rem)	Maximum Exposure (rem)
Facility Employees	287	9	0.03	0.75
Contractors	2441	200	0.08	1.94
Total	2728	209	0.08	-

TABLE 4.6b. Distribution of Exposure During the First Annual Inspection at Fukushima Daini, Unit 1

	<0.13 rem	0.13 - 0.4 rem	0.4 - 1.3 rem	1.3 - 3 rem	Total
Facility Employees	270	13	4	0	287
Contractors	2041	244	141	15	2441
Total	2311	257	145	15	2728

TABLE 4.7. Exposure for Selected Annual Inspections

Plant	Duration, Months	Man-Rem	Effective Monthly Rate of Exposure (Rem/Month)
Fukushima Daini Unit 1	4	209	52.3
Fukushima Daiichi Unit 1	9.3	3159	339.7
Fukushima Daiichi Unit 2	6.3	1686	267.6
Tokai Daini	3.3	289	87.6
Hamaoka Unit 2	4	301	75.3
Fukushima Daiichi Unit 4	3.5	234	66.9
Fukushima Daiichi Unit 6	4	217	54.3
Takahama Unit 1	8	640	80.0
Mihama Unit 1	6	825	137.5
Ohi Unit 2	6	325	54.2
Mihama Unit 3	6.3	371	58.9
Takahama Unit 2	4.6	289	62.8

TABLE 4.8. Radiation Exposure in the Japanese Nuclear Industry

Items	Japanese FY	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83
Number of Employees	Facility Employees	2,076	2,282	2,555	3,233	3,578	3,759	3,976	4,374	4,688	5,367
	Subcontractors, etc.	10,282	13,798	17,241	22,129	30,577	30,495	31,978	36,158	35,941	41,072
	Total	12,358	16,080	19,796	25,362	34,155	34,254	35,954	40,532	40,629	46,439
Total Exposure	Facility Employees	701	716	769	726	766	826	796	784	733	660
(Man - Rem)	Subcontractor, etc.	2,427	4,283	5,473	7,390	12,360	10,759	11,952	11,933	11,767	11,206
	Total	3,127	4,998	6,241	8,117	13,127	11,585	12,747	12,718	12,500	11,867
Average Exposure (Rem)	Facility Employees	0.34	0.31	0.30	0.22	0.21	0.22	0.20	0.18	0.16	0.12
	Subcontractor, etc.	0.24	0.31	0.32	0.33	0.40	0.35	0.37	0.33	0.33	0.27
	Total	0.25	0.31	0.32	0.32	0.38	0.34	0.35	0.31	0.31	0.26
Number of Units		12	13	14	19	21	21	22	24	24	27

TABLE 4.9. Routine Inspections (Surveillance Testing) at Japanese Power Plants

1. Examples of PWR Surveillance Tests Under Normal Operation

Items and Test	Frequency	Description
Diesel Generator		
• Manual start	once/month	Start and manually load the diesel generator from the central control room to obtain operating data, including measurement of time to come up to speed.
Control Rod Drive Mechanism	twice/month	15-20 step insertion and pull-out for all banks (except control group banks) used in reactor control
Safety Injection System		
• Manual starting of high-pressure injection pump	once/month	Checking of pump operation manual starting from control room
• Operation of motor-operated valve	once/month	Checking of valve operation by manually opening/closing from the control room
Residual Heat Removal System	once/month	Checking of pump operation by manually starting from the control room
Containment Spray System		
• Manual starting pump	once/month	Checking of pump operation by manually starting from the control room
• Operation of motor operated valve	once/month	Checking of valve operation by manually opening/closing from the control room
Heating and Ventilation System		
• Manual starting of ventilation fan for containment vessel	once/month	Checking of fan operation by manually starting from control room

TABLE 4.9. (contd)

Items and Test	Frequency	Description
• Manual starting of emergency filter fan for the control room	once/month	Checking of fan and damper operation by manual starting from the control room.

2. Examples of BWR Surveillance Conducted During Normal Operation

Items and Test	Frequency	Description
Diesel generator		
• Manual start	once/month	Start and manually load the diesel generator from the control room to obtain operating data including measurement of time to come up to speed
Control Rod Driving System		
• One notch test	once/week	Withdraw and insert all the control rods by one notch.
Reactor Protection System		
• Functional test of average power range	once/week	Confirm the function of average power range monitor with signals of malfunction and high neutron flux, respectively.
• Manual SCRAM test	once/month	Push the manual SCRAM button on one side in the main control room and confirm the SCRAM signal of the channel on the same side.
Stand-by Gas treatment System		
• Functional test	once/month	Start the system manually and confirm the normal movement of auto valves and the normal function of the system.

TABLE 4.9. (contd)

Items and Test	Frequency	Description
Stand-by Liquid Control System		
• Manual operation of pump	once/month	Confirm the normal movement of pump and the normal function of the system.
• Density of poison	once/month	Sample and confirm density in the prescribed range.
• Volume and temperature of poison	once/week	Confirm volume and temperature of poison in the prescribed range.
Reactor Core Spray System		
• Manual start of pump	once/month	Start the pump manually from the main control room and confirm normal function.
• Manual operation of motor valve	once/month	Open and close motor valve manually from the main control room and confirm normal movement.
Residual Heat Removal System		
• Manual start of pump	once/month	Start the pump manually from the main control room and confirm normal function.
Reactor Auxiliary Cooling Water System		
• Manual start of pump	once/month	Start the pump manually from the main control room and confirm normal function.
High-Pressure Coolant Injection System		

TABLE 4.9. (contd)

Items and Test	Frequency	Description
• Manual start of pump	once/month	Start the pump manually from the main control room and confirm normal function of the pump.
• Manual operation of motor valve	once/month	Open and close motor valve manually from the control room and confirm normal involvement.
Main Steam Isolation Valve		
• 10% close	once/week	Close MSIV manually to 90% opened position and confirm normal movement.
• Full close	once/three months	Close MSIV manually at under 60% power and measure its full stroke time.

TABLE 4.10. Summary of Selected Maintenance Items

	Disassemble and Inspect	Simple Inspection	General Inspection	Open and Inspect	Hydrostatic Test	In-Service Ins.	Full System Functional Test	Partial System Function Test	Verification
High Pressure Core Spray (HPCS)									
Fukushima (HPCS)	4y*(3)	ai	-	-	ai*	ai*	ai*	31d	-
Susquehanna (HPCS)	-	-	-	-	(2)	ASME	18m	18m(1)	31d
LaSalle (HPCS)	-	-	-	-	(2)	ASME	18m	18m(1)	31d
Low Pressure Core Spray (LPCS)									
Fukushima (LPCS)	4y*(3)	ai	-	-	(2)	ai*	ai*	31d	-
Susquehanna (CSS)	-	-	-	-	(2)	ASME	18m	(1)	31d
LaSalle (LPCS)	-	-	-	-	(2)	ASME	18m	(1)	31d
Low Pressure Core Injection (LPCI)									
Fukushima	4y*(3)	ai	-	-	(2)	ai*	ai*	31d	-
Susquehanna	-	-	-	-	(2)	ASME	18m	(1)	31d
LaSalle	-	-	-	-	(2)	ai*	ai*	18m	31d
Residual Heat Removal (RHR) Sea Water/Service Water									
Fukushima (sea water)	ai(3)	-	-	-	-	-	-	-	-
Susquehanna (service water)	-	-	-	-	-	-	-	-	31d
LaSalle	-	-	-	-	-	-	-	-	31d
LPCI/RHR Heat Exchangers									
Fukushima	-	-	-	4y	-	-	-	-	-
Susquehanna	-	-	-	-	-	-	-	-	12h
LaSalle	-	-	-	-	-	-	-	-	12h
Automatic Depressurization Valves									
Fukushima	-	-	ai	-	-	-	ai*	-	-
Susquehanna	-	-	-	-	-	-	18m	18m	18m
LaSalle	-	-	-	-	-	-	18m	18m	18m
Reactor Core Isolation Cooling									
Fukushima	5y(3*,4)	-	-	-	-	ai*	ai*	-	-
Susquehanna	-	-	-	-	-	ASME	18m	92d	31d
LaSalle	-	-	-	-	-	ASME	18m	92d	31d
Recirculation System									
Fukushima	5y*(3)	ai*	-	-	ai*	ai*	-	-	-
Susquehanna	-	-	-	-	-	ASME	-	18m	24h
LaSalle	-	-	-	-	-	ASME	-	18m	24h
Emergency Diesel Generator									
Fukushima	ai*(5)	-	-	-	-	-	ai*	31d	-
Susquehanna	18m(6)	-	-	-	-	-	31d	31d	31d
LaSalle	18m(6)	-	-	-	-	-	31d	31d	31d
Control Rod Drive Mechanisms									
Fukushima	5y*(7)	-	-	-	-	ai*	ai*	7d	-
Susquehanna	-	-	-	-	-	-	99d	7d	24h
LaSalle	-	-	-	-	-	-	99d	7d	24h
Control Rod Drive Hydraulic Pumps									
Fukushima	ai*	-	-	-	-	ai*	-	-	-
Susquehanna	-	-	-	-	-	-	-	-	-
LaSalle	-	-	-	-	-	-	-	-	-
Standby Liquid Control									
Fukushima	5y*(3)	-	-	-	-	ai*	ai*	31d	-
Susquehanna	-	-	-	-	-	-	18m	18m(1)	24h
LaSalle	-	-	-	-	-	-	18m	18m(1)	24h

NOTES: (1) Additionally performed persuant to the tests of Section IX of the ASME Code for Boilers and Pressure Vessels.
(2) Reactor Coolant System pressure isolation valves are leak checked at normal operating pressure.
(3) Pump.
(4) Turbine.
(5) The generator is inspected annually and disassembled for inspection every 8y.
(6) Subject to manufacturers recommendations.
(7) Including hydraulic control units.

* - Maintenance item is observed by a MITI representative.
y - year m - month d - day h - hour ai - annual inspection ASME - Code, Section XI

5.0 ORGANIZATION AND MANAGEMENT PRACTICES AT JAPANESE POWER PLANTS

Maintenance activities are strongly influenced by a set of factors external to the task itself. These factors include 1) the management approach and organizational form adopted by the utility, 2) the regulatory approach in place for the industry, 3) the economic forces confronting the utilities and regulatory bodies, and 4) the overall culture. When analyzing the Japanese approach to nuclear power plant maintenance, these factors emerge as possible determinants of observed differences between the U.S. and Japan. Significant differences in management and organization, regulation, economic forces, and culture exist for the U.S. and Japanese nuclear industries. This section examines these factors in order to identify significant similarities and differences in U.S. and Japanese experience and trace the implications that these differences have for nuclear power plant maintenance.

Following this introduction, Section 5.1 will outline the current state of the nuclear power industry in Japan. Section 5.2 describes the regulatory context. Section 5.3 describes the nature of the utility's relations with vendors, subcontractors, and labor. Section 5.4 describes the internal management and organization approach. Section 5.5 summarizes the issues relative to organization and management practices.

Before the discussion of these areas, two preliminary points must be made. First, the current discussion is based on information collected during two trips to Japan, selected published documents, and some additional information collected by correspondence.[a] While additional information would be required for a comprehensive discussion of the social context of NPP maintenance in Japan, the available information does allow for at least an initial overview of the problem.

The second point concerns the interpretation of observed differences in U.S. and Japanese approaches. One danger is to automatically assume that each observed difference is culturally based. Taken in its extreme, such a view would mean that nothing useful could come from a comparison of U.S. and Japanese approaches, since each approach would be so imbedded in its host culture that it could not possibly serve as a model or lesson for the nuclear industry in other countries. At the other extreme is the notion that the two approaches are simply alternative strategic responses to common problems, and that the Japanese approach can be adopted, as is,

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[a]See R.V. Badalamente, M.H. Morgenstern, and W.T. Russell, "Trip Report: Review of Japanese Nuclear Power Plant Maintenance, Regulation and Practice," Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, May 1984 (unpublished). Additional information comes from the NRC transcripts of "The Second Meeting on Nuclear Regulatory Matters between U.S. and Japan." Other sources have been referenced as appropriate.

by U.S. utilities. The analysis that follows, however, suggests a) some differences are cultural while others are strategic and b) even culturally determined practices may be approximated in the other culture through the use of appropriate incentives.

5.1 THE NUCLEAR INDUSTRY IN JAPAN

This section presents an overview of the Japanese nuclear industry. It includes information about the organization of the industry and a brief discussion of the role of the nuclear industry in the production of power in Japan.

5.1.1 Description of the Nuclear Industry

Table 5.1 provides descriptive information on the current state of the nuclear industry in Japan. As of September 1983, there were 24 units operating with a total output in excess of 17,000 MWe. While this is only roughly one third the output of the U.S. nuclear industry, the 24 units make Japan the free world's third largest producer of commercial nuclear power. The 24 units are divided across seven utilities: Tokyo Electric Power Company and Kansai Electric Power Company are the two largest with seven units each. Eleven more units are under construction and nine more are planned. The units under construction will add 10,204 MWe and the planned units 8,253 MWe to the industry total. Of the operating plants, one is gas-cooled, twelve are BWRs, and eleven are PWRs.

The Japanese utility industry took its basic form in 1951 as a result of an imposed reorganization during the U.S. occupation following World War II. The utility organizations before that time were similar to U.S.-based utilities in that they dated back to the turn of the century or earlier. However, the reorganization created nine new regionally based, private utilities. Several organizations, including the Japan Atomic Power Co., have been created since to provide wholesale distribution of electricity for the nine utilities.

Several features of this pattern are worthy of note. First, there are many fewer utilities in Japan than in the U.S. Among other effects, this may facilitate cooperation within the industry as is seen in the sharing of operational and incident data through the Nuclear Information Center of the Central Research Institute of the Electric Power Industry (CRIEPI). Second, the small number of utilities means that each is relatively large. This suggests an ability to make the commitment to and investment in nuclear power to an extent necessary for success. Third, each of the utilities is involved in both the production and distribution of electrical power. Fourth, due to the reorganization after World War II, the utilities are relatively young organizations with most of their operating experience coinciding with the nuclear era. Finally, as can be seen from Table 5.2, most of the utilities combine a mix of power-generating technologies, including a significant nuclear component.

TABLE 5.1. Commercial Nuclear Power Plants - Japan

Power Plant		Operator (a)	Type of Reactor	Capacity (MWe:Gross)	NSSS Supplier	Start of Operation
In Operation						
Tokai		JAPCO	GCR	166	GEC	Jul. '66
Tokai Daini		JAPCO	BWR	1,100	GE/Hitachi	Nov. '78
Tsuruga	(No. 1)	JAPCO	BWR	357	GE	Mar. '70
Fukushima Daiichi	(No. 1)	TEPCO	BWR	460	GE	Mar. '71
Fukushima Daiichi	(No. 2)	TEPCO	BWR	784	GE/Toshiba	Jul. '74
Fukushima Daiichi	(No. 3)	TEPCO	BWR	784	Toshiba	Mar. '76
Fukushima Daiichi	(No. 4)	TEPCO	BWR	784	Hitachi	Oct. '78
Fukushima Daiichi	(No. 5)	TEPCO	BWR	784	Toshiba	Apr. '78
Fukushima Daiichi	(No. 6)	TEPCO	BWR	1,100	GE/Toshiba	Oct. '79
Fukushima Daini	(No. 1)	TEPCO	BWR	1,100	Toshiba	Apr. '82
Fukushima Daini	(No. 2)	TEPCO	BWR	1,100	Hitachi	Feb. '84
Hamaoka	(No. 1)	CBEPCO	BWR	540	Toshiba	Mar. '76
Hamaoka	(No. 2)	CBEPCO	BWR	840	Toshiba/Hitachi	Nov. '78
Mihama	(No. 1)	KEPCO	PWR	340	Westinghouse	Nov. '70
Mihama	(No. 2)	KEPCO	PWR	500	Mitsubishi	Jul. '72
Mihama	(No. 3)	KEPCO	PWR	826	Mitsubishi	Dec. '76
Takahama	(No. 1)	KEPCO	PWR	826	Westinghouse	Nov. '74
Takahama	(No. 2)	KEPCO	PWR	826	Mitsubishi	Nov. '75
Ohi	(No. 1)	KEPCO	PWR	1,175	Westinghouse	Mar. '79
Ohi	(No. 2)	KEPCO	PWR	1,175	Westinghouse	Dec. '79
Shimane	(No. 1)	CGEPCO	BWR	460	Hitachi	Mar. '74
Ikata	(No. 1)	SEPCO	PWR	566	Mitsubishi	Sep. '77
Ikata	(No. 2)	SEPCO	PWR	566	Mitsubishi	Mar. '82
Genkai	(No. 1)	KYEPCO	PWR	559	Mitsubishi	Oct. '75
Genkai	(No. 2)	KYEPCO	PWR	559	Mitsubishi	Mar. '81
Sendai	(No. 1)	KYEPCO	PWR	890	Mitsubishi	Jul. '84
Onagawa		THEPCO	BWR	524	Toshiba	Jun. '84
Subtotal			(27 units)	19,691		
Under Construction						
Tsuruga	(No. 2)	JAPCO	PWR	1,160	Mitsubishi	Jun. '87
Fukushima Daini	(No. 3)	TEPCO	BWR	1,100	Toshiba	Jul. '85
Fukushima Daini	(No. 4)	TEPCO	BWR	1,100	Hitachi	Sep. '87
Kashiwazaki/Kariwa	(No. 1)	TEPCO	BWR	1,100	Toshiba	Oct. '85
Kashiwazaki/Kariwa	(No. 2)	TEPCO	BWR	1,100		Oct. '90
Kashiwazaki/Kariwa	(No. 5)	TEPCO	BWR	1,100		Apr. '90
Shimane	(No. 2)	CGEPCO	BWR	820		Sep. '88
Hamaoka	(No. 3)	CBEPCO	BWR	1,100	Toshiba	Sep. '87
Takahama	(No. 3)	KEPCO	PWR	870	Mitsubishi	Feb. '85
Takahama	(No. 4)	KEPCO	PWR	870	Mitsubishi	Aug. '85
Sendai	(No. 2)	KYEPCO	PWR	890	Mitsubishi	Mar. '86
Tomari	(No. 1)	HEPCO	PWR	579	--	Jun. '89
Tomari	(No. 2)	HEPCO	PWR	579	--	Jun. '91
Subtotal			(13 units)	12,368		
Planned						
Maki	(No. 1)	THEPCO	BWR	825		Dec. '94
Ikata	(No. 3)	SEPCO	PWR	890		Oct. '90
Genkai	(No. 3)	KYEPCO	PWR	1,180		Mar. '93
Genkai	(No. 4)	KYEPCO	PWR	1,180		Mar. '94
Subtotal			(4 units)	4,075		
TOTAL			(44 units)	36,134		

(a) JAPCO: Japan Atomic Energy Co.
TEPCO: Tokyo Electric Power Co.
CBEPCO: Chubu Electric Power Co.
CGEPCO: Chugoku Electric Power Co.
KEPCO: Kansai Electric Power Co.
SEPCO: Shikoku Electric Power Co.
KYEPCO: Kyushu Electric Power Co.
THEPCO: Tohoku Electric Power Co.
HEPCO: Hokkaido Electric Power Co.

Adapted from: "Progress of Power Plants to Date," Atoms in Japan, January, 1985.

TABLE 5.2. Generating Capacity by Plant Type for Japanese Utilities in 1983

Utility	Generating Capacity (MWe) and Percentages Nuclear	Fossil	Hydro	Total
Hokkaido EPCo.	0	2,809 (75.2%)	926 (24.8%)	3,735 (100%)
Tohoku EPCo.	0	5,780 (72.1%)	2,237 (27.9%)	8,017 (100%)
Tokyo EPCo.	5,796 (16.7%)	23,781 (68.7%)	5,053 (14.6%)	34,630 (100%)
Chuba EPCo.	1,380 (7.9%)	12,552 (72.2%)	3,462 (19.9%)	17,394 (100%)
Hokuriku EPCo.	0	1,912 (53%)	1,693 (47%)	3,605 (100%)
Kansai EPCo.	5,668 (23.1%)	12,991 (53.1%)	5,827 (23.8%)	24,486 (100%)
Chugoku EPCo.	460 (5.9%)	5,668 (72.9%)	1,652 (21.2%)	7,776 (100%)
Shikoku EPCo.	1,132 (22.3%)	3,172 (62.5%)	773 (15.2%)	5,077 (100%)
Kyushu EPCo.	1,118 (11.2%)	7,225 (72.5%)	1,617 (16.2%)	9,960 (100%)
Electric Power Development Co.	0	3,493 (35%)	6,490 (65%)	9,982 (100%)
Japan Atomic Power Co.	1,623 (100%)	0	0	1,623 (100%)

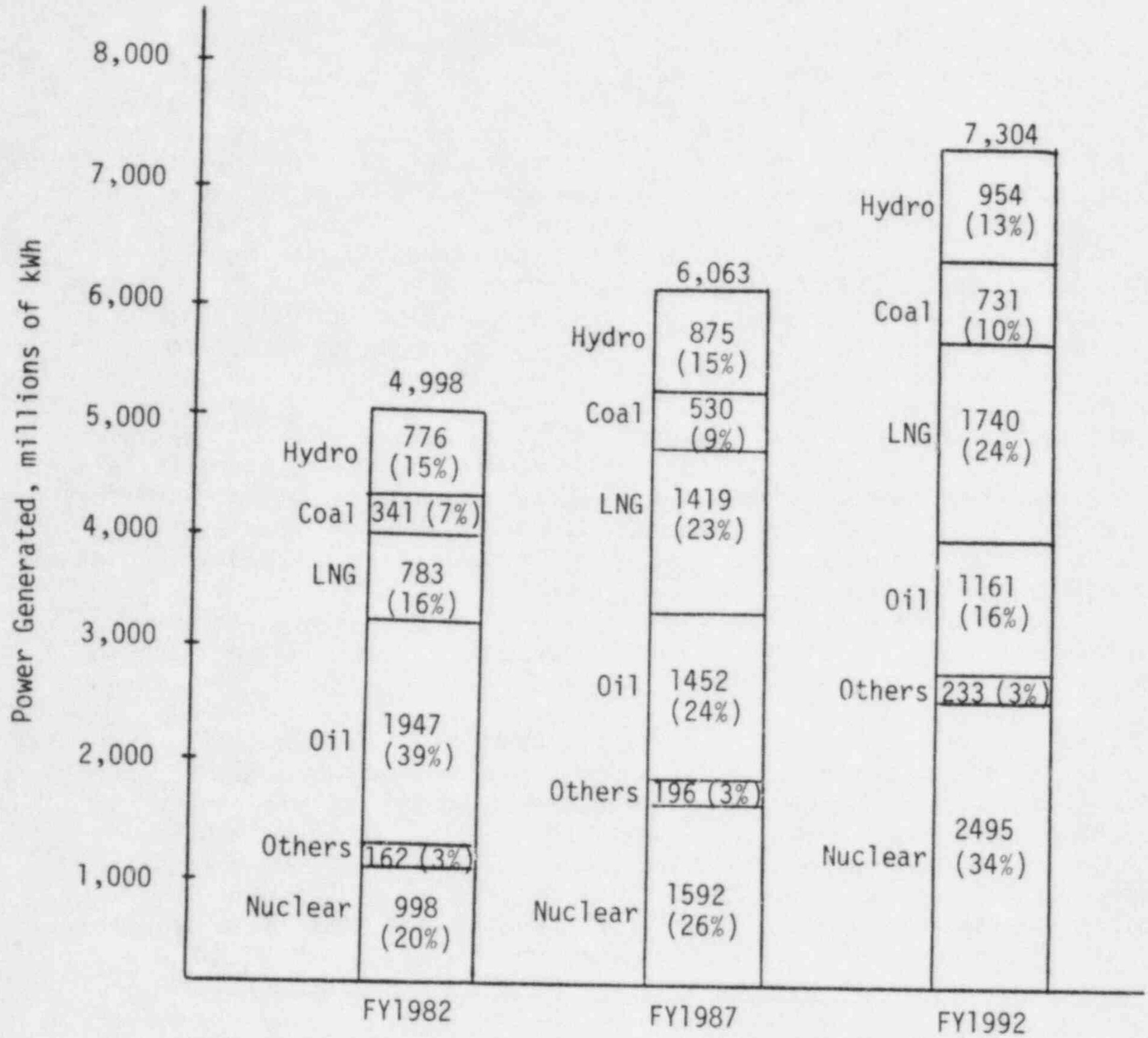
Adapted from: "Electric Power Industry in Japan 1983," Overseas Electric Industry Survey Institute, Inc., 1984.

Figure 5.1 contains information on the current and future contribution of nuclear power to the total electrical generation of Japan. As can be seen, nuclear power currently constitutes 20% of all electrical power generated (compared to 11% for the U.S.). However, that percentage is expected to rise fairly rapidly to 34% by 1992. For some of the utilities, the percentage will rise to nearly 50%. The growth of the Japanese nuclear industry at a time when the U.S. nuclear industry is stagnant is due, in part, to the Japanese quest for energy self sufficiency. Japan is very heavily dependent on imported oil and coal for its energy needs. Not only does this create a position of vulnerability relative to the supply of these fuels, but it is the major threat to Japan's positive trade balance. In addition, the costs of producing electricity from nuclear energy are less in Japan than for alternative sources such as oil and coal. One set of estimates for 1984, for example, sets generating costs at the point of production in Japan at approximately 5.7 cents/kWh for nuclear power, 6.1 cents/kWh for coal, 7.4 cents/kWh for Liquified Natural Gas and 7.4 cents/kWh for oil. When NPPs are offline, replacement power normally comes from the more expensive oil plants (Japan Atomic Industrial Forum 1985). Although the recent oil surplus has somewhat decreased the competitive advantage of nuclear power, this advantage will likely continue if the Japanese are successful in improving both plant availability and LWR designs.

Finally, because nuclear power plant costs are primarily in the construction phase, and because the world supply on nuclear fuels appears stable with depressed prices, an increased reliance of nuclear energy can help Japan approximate energy self sufficiency. This has led both the Japanese government and the utilities to pursue nuclear power as the main alternative to imported oil. These facts contribute to the continued viability of nuclear power in Japan. This viability appears to exceed the current U.S. conditions and can be expected to influence a wide range of utility and regulatory activities.

Because of these facts, nuclear power in Japan is a more central factor in national policy than it is in the U.S. This has important implications for the regulatory approach adopted by the Japanese. It also means that the importance of nuclear power to the individual utility is heightened. A review of the 1983 annual reports for all of the nuclear utilities revealed that the expansion of nuclear generating capacity was the number one expansion goal. This suggests a centrality in planning and staffing for nuclear power production that may not be taking place in U.S. utilities where the outlook for nuclear power is less positive.

Nuclear power technology in Japan was originally an imported technology, with General Electric and Westinghouse providing the bulk of technical skills and power plant components. Currently, however, over 90% of each plant being built is composed of domestic (Japanese) parts, and Japanese firms are engaging in significant research and development efforts in nuclear power production. The NSSS vendors in Japan are currently Mitsubishi (PWR), Hitachi, and Toshiba (BWR). In addition, the nuclear industry also supports several hundred subcontracting firms for



Derived from Masatoshi Toyota, "Nuclear Power Development in Japan," Fourth Pacific Basin Nuclear Conference, September 1983.

FIGURE 5.1. Distribution of Power Generation by Type of Source

construction, training, and maintenance as well as numerous nuclear-related research institutes and industry associations.[a]

5.1.2 Summary

The U.S. and the Japanese nuclear power industries operate with the same basic technologies and share many of the same organizational characteristics. However, the considerably greater projected role for nuclear power in overall power production in Japan creates a significant difference between the U.S. and Japanese experiences. This difference can be seen even more clearly in the nature of regulatory relationships discussed in the next section.

5.2 THE REGULATORY CONTEXT

This section focuses on the nature of the regulation of commercial nuclear power in Japan. First, it outlines the major regulatory bodies and their responsibilities. Second, it describes the major regulatory activities during steps from site selection through operation of the nuclear power plants. Third, the nature of the relationship between the utility and the regulatory bodies in Japan is examined.

5.2.1 Regulatory Structure[b]

The primary legal bases for the regulation of commercial nuclear power are established by two laws: The Electrical Utility Industry Law and the Law for Regulation of Nuclear Source Material, Nuclear Fuel Material, and Reactors. Under these laws, the Ministry of International Trade and Industry (MITI) is given primary responsibility for commercial nuclear power regulation with significant input from various units in the Office of the Prime Minister. The Ministry of Transportation has equivalent responsibility for ship-based reactors and the Science and Technology Agency (STA) for research reactors. Figure 5.2 provides a simplified description of the governmental units that regulate nuclear reactors.

Since commercial nuclear reactors are the responsibility of MITI, this ministry will be discussed first. The assignment of this function to MITI is, perhaps, indicative of the important economic role of nuclear power in Japan. Table 5.3 outlines the major units within MITI which are

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[a]See Summary of Japan's Atomic Energy Organizations (Japan Atomic Energy Relations Organization 1982) for a description of the major institutes and associations.

[b]More detailed treatments may be found in Summary of Japan's Atomic Energy Organizations, Japan Atomic Energy Relations Organization (1982) and Outline of Safety Regulations Administration for Commercial Nuclear Power Plants in Japan, Agency of Natural Resources and Energy, Ministry of International Trade and Industry (1983).

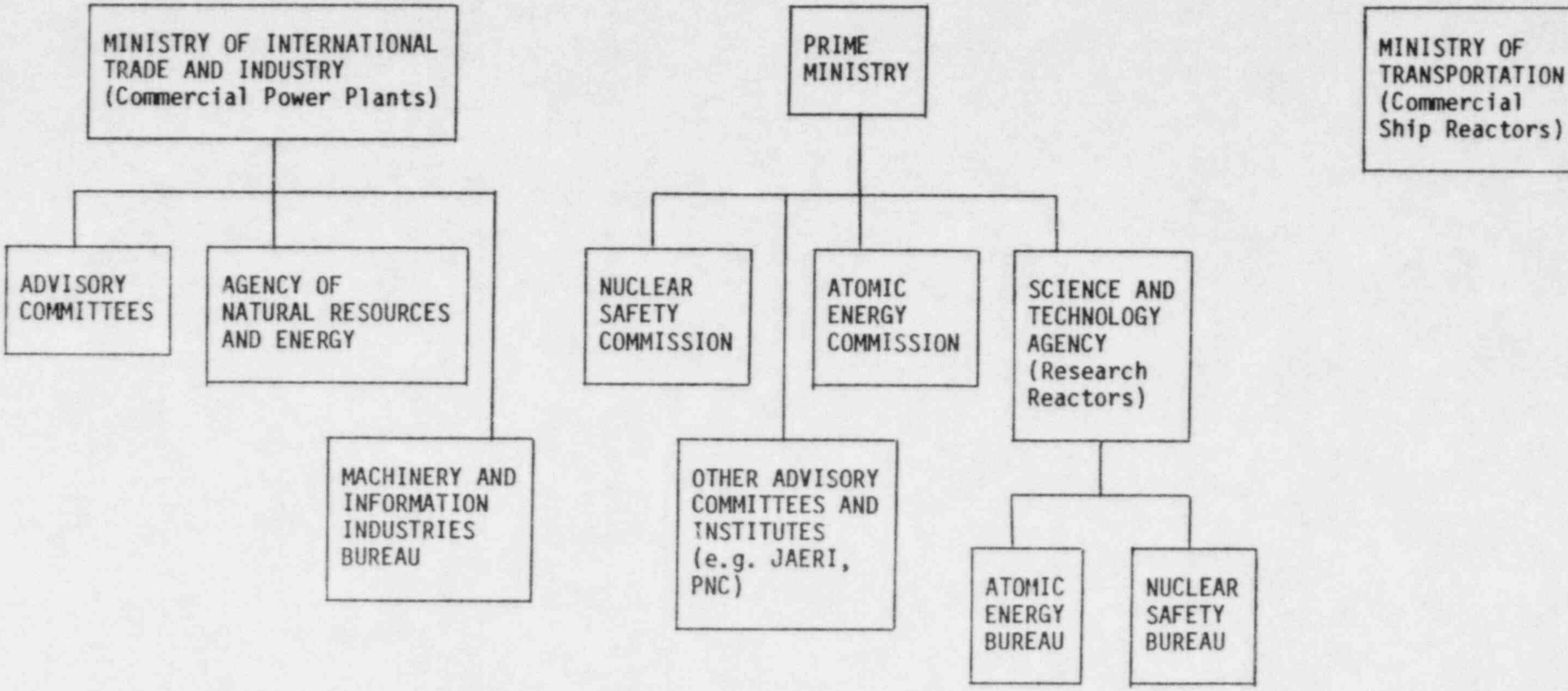

FIGURE 5.2. Major Governmental Units Engaged in Nuclear Reactor Regulation

TABLE 5.3. Main Nuclear-Related Components in the Ministry of International Trade and Industry

Bureau	Division in Charge	Main Duty
Machinery and Information Industries Bureau	Electrical Machinery Division	Technical development of nuclear power generating machines and apparatus, and encouragement and intensification of nuclear power machinery industries.
Director-General's Secretariat of Natural Resources and Energy Agency	General Coordination Division	• General coordination of the agency • Overall policy making and planning • Secretariat for Overall Energy Survey Institute
	International Division	• Coordination of clerical tasks concerning international cooperation on minerals and energy
	Nuclear Energy Industry Division	• General adjustment and overall coordination of the office work of the ministry involving nuclear energy.
Public Utilities Department of Natural Resources and Energy Agency	Planning Division	• General coordination of departmental tasks • Secretariat for the Electric Utility Industry Council • Licensing of the alteration of electrical installations
	Electric Power Development Division	• Preparation of electric power development program • Enforcement of three laws related with the power development such as Law on the Development of Areas Ajacent to Electric Power Generating Facilities, etc.
	Thermal Electric Power Division	• Environmental examination of nuclear power generating plant • Licensing of construction plan of turbine generator for nuclear power generation and inspection of welding
	Nuclear Power Generation Division	• Surveys and analysis on nuclear power generation and the location of nuclear power stations • The development of nuclear power generation based on the nuclear power program and adjustment of this development and industries concerned
	Nuclear Power Safety Examination Division	• Licensing for construction of nuclear power station • Authorization of construction program • Secretariat for the Conference of Nuclear Power Generation Engineering Advisors
	Nuclear Power Safety Administration Division	• Inspection of Nuclear Power Plant • Supervisory administration of operation • Establishment and revision of technical standards
General Coordination Department of Agency of Industrial Science and Technology	Research Administration Division	• Coordination and promotion for making and practicing of laboratory research programs by the research institutes of the Agency

Derived from: "Summary of Japan's Atomic Energy Organizations" (Japan Atomic Energy Relations Organization 1982).

concerned with commercial nuclear power. As can be seen, MITI contains units which are concerned with both safety and nuclear power promotion. Many of the traditional safety regulation functions are carried out by the Public Utilities Department of the Natural Resources and Energy Agency. Within this Department there are Divisions dealing with power plant siting, licensing for construction, inspection, and enforcement. Also within MITI is the Machinery and Information Industries Bureau, which is engaged in the promotion of nuclear power technology. Finally, MITI makes use of several advisory committees in its decision making. These committees provide both technical input and independent reviews. Examples include the Advisory Committee on Environmental Matters and the Technical Advisory Committee on Nuclear Power Generation.

Within the Prime Minister's Office, three units are particularly important to note: the Atomic Energy Commission (AEC), the Nuclear Safety Commission (NSC), and the Science and Technology Agency (STA). The AEC and the NSC were created with their current responsibilities in 1978 by a reformation of the pre-existing AEC into a commission with primary responsibility for the advancement of nuclear power (AEC) and a commission with primary responsibility for nuclear safety (NSC). This reformation was substantially similar to the reformation of the Atomic Energy Commission in the U.S. into the Department of Energy and the Nuclear Regulatory Commission (NRC). The basic premise behind this reformation was that it would give public safety a more central, autonomous role within the overall administration of nuclear power by the government. The commissioners of both units are appointed by the Prime Minister with approval by the Diet.

The major responsibilities of the AEC are to plan, examine, and propose policy relative to:

- using nuclear energy
- coordinating the activities of other administrative organizations concerned with nuclear power
- developing resource allocation plans for nuclear energy use and administration
- regulating and controlling nuclear energy activities not under the domain of the NSC.

The main tasks of the NSC include planning, study, and the formulation of proposed policy relative to:

- nuclear energy safety
- nuclear fuel safety
- public input into safety issues
- protection from fall-out by radioactive substances.

Both the AEC and the NSC are advisory bodies to the Prime Minister. The actual administration of nuclear energy policy falls primarily on the STA and MITI. The STA contains both an Atomic Energy Bureau (AEB) and a Nuclear Safety Bureau (NSB). The AEB is concerned with such promotional areas as promotion of nuclear energy research and development, relations with local governments, and energy usage planning and analysis. The NSB focuses on safety issues in nuclear energy. The STA's primary concern is with research reactors, and with the promotion of nuclear research.

5.2.2 Regulatory Process

The roles of the various units can be seen by tracing through the process from site selection for a new plant to the operational stage. Table 5.4 summarizes this process. Site selection issues are handled by MITI with input from local governments and several advisory bodies. The construction stage is more complex. Again, MITI takes the lead by submitting a Safety Analysis Review of the utility's construction plan and capabilities, along with other supporting documentation to the AEC and the NSC for review. The NSC, in turn, provides a mechanism (public hearings) for public input into the decision. Consent of the Prime Minister is also sought at this point.

The issue of public opposition to nuclear power deserves some attention. The issue of nuclear power plant siting is sometimes an emotional issue in Japan, just as it is in the U.S. For example, one recent public opinion poll in Japan found approximately 70% of the respondents to be apprehensive about the safety of nuclear power (The Japan Times 1984). A number of factors contribute to the large level of public concern, including the following:

- Japan's first-hand experience with radiation-induced death, injury, and disease resulting from the bombing of Hiroshima and Nagasaki
- concern over nuclear waste disposal
- the scarcity of suitable, yet isolated sites--resulting in competition between the use of a site for a power plant and fishing, agriculture, or residential uses
- the added risk of being in a geologic zone with a frequency of earthquakes
- an active and generally critical press coverage of the nuclear industry.

To address these concerns, both the government and the utilities have taken positive actions, including:

- holding public hearings on siting of nuclear power plants (see Table 5.4)

TABLE 5.4. Major Steps in Japanese Regulatory Process for Commercial Nuclear Reactors

Phase	Utility Action	Regulatory Action
Selection of Plant Site	1. Environmental Survey 2. Environmental Impact Report	1. Environmental Review by MITI a. Advised by Advisory Committee on Environmental Matters b. Public Hearings 2. Consent of local government 3. Approval of Electric Power Resources Development Coordination Council
Construction of Plant	Application for Construction Permit Construction Begins	1. MITI reviews Application a. Advised by Technical Advisory Committee on Nuclear Power Generation 2. MITI prepares Safety Analysis Review and submits for consideration to a. Atomic Energy Commission b. Nuclear Safety Commission and Public Hearing 3. Consent of Prime Minister 4. MITI Approval of Construction Permit 5. Inspection by MITI at key stages and of key processes
Operation of Plant	Apply for Operating License Submitting Operating Program and Safety Rules Periodic Inspection and Maintenance	1. Reviewed and Approved by MITI 2. Periodic (yearly) inspection by MITI 3. Continual Evaluation by Resident Expert (MITI)

- involving local government in siting issues (see Table 5.4)
- the payment of compensation for fishing and agricultural use lost
- the payment of incentives for regional energy export
- the use of nuclear energy in an overall economic development plan for certain regions
- the use of rigorous, extensive maintenance programs to promote public confidence
- aggressive public education programs about the safety and importance of nuclear power
- the utilization of thermal discharge to promote other industries (fish farms).

Overall, these efforts may contribute to the somewhat shorter construction periods experienced for nuclear plants in Japan, once formal approval for construction has been granted. That is, by securing public approval at the siting stage and through an ongoing process of public education, construction can typically continue without disruption from the public and local government.

The input and review process outlined so far illustrates two important aspects of the Japanese approach to nuclear power regulation. The first is the existence of energy policy, along with safety, as a key dimension of the review process. More emphasis is placed on the role of the proposed plant in meeting energy needs than in the United States. This concern carries over into a concern with plant reliability and efficiency. Although there is a division of labor among and within the agencies relative to the public safety and the energy policy goals, the review process appears to allow greater attention to the promotion of nuclear power than in the United States.

The second important aspect of the review process is the notion of the "double check." As already mentioned, separate units are engaged in the review of energy policy and safety issues. In addition, two separate Ministries are involved in evaluating both goals. The double check system is extended even further through the use of numerous advisory commissions and through the public input at several points in the process. The complex, involved process of input from a wide variety of sources is intended to improve the accuracy of decision making, particularly relative to public safety. It also allows the various government agencies to form a working consensus on matters related to commercial nuclear power.

After the approval of a construction plan by MITI, MITI takes responsibility for inspecting the construction process at each phase (i.e., hold point). Inspections are undertaken at key hold points to assure that the construction plan is being followed and that the quality of the work is satisfactory. Key components (e.g., turbine, reactor,

reactor cooling system) and processes (e.g., welding) are inspected by MITI.

After the completion of construction, notification of MITI of the utility's Operating Plan, and MITI approval of a Safety Rule, the plant is allowed to ascend to power. In the operational mode, MITI again takes primary regulatory responsibility. Three main mechanisms are used to monitor plant performance for regulatory purposes.

The first mechanism is the annual inspection (see Section 4.2 for a more detailed discussion). The annual inspection is based on the plant's status relative to the Basic Maintenance Rule. The Basic Maintenance Rule defines the operating standards for equipment and procedures which are developed by the utility and approved by MITI. In general, the numbers and types of components subject to inspection are much greater and more numerous, respectively, than those in current requirements in the U.S. In addition, the inspection frequently goes beyond visual inspection to include disassembly and measurement for wear. The annual inspection takes approximately three months. The witnessing of the inspection is sometimes carried out by a contractor to MITI.

The second mechanism is the "resident expert" assigned to the plant by MITI. The functions of the resident expert include monitoring compliance with the Basic Maintenance Rule through attendance at periodic voluntary inspections, inspecting records related to operational management, and filing reports on significant events. The resident expert is not responsible for the actual inspection itself, and may serve to resolve differences of opinion between inspectors and the utility.

The third mechanism consists of the requirements placed on the utility to notify MITI in case of an event. The "Electricity Utility Industry Law" and "Law for Regulations of Nuclear Source Material, Nuclear Fuel Material, and Reactors" require that nuclear power plants report such events to MITI. MITI then investigates and analyzes the cause of the events, examines the countermeasures, and guides the utilities in performing the countermeasures. The Nuclear Power Operating Administration Office is responsible for these tasks. Due in part to the sharing of information on off-normal events, the reoccurrence of the same off-normal event is rare. In general, it appears that these requirements do not apply to some of the less significant events that are reportable in the U.S. Reportable events include exposures, radioactive releases, accidents involving injuries, fires, events affecting power production, and new construction on electrical-related parts of the plant. Utilities and the resident expert are required to file reports to MITI on such events.

5.2.3 Utility-Regulatory Agency Relations

Both the U.S. and Japanese nuclear energy industries are characterized by private, regional utilities with public safety regulations formulated and administered by agencies of the national government. Thus the nuclear industry in both countries exists in a

sometimes cooperative, sometimes antagonistic relationship with the regulators. However, there is considerable evidence that the Japanese experience more cooperation and less antagonism than the U.S. In this section some of the reasons for and dimensions of such heightened cooperation will be explored.

Japanese utilities and regulators appear to have a greater commonality of interest than in the U.S. The primary reason for this is the important role played by nuclear power in the nation's energy policy. Even though the energy promotion and public safety functions are split among regulatory units, the government is keenly interested in promoting nuclear energy. This basic support probably increases the level of trust felt by the industry toward the government.

This trust is heightened by specific actions taken by the government to promote nuclear power. One program concerns joint efforts to decrease down-time due to maintenance, particularly during the annual inspection, and thus increase capacity. This program includes research oriented toward determining safe and realistic inspection standards, research into the automation of certain plant processes, and efforts to standardize plant design. The goal of increasing the capacity factor was also recently endorsed by the General Energy Investigating Council (Sogo Enerugi Chosakai). In its interim report, issued in August 1984, the Council set a target capacity of 80% to 85%. Most of the improvement in the capacity factor is expected to derive from shortening the length of the annual inspection to an average of 60 days.

A second program is aimed at improved design and involves vendors, utilities, and government. Such joint efforts illustrate the closer, more cooperative approach to regulatory relations characterizing nuclear power in Japan, and also serve to promote trust between utilities and the government.

Recently, MITI began a major program whereby MITI and the major vendors would develop robots to inspect nuclear power plants. MITI has also expressed its interest in developing maintenance training centers in each regional block, and in introducing a training program and certification system in each company. MITI also coordinates its activities with the Japan Power Plant Inspection Institute, which was established in October 1980. The objective of this institute is to collect and analyze 1) data on inspections, 2) information on ways to improve the inspection system, and 3) information on improved maintenance technology.

Utility-regulator cooperation is recognized in Japan as not being just a one-way street, with the regulators actively promoting utility interests. Both the regulatory and utility organizations seem to share a commitment to public safety. As mentioned elsewhere, Japanese business leaders are keenly aware of the public image of their firms. They are likely to take personal responsibility for failure of the firm in its responsibility to the public. This same feeling permeates all levels of the organization, since the organization is a main source of identity for

the workers in the community. Consequently, the utility is very anxious concerning its public image in relation to nuclear safety problems. The utilities are also aware that the Japanese courts have awarded large sums to workers in personal injury suits involving radiation exposure and are anxious to avoid such financial penalties.

As in the U.S., the relationship between the regulatory system and the industry is not always cooperative. Examples exist of the use of substantial regulatory sanctions against the utilities. For example, at Tsuruga Nuclear Power Plant there were two incidents: 1) water leakage from the superheater of the water supply system, and 2) radiation contamination in public water due to overflow from the filter-sludge tank in the waste treatment plant in January and March, 1981, respectively. However, the owner of the plant, Japan Atomic Power Company, did not report these causes as required by law. MITI concluded that the incident could damage the public perception of nuclear power, and thereby ordered the plant to stop operation for six months as a punishment.

5.2.4 Summary

The available information indicates a general similarity between the U.S. and Japanese regulatory contexts. This suggests a common experience upon which to base comparisons along other dimensions (e.g., maintenance practices). However, there are some significant differences between the U.S. and Japan, including the following:

- a greater emphasis on nuclear energy promotion by the government in Japan
- a higher level of regulator-utility cooperation in Japan, as indicated by the high level of joint research and development activities, power production planning, and safety analyses
- a very intricate pattern of "double-checks" on the regulatory process.

5.3 UTILITY RELATIONS WITH VENDORS AND CONTRACTORS

One key to the safety and reliability of a nuclear power plant can be found in the performance of the vendors and contractors used by the utility. There appear to be some significant differences in the way in which the vendor and contractor responsibilities and relations to the utility are defined in Japan and the U.S. These differences reflect a pattern of relationships found in other industries within the respective economies and can be expected to have a significant effect on the approach and quality of maintenance. In this section, vendor-utility and contractor-utility relations are examined for the Japanese case and implications for the U.S. case are identified.

5.3.1 Utility-Vendor Relations

The earlier stages of nuclear power development in Japan were characterized by a substantial dependence on foreign vendors. Because of

certain quality problems experienced in dealing with foreign vendors, and because of a general preference for dealing with domestic firms, Japanese utilities are currently building nuclear power plants containing over 90% domestic components. This means that the current vendor-utility relationship is between two or more Japanese firms. Relationships between Japanese firms are guided by a somewhat different set of expectations than are relationships among American firms. In this section, some of these differences will be identified.

Mitsubishi, Hitachi, and Toshiba are the NSSS vendors in Japan. Hitachi and Toshiba build GE-type BWRs while Mitsubishi builds Westinghouse-type PWRs. These firms also produce and market other power plant components, equipment, and testing devices. All three vendors have been expanding their research and design capabilities to the point of making major changes in the basic BWR and PWR reactors originally produced by the U.S. firms.

The NSSS vendors produce turn-key operations for the utility. That is, the vendors not only provide NSSS components, but also much of the rest of the plant, and supervise construction, licensing support, and preoperational testing. This is a much wider scope of participation than what is characteristic of the NSSS vendors in U.S. plant construction. Vendor support continues through the operational stage. In some plants, vendors are responsible for much (70%) of the periodic maintenance activities. In addition, vendors generally are responsible for plant modifications. Training for maintenance and operations workers employed by the utilities is sometimes also provided by the vendors. Finally, the vendors have active programs for the analysis of component performance information, and for research and development issues relevant to existing plants. In short, the NSSS vendors in Japan interact with the utility on a much wider scope of activities and for the entire length of the plant's life.

In addition to the difference in scope, there is also a difference in the quality of the vendor-utility relationship. In general, vendor-client relationships in the Japanese business culture tend to be based on informal trust as well as formal contract. While there are examples of this in U.S. business, it is not common in the nuclear industry. When a Japanese firm chooses a vendor or contractor, the firm is assuming, generally, that it will be a long-term relationship. Consequently, the firm looks at a somewhat different set of selection criteria than do U.S. firms.

One such criterion is trust. Since the Japanese economy is highly competitive, firms are usually quite concerned about protection of proprietary information and avoidance of public release of "internal" problems. However, the relationship between vendor and client firm in Japan usually requires the sharing of very detailed information. Such partnerships, therefore, are not entered lightly. Each firm involved evaluates the other on the basis of the amount of trust that can be placed in the firm.

A second criterion is quality of performance. In part because the scope of the services is so wide, the client firm is very dependent on the

performance of the vendor firm. The client firm has to be able to expect close to zero-defect performance from the vendor. Consequently, the client firm imposes strict quality control criteria on the firm it selects as a vendor. The client firm will be conscious of the quality standards employed, the quality control mechanisms used, and the training that workers and managers alike receive in quality issues.

A third criterion is willingness to provide individualized service. The client firm is not expecting to be purchasing objects alone. Rather, the client firm expects to be purchasing service and technical expertise. The client firm expects the vendor to become very familiar with its unique operational needs.

A final criterion is stability. The client firm expects an ongoing relationship. The client firm expects to be able to work with a fairly stable team of representatives from the vendor firm. The client firm expects to be able to get parts and technical service on components, even when purchased years earlier. On its part, the vendor expects the client firm to respect the relationship and not change vendors casually or for a short-term "better deal."

Within the nuclear industry, this pattern of vendor-client relationship seems to provide a context for quality performance. The stability and scope of the vendor-utility relationship creates a mutual dependence which leads to integrated efforts to improve performance.

5.3.2 Utility-Contractor Relations

The use of subcontract organizations in the area of maintenance is a very common practice in the nuclear industry in Japan. During the scheduled maintenance outages, most of the work is conducted either by personnel supplied by the vendors or by subcontractor organizations. The organizations are sometimes subsidiaries of the utilities. The smaller, utility maintenance staff serves in a largely supervisory and quality control capacity during scheduled maintenance work. At Kyushu Electric's Genkai plants, all maintenance is performed by an affiliate firm working on a contract basis (Atoms in Japan 1984b, pp. 21-22).

One very important difference between the U.S. and Japanese approaches to contract maintenance is that in the U.S., the craft unions tend to control worker hiring through the union hiring halls, while in Japan the contracting organization fills the selection function. These contracting organizations tend to use the lifetime employment system wherein workers stay with the company throughout their work careers. This creates a situation where there is considerably more opportunity for stability in the composition of the periodic maintenance work force. Since the contracting companies tend to use the lifetime employment systems, it is reasonable to assume that the maintenance workers in Japan would develop a more detailed familiarity with particular plants than do maintenance workers in the U.S. These contracting firms are responsible for providing training to the workers, as well.

The contracting organizations frequently have close organizational ties to the utilities. For example, it would not be unusual for retiring utility managers to take positions in the contracting organization. The combination of employment stability among contract maintenance personnel and the close organizational relationships characteristic of interfirm relationships in Japan appears to enhance the quality of maintenance performance. While the specific approaches applied in Japan may not be directly applicable to the U.S., particularly given the differences in labor practices, alternative strategies for promoting labor force stability among contract maintenance workers may exist and may contribute significantly to the quality of the work performed.

5.3.3 Summary

The Japanese nuclear industry is characterized by close, stable relationships between the utilities and vendors and subcontractors. The implications for plant maintenance are significant, with vendors providing continuing maintenance and maintenance training for the utilities. Maintenance contractors provide a stable maintenance work force for scheduled maintenance activities. These patterns appear to allow the utilities to have a highly reliable maintenance program and work force.

5.4 MANAGEMENT AND ORGANIZATION

The "typical" Japanese management style is recognized as varying widely from its western counterpart. The available information indicates that this variation extends to differences in the management and organization of nuclear utilities in Japan and the U.S. The differences are sometimes quite large, but more typically are differences of emphasis on issues common to both countries. In this section, U.S. and Japanese approaches to management and organization are compared for nuclear utilities, and the implications for maintenance are examined. The discussion is organized into three issue areas: 1) human resources management, 2) labor relations, and 3) organizational structure and processes.

5.4.1 Human Resource Management

Human resource management refers to the approach the organization takes toward developing, using, and maintaining its human element. In this subsection there are four major topics: 1) the view of the individual relative to the group, 2) the lifetime employment system, 3) the use of rewards and sanctions, and 4) the approach to qualifications and training.

5.4.1.1 The View of the Individual

The Japanese approach to human resource management begins with the view of the individual in relationship to the group. Briefly put, the Japanese approach is more group oriented while the U.S. approach is more individually oriented. The origins of the group orientation are not essential to this discussion. What is important, however, is that in

Japan an individual's status and identity are somewhat more closely tied to group membership than in the U.S., where individual achievement is stressed. This is not to say that the individual is unimportant in Japan, but that the importance of the individual derives from commonality with others (group membership) rather than uniqueness from others (individual achievement). One important implication of the group orientation for the employee and employing firm is the commitment to total involvement. Because the group rather than the individual worker or management interest is most important, Japanese firms foster conditions of unity, commitment, and total involvement which are considerably more rare in the U.S.[a]

5.4.1.2 Lifetime Employment System

The lifetime employment system is one manifestation of the patterns of unity, commitment, and involvement which are based on the group orientation. This system is often singled out as the central, strategic principle of Japanese management.

This system refers to the practice characteristic of most large firms, wherein employees are hired at the beginning of their work careers with the expectation that they will stay with the firm until retirement. In exchange for what is essentially guaranteed employment, the worker agrees to commit to a lifetime of service to the firm. There are several implications of this system for other behaviors and practices.

First, the lifetime employment system creates a situation where there is low labor turnover. Turnover rates are typically much lower in Japanese firms than in U.S. firms within the same industry. Not only does the lifetime employment system shield the worker from layoffs, but it also creates a situation where there are few job alternatives since 1) other firms are also using the lifetime employment system and 2) mobile workers give the impression to potential employers of having low commitment. Clearly, however, low labor turnover is a desirable characteristic for maintaining skill levels and for realizing returns on investment in training.

Second, the lifetime employment system appears to build commitment. Because of the long-term nature of the relationship, the average employee identifies with the firm to a greater extent than does the U.S. counterpart. This mutual commitment takes many forms. For the worker, it means pride in the company, identification with its goals, and a willingness to

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[a]Although there is agreement over the relative degree of group orientation in Japanese culture as compared to the U.S., there is less agreement over whether such practices as the lifetime employment system are simple expressions of the underlying Japanese culture (inherited from Budhism via the Japanese feudal society) or whether they are conscious management attempts to assure a cooperative, stable labor supply. The resolution of this debate is not particularly important to the purpose at hand--tracing the effects of such a system on maintenance performance.

work long hours. For the company, it means a willingness to invest resources in training and education, to provide a wide range of benefits (housing, recreation), and to take a direct, active role in the employee's nonwork life. While not all of these practices would be evaluated favorably by U.S. workers, in Japan they serve to strengthen the bond between the worker and the firm. As this bond is strengthened, the willingness of the worker to work hard in pursuit of the organization's goals tends to increase.

The available information suggests that the lifetime employment system is in place for at least some parts of the nuclear power industry in Japan including the vendors, the utilities, and many of the first level of contractors. This means that the vendors, utilities, and subcontractors are probably experiencing the low turnover rates characteristic of other industries. It probably also means that there are high levels of organizational commitment in these firms. Employment stability and commitment may be two factors accounting for the observed, high levels of performance characterizing the Japanese nuclear industry.[a]

5.4.1.3 Rewards and Sanctions

The group orientation and the lifetime employment system combine to create significant differences between the U.S. and Japanese approaches to rewards and sanctions. Rewards and sanctions are generally allocated at the group level. Since there exists high levels of firm and work-group identification, such a group reward orientation is consistent with the individual worker's expectations. The base salary is usually quite low in Japan. However, it is significantly augmented by performance bonuses, usually tied to the firm's profitability. This means that an individual's performance is rewarded on how well the collectivity performs.

Group pressure is a significant motivator in Japan. The group orientation not only characterizes the individual's orientation toward the firm but toward the work group as well. Poor performance within the work group will be met with considerable pressure from peers to improve performance. The group will also try to provide the individual with the skills and assistance necessary to do a good job.

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[a]Several clarifications about the lifetime employment system are called for. First, the system does not apply to everyone. Most organizations maintain a cadre of temporary workers or, in some cases, subcontractors, to buffer the firm against fluctuations in production needs. Second, some industries (agriculture, service) do not generally use the system. Third, mobility is characteristic or even encouraged in some sectors (government). Finally, there is some indication that the mobility of Japanese workers is increasing, both by choice and because some firms are experimenting with using layoffs during periods of low product demand or to offset increases in other operating expenses.

This pattern can be contrasted with a somewhat greater tendency in the U.S. to use individually based rewards and sanctions. Here, monetary rewards and threats of dismissal are likely to supplant peer pressure and commitment as primary motivators. While there is no direct evidence that one approach is better than the other in the nuclear power industry, the overall success of Japanese industry suggests that the usefulness of the group-based approach should be explored for the U.S.

5.4.1.4 Qualifications and Training

A final but very important dimension of human resources management concerns qualifications and training. The use of the lifetime employment system and the group orientation also affect this area. Concerning qualifications, Japanese employers use somewhat different selection criteria. Because the employment is expected to be lifelong, the firm is concerned with finding workers who can "fit in" to the firm. This means that workers who will be committed, workers with appropriate social and work habits, and workers who are capable of performing a wide range of activities, are preferred by the company.

Japanese firms are somewhat less likely to hire on the basis of specific skills. Written entrance exams and manual dexterity tests are not generally used. Several factors influence this approach. First, the low rate of turnover means that the firm can absorb more of the training costs than its U.S. counterpart, because investment in training will not be lost to turnover at as high a rate. Second, the group orientation approach leads Japanese firms to prefer that the individual's primary identification be with the firm rather than an occupation. Requiring specific skills as a prerequisite of employment would tend to limit the selection process to those who have already forged an occupational (e.g., electrician, accountant) identification. Third, the practice of frequent job rotation in Japanese firms allows for the eventual matching of aptitude with job requirements. Consequently, the Japanese firms tend to hire less highly trained individuals and then provide greater intra-firm training opportunities for them.

Japanese workers are also likely to be trained in many different jobs. Japanese firms like to create generalists rather than specialists. Generalists are less likely to forge a narrow occupational identification. Generalists are also more likely to be aware of where their particular job of the moment fits into the overall scheme. Consequently, Japanese firms move their workers around giving them on-the-job training in many different areas (Atoms in Japan 1984b, pp. 18-25). There is also a general belief that "well-rounded" workers are better workers. This leads to the Japanese business practice of promoting hobbies and crafts and of paying for educational opportunities for employees in areas unrelated to their job requirements.

The emphasis on multi-faceted, on-the-job training extends to the nuclear industry. Workers are generally hired out of high school or technical school. The available information on maintenance training is

limited. Consequently, a brief description of operations training is offered to illustrate the general Japanese approach.[a]

The first stage of training usually involves learning, in detail, about the company, its history, and its goals. The new recruit is also introduced to general aspects of the work. For potential operators, this means an introduction to the fundamentals of nuclear power production. This is followed by 3 to 4 years of field training in the plant. This consists of participating in the inspection of equipment, and its goal is to achieve a high level of understanding and familiarity with the entire plant. The operator trainee is also exposed to inhouse and training center programs to learn the responsibilities of the operator. This is followed by 3 to 4 years as an assistant operator, observing the operations crew in the control room. In all, it takes 7 to 8 years to become an operator and 12 to 14 years to become head of the operating crew. This long training period is consistent with the lifetime employment system and with the generally slow, seniority-based promotion system characteristic of Japanese industry. It is also consistent with a relative emphasis on knowledge-based training (e.g., understanding of basic principles, and comprehension if the system) rather than on skill-based training.

Less information is available concerning qualifications and training of maintenance personnel. Although there are no government tests for maintenance qualifications, MITI does review the utility's maintenance training plan. It can safely be assumed that primary training takes place in an on-the-job context within the utility or subcontracting firm. More specialized training in maintenance methods and plant systems and functions is increasingly available. The available information indicates that maintenance workers are trained in a variety of skills. For example, the maintenance supervisors at Kyushu Electric's Genkai plants are trained in a variety of maintenance skills, and so are much of the maintenance personnel in the affiliated firm that conducts all of Genkai's maintenance (Atoms in Japan 1984b, pp. 18-25). In addition, many utilities have their own programs to rotate plant personnel between operation and maintenance areas.

Recently, industry-wide vendor- and utility-sponsored training facilities have become available for maintenance workers. In 1981, Kansai Electric announced its plans to build Japan's first training center specializing in nuclear power plant maintenance. Plans included boarding facilities for 40 people. Equipment included a full-scale reactor container and coolant pumps, and the environmental conditions (temperature, humidity, space, etc.) resemble those at a real nuclear power plant. By 1984--in addition to Kansai Electric Power Co.--Tokyo

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[a]This discussion is primarily based on Research on Operation, Maintenance and Human Factors in Nuclear Power Plants (Technova 1983) and on Investigation into Human Factors in Atomic Power Plants (Institute of Policy Sciences 1981).

Electric Power Co., Kyushu Electric Power Co., and Chubu Electric Power Co. had established maintenance training centers (Atoms in Japan 1984a, p. 33).

5.4.2 Labor Relations

Another contrast between the U.S. and Japanese approaches to nuclear power plant management and organization is the nature of labor relations. Within most industries, including the electric power industry, Japanese unions are typically company unions. This means that all the workers within a given firm belong to the same union and that the union does not extend across firm boundaries. In the U.S., of course, unions are organized on the basis of craft or industry, and such company unions are prohibited by law.[a] This basic difference has several important ramifications for maintenance.

First, labor relations in Japan tend to be more cooperative and less militant than in the U.S. Since the unions are company unions, there is an even more direct relationship between company and union interests. The current practice of basing pay on bonuses that reflect company profits and the existence of the lifetime employment system stimulate a willingness on the part of the workers, and consequently the union, to adopt productivity as a goal. While there continues to be confrontation between union and management, including occasional work stoppages, such confrontation tends to affect neither the work schedules nor the basic trust between labor and management. For example, Japan currently experiences less than 5% of the number of days lost to work stoppages experienced by the U.S.

A second implication is that unions tend to impose fewer restrictions on management practices in Japan than in the U.S. Because of the higher level of trust and cooperation, opposition to attempts to improve labor productivity through automation is not as great. Since jobs are not threatened, and increased productivity suggests increased bonuses, automation is comparatively well received.[b] Although detailed information is not currently available, this suggests a greater potential for the automation of certain maintenance activities in Japan than in the U.S. Since unions are not based on crafts, they are also less likely to be concerned with work rules. Management is considerably freer in Japan to rotate employees to different jobs and even transfer them to different

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[a]This discussion refers to the current state of labor relations in the private, industrial sector. Japan had a significant history of labor militancy until recent times. In addition, public employee unionism and union movements in the extractive (agriculture, mining, fishing) sector do not always fit the above description.

[b]There are, of course, limits to this acceptance in Japan. For example, the introduction of robotics into the auto industry has increased the productivity of capital to the point where labor fears significant layoffs.

sites. A third implication is that training in Japan is much more the responsibility of the firm and much less the responsibility of the union. The craft is not the primary source of learning the basic maintenance skills. Instead, this function can be integrated into the utility's and maintenance subcontractor's overall training plans.

The available information suggests that these basic patterns pertain to the nuclear power industry in Japan as well as the more general case. Reviews of utility annual reports revealed numerous references to labor-management cooperation in increasing productivity and the general cooperative spirit that exists. This includes references to successful quality circle programs where worker groups contribute their ideas for safety and productivity improvements to the firm.

5.4.3 Organizational Structure and Process

The main factor influencing the organizational structures and processes in the Japanese nuclear industry is, like the U.S. case, the nature of the nuclear technology. That is, since the basic technologies are the same, the basic approaches to organizational structure and work process are also essentially the same. However, there are some important differences which will be discussed in this section. Specifically, this section discusses 1) the general functional structure, 2) patterns of job definition, and 3) staffing practices.

5.4.3.1 Functional Structure

The available information suggests an essential equivalence between Japan and the U.S. in the division of the organization into functional areas. Figures 5.3 and 5.4 are organizational charts for the Kyushu utility and its Genkai power plant respectively. At the utility level, few apparent differences exist between U.S. and Japanese functional structures. It is interesting to note, however, that the plant siting and environment unit seems to have special prominence in the utility organization, as does the whole nuclear power area. Thus, the organizational form seems consistent with the central role of nuclear power in the utility's future. Relative to maintenance, it should be noted that Kyushu apparently does not employ a centralized maintenance unit across fossil and nuclear technologies, as is sometimes the case in the U.S.

At the plant level, again, there is essential similarity between the U.S. and Japan. Only the presence of the plant siting unit and the environment and public affairs unit is in contrast to the U.S. approach. However, it is very difficult to make direct comparisons based only on organizational charts. Additional information on the responsibilities of each unit would be needed for a more systematic analysis.

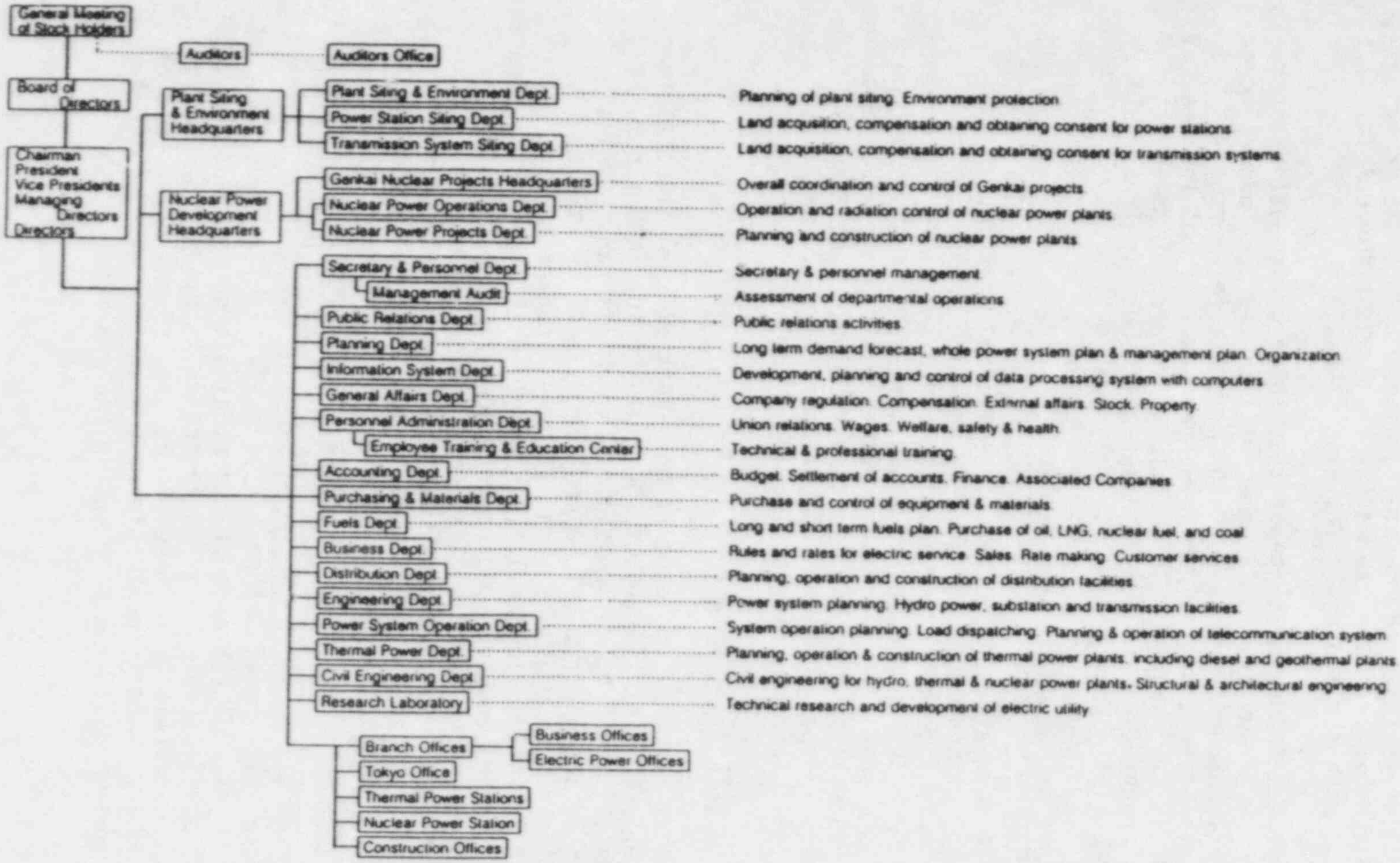

FIGURE 5.3. Typical Utility Organization

(As of Dec. 1, 1983)

- GENKAI Nuclear Projects Headquarters
  Director 1
  - GENKAI Nuclear PS (No.1 & No.2 Unit)
    Superintendent 1
    Sub-superintendent 4
    Deputy 5
    - General Affairs Div. 19
    - Plant Eng. & Nuclear Fuel Mang. Div. 40
    - Radiation Control & Chemical Eng. Div. 28
    - Operating Div. 82
    - Maintenance and Repair Div.[a] 56
    - Environment and Public Relations Div. 4
    - Sub-Total 240
  - GENKAI Nuclear PS Construction Preparation Office (No.3 & No.4 Unit)
    Superintendent 1
    Sub-superintendent 1
    Deputy 1
    - General Eng. Div. 4
    - Civil Eng. & Architect Eng. Div. 15
    - Plant Siting Div. 2
    - Sub-Total 24

Total 264

(a) See Figure 5.5.

FIGURE 5.4. Typical Nuclear Power Plant Organization

5.4.3.2 Job Definition

One important area of contrast between the U.S. and the Japanese approach to organization lies in the area of job definition. In general, the U.S. approach is to specialize job functions by limiting the job responsibilities of a given position to a few clearly defined and closely related activities. This approach is assumed to improve the worker's efficiency and accuracy, and to assist management in the unambiguous planning, staffing, and execution of the work. The Japanese approach, on the other hand, intentionally avoids such specialization. Instead, job positions are defined broadly, even to the point of having several different jobs responsible for the same activities.

Several reasons can be given for the Japanese approach to job definition. First, as mentioned earlier, the Japanese prefer to avoid allowing the worker's job or occupation to become the primary focus of identification. This would detract from a more general identification with the firm. Increasing specialization is seen as decreasing the common experience that a worker shares with other members of the firm and, therefore, is to be avoided. A second reason for the lack of specialization is that the Japanese see specialization as counterproductive to coordination and the development of consensus. Within the nuclear industry, for example, the increasing specialization of the control room operator through the addition of standardized examination and job requirements, has been seen as a threat to the ability of the operator to work effectively with other areas of the plant, particularly maintenance. And, because decision making in Japanese firms tends to be based on the development of a consensus solution, the creation of highly specialized job functions is seen as threatening the ability of the organization to forge a consensus based on common understanding.

Several mechanisms are used to promote the more general orientation to job definition. First, as already mentioned, training takes place in the firm and includes general, as well as task-specific, knowledge. Second, job rotation is used to give workers a broad exposure and to decrease the probability that occupational identification will exceed identification with the firm. Many utilities have programs for rotating workers across maintenance job skills and even between maintenance and operations. Third, jobs are frequently more broadly defined in terms of skills and responsibilities. There is more emphasis on team work and on doing all phases of a particular job rather than a single segment defined by a specific skill. For example, the Japanese tend not to support a separate QA component. The team of maintenance workers is itself responsible for ensuring the quality of the work by having the team members inspect each others' work. The Japanese feel that placing the responsibility for QA on the maintenance workers who do the work creates a system of accountability and motivation that is conducive to lower error rates.

Figure 5.5 suggests a significant difference between maintenance organization in Japan and the U.S. In the U.S., the most common approach to organizing the maintenance unit is to organize along craft lines (e.g.,

(As of Dec. 1, 1983)

- MAINTENANCE/REPAIR Div.
  - Div. Chief 1
  - Q.C. Eng. 1
  - Safety Eng. 1
  - Reacter Sec. — 21
    - Sec. Chief 2
    - (1/unit x 2 units)
  - Turbine Sec. — 9
  - Electrical Equips. Sec. — 7
  - Control Devices & Instruments Sec. — 18
    - (1/unit x 2 units)

Total 58

FIGURE 5.5. Typical Maintenance Organization

mechanical, electrical). In Japan, some utilities organize maintenance by power plant system (e.g., reactor, turbine). Thus, it appears that the average Japanese maintenance worker may be responsible for a wider range of skills than the average U.S. maintenance worker.

5.4.3.3 Staffing Practices

The staffing of the particular functions at the plant level varies somewhat between the U.S. and Japan. The total staff level for the two-unit Genkai power station in Figure 5.4 is only 264. Two-unit sites in the U.S. generally are nearly twice the size. The differences are due to higher U.S. staffing levels in several functions, including radiation control, operations, and maintenance. The one area where the Japanese plant may staff in excess of the U.S. plant is in the engineering function. However, complete and more detailed data would be needed on both U.S. and Japanese staffing to make valid, reliable comparisons between staffing practices.

It should be remembered that the Japanese make liberal use of both vendor and subcontractor personnel in the maintenance area. The smaller number in the maintenance unit, therefore, is probably due to a greater dependence on the contractor personnel. Whether contractor personnel are used in other functional areas has yet to be explored.

5.4.4 Summary

The management and organization of U.S. and Japanese power plants have a basic similarity brought on by the basic technological similarity. However, there are significant differences which have implications for maintenance. Among the most important differences are in labor relations, job definition, qualifications, and use of contractors.

5.5 SUMMARY OF ISSUES RELATIVE TO ORGANIZATION AND MANAGEMENT PRACTICES

The review of the available information on the nuclear industry, regulatory context and management and organization in Japan has revealed both major similarities and differences. Both Japan and the U.S. have well-developed nuclear power industries. However, in Japan the industry is even more central in overall electrical power production, and thus has greater economic importance. In addition, partially due to aggressive government promotion, nuclear power in Japan continues to prosper and grow.

There are many similarities between the U.S. and Japanese regulatory structures. A major difference, however, is that the Japanese structure pursues the dual goals of energy promotion and public safety, even within a single agency. The result appears to be a somewhat higher level of government-industry cooperation in Japan than in the U.S.

A key difference between the U.S. and Japanese nuclear power industries concerns the nature of the relationships between the utilities and other organizations in the industry. In Japan, the utilities'

relationships to vendors and subcontractors appear to be more stable and cover a wider range of activities. For example, a single vendor is likely to construct the complete plant for the utility and then contribute significantly to ongoing, periodic maintenance. This stability may contribute to greater plant reliability.

Finally, the organization and management of maintenance in the plant also seem to differ. While the basic maintenance work appears to be similar in the U.S. and Japanese industries, significantly different approaches are taken to training and managing maintenance workers. One such difference with potential application to the U.S. is the practice of training workers and managers in a variety of job functions and periodically rotating them among departments.

While it is not possible at the present time to identify which, if any, of the Japanese practices can and should be tried in the U.S., even this preliminary review has identified potentially important lessons to be learned from the Japanese approach. Future work in this area should be directed toward obtaining additional information and identifying those Japanese practices most likely to be of benefit to maintenance in the U.S. nuclear industry.

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APPENDIX A

ADJUSTED EVENT DATA

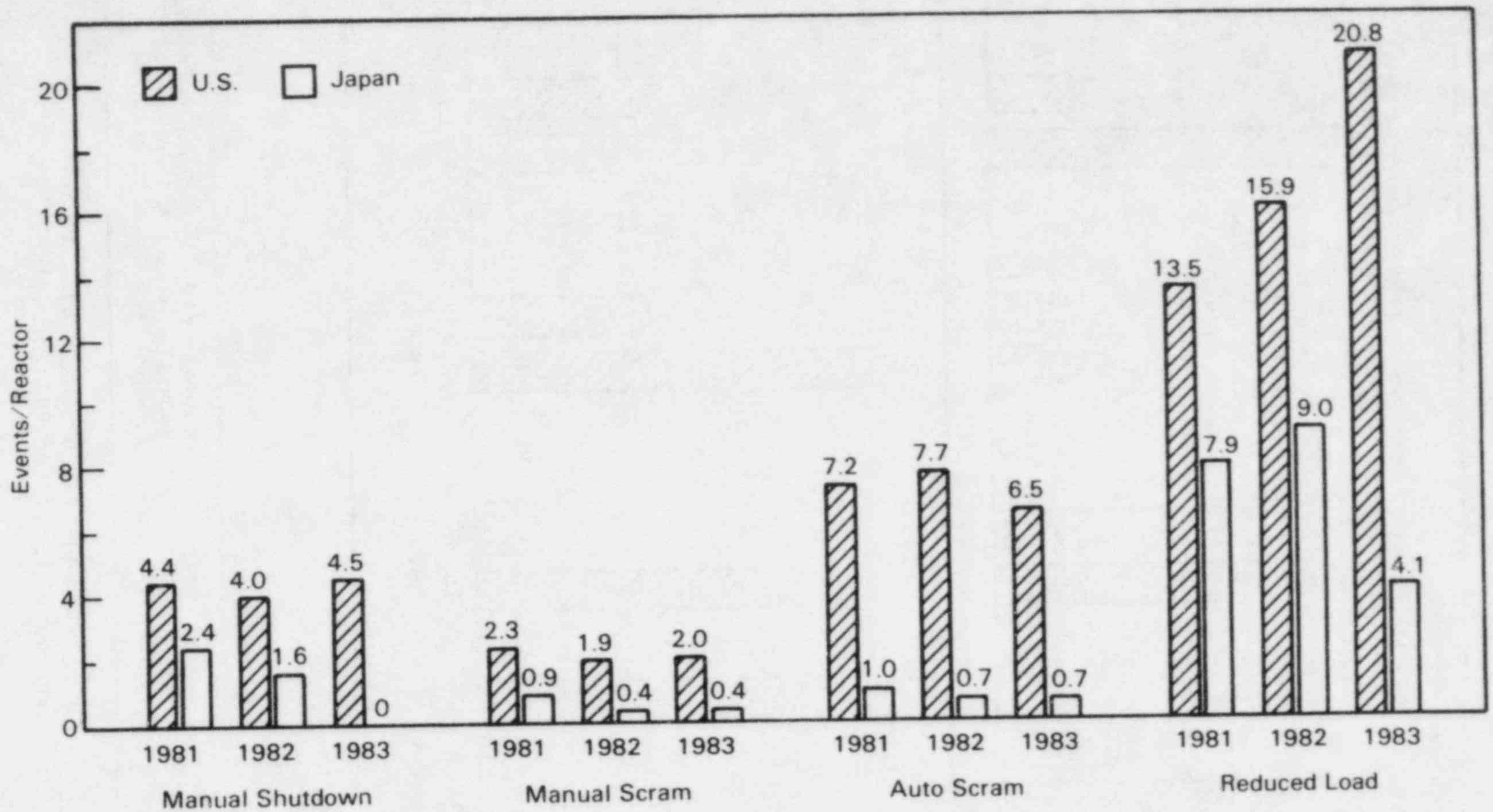

FIGURE A.1. Adjusted Events Per Full-Year Commercial Reactor Operation for 1981-1983: U.S. (G.E. and Westinghouse Reactors) - Japan (BWR and PWR Reactors)

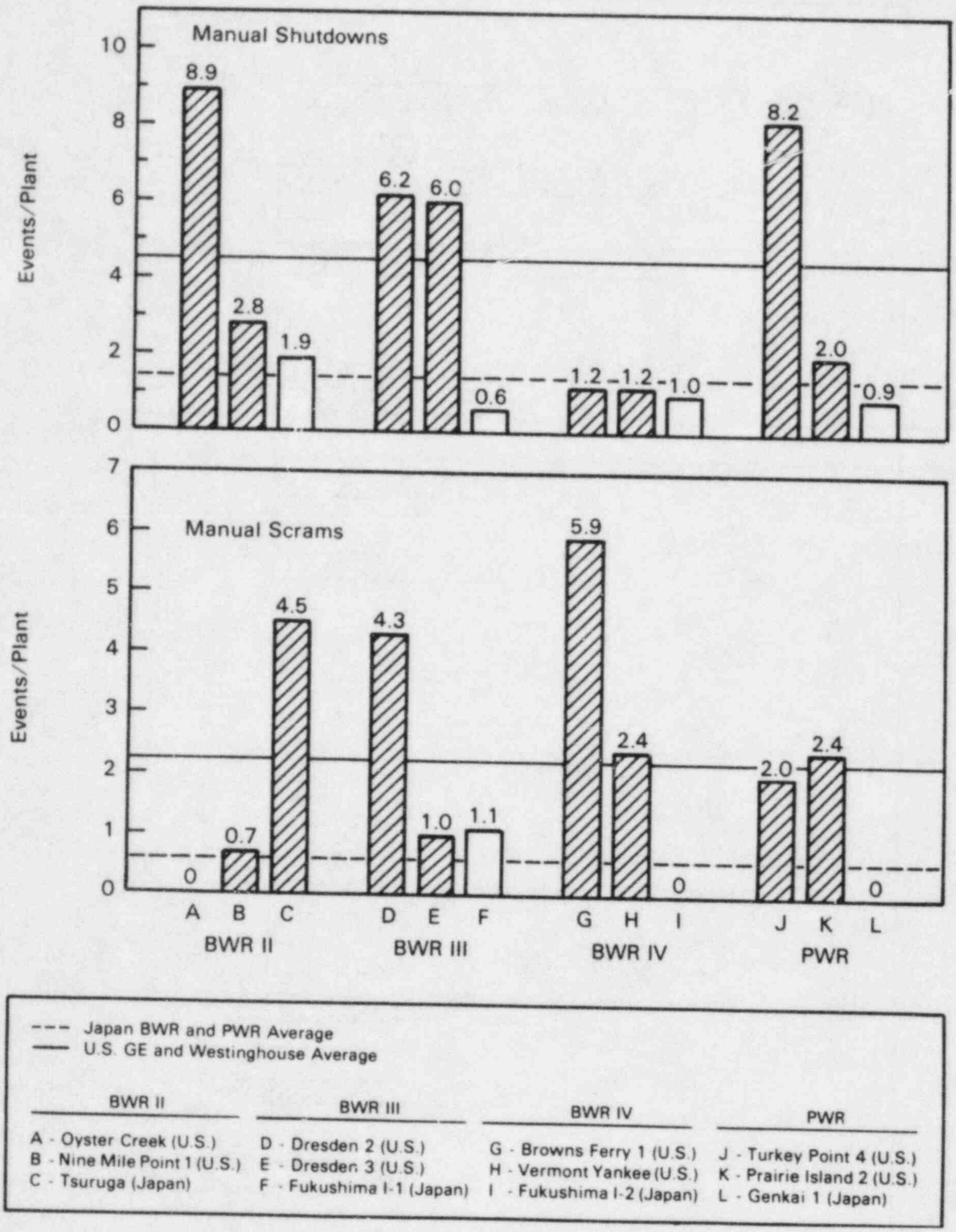

FIGURE A.2. U.S. and Japanese Sister Plant Comparison. Adjusted Events Per Reactor: 1981-1983

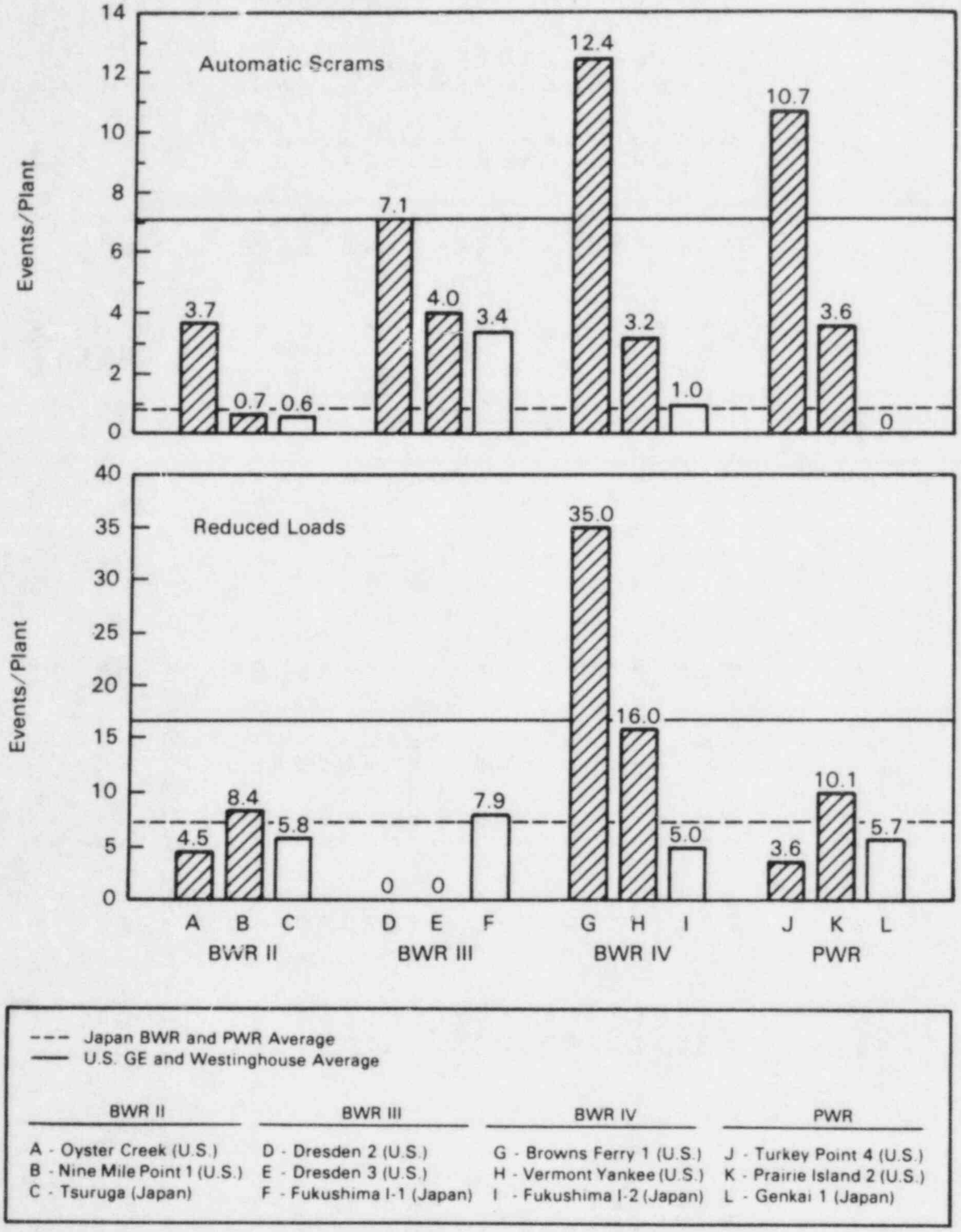

FIGURE A.2. (contd)

TABLE A.1. Japanese and U.S. BWR/PWR Nuclear Plant Event Data: 1981, 1982, 1983

		1981				1982				1983			
FACILITY	COMMERCIAL START-UP	AVAIL. (%)	AUTO TRIPS	ADJUST. COUNT	MTBE	AVAIL. (%)	AUTO TRIPS	ADJUST. COUNT	MTBE	AVAIL. (%)	AUTO TRIPS	ADJUST. COUNT	MTBE
JAPANESE BWR & PWR REACTORS													
FUKUSHIMA I-1	03/71	28.5	1.0	3.5	104	65.5	2.0	3.1	120	84.3	2.0	2.4	154
FUKUSHIMA I-2	07/74	57.9	1.0	1.7	211	86.0	1.0	1.2	314	56.3	0.0	0.0	*
FUKUSHIMA I-3	03/76	55.5	0.0	0.0	*	46.1	0.0	0.0	*	64.4	0.0	0.0	*
FUKUSHIMA I-4	10/78	70.3	0.0	0.0	*	88.8	0.0	0.0	*	74.0	0.0	0.0	*
FUKUSHIMA I-5	04/78	68.6	1.0	1.5	*	66.1	2.0	3.0	121	83.7	1.0	0.0	306
FUKUSHIMA I-6	10/79	81.7	0.0	0.0	*	75.1	1.0	1.3	274	60.7	1.0	0.0	222
FUKUSHIMA II-1	04/82				*					70.0	0.0	0.0	*
GENKAI 1	10/75	59.3	0.0	0.0	*	80.7	0.0	0.0	*	87.6	0.0	0.0	*
GENKAI 2	03/81				*	79.1	0.0	0.0	*	80.5	1.0	0.0	320
HAMAOKA 1	03/76	52.6	0.0	0.0	*	71.2	0.0	0.0	*	71.2	0.0	0.0	*
HAMAOKA 2	11/78	70.7	0.0	0.0	*	32.2	0.0	0.0	*	71.4	0.0	0.0	*
IKATA 1	09/77	68.8	0.0	0.0	*	76.1	0.0	0.0	*	99.9	0.0	0.0	*
IKATA 2	03/82				*				*	77.6	0.0	0.0	*
MIHAMA 1	11/70	42.2	0.0	0.0	*	5.2	0.0	0.0	*	42.6	0.0	0.0	*
MIHAMA 2	07/72	66.6	0.0	0.0	*	56.6	0.0	0.0	*	37.2	0.0	0.0	*
MIHAMA 3	12/76	85.0	0.0	0.0	*	79.4	0.0	0.0	*	72.3	0.0	0.0	*
OHI 1	03/79	30.7	0.0	0.0	*	69.4	0.0	0.0	*	83.1	2.0	0.0	152
OHI 2	12/79	51.3	0.0	0.0	*	89.9	1.0	1.1	328	76.1	1.0	0.0	278
SHIMANE 1	03/74	59.5	0.0	0.0	*	62.8	0.0	0.0	*	71.6	0.0	0.0	*
TAKAHAMA 1	11/74	58.4	0.0	0.0	*	58.0	1.0	1.7	212	84.5	1.0	0.0	308
TAKAHAMA 2	11/75	69.4	1.0	1.4	253	61.7	1.0	1.6	225	53.0	1.0	0.0	193
TOKAI DAINI	07/66	65.6	3.0	4.6	80	60.9	0.0	0.0	*	72.3	1.0	0.0	264
TSURUGA	03/70	22.6	0.0	0.0	*	59.9	1.0	1.7	219	73.8	0.0	0.0	*
US GENERAL ELECTRIC BWR & WESTINGHOUSE PWR REACTORS													
BEAVER VALLEY 1	03/77	73.6	6.0	8.2	44.8	41.6	8.0	19.2	19.0	68.0	7.0	10.3	35.5
BIG ROCK POINT	12/62	90.6	0.0	0.0	0.0	70.8	1.0	1.4	258.4	71.0	0.0	0.0	0.0
BROWNS FERRY 1	08/74	50.7	5.0	9.9	37.0	91.0	13.0	14.3	25.6	27.0	4.0	14.8	24.6
BROWNS FERRY 2	03/75	85.1	12.0	14.1	25.9	54.5	4.0	7.3	49.7	74.0	11.0	14.9	24.6
BROWNS FERRY 3	03/77	72.6	8.0	11.0	33.1	57.3	1.0	1.7	209.1	62.0	2.0	3.2	113.2

TABLE A.1. (contd)

FACILITY	COMMERCIAL START-UP	1981 AVAIL. (%)	1981 AUTO TRIPS	1981 ADJUST. COUNT	1981 MTBE	1982 AVAIL. (%)	1982 AUTO TRIPS	1982 ADJUST. COUNT	1982 MTBE	1983 AVAIL. (%)	1983 AUTO TRIPS	1983 ADJUST. COUNT	1983 MTBE
BRUNSWICK 1	03/77	47.5	8.0	16.8	21.7	62.0	9.0	14.5	25.1	24.0	1.0	4.2	87.6
BRUNSWICK 2	11/75	66.3	7.0	10.6	34.6	38.6	6.0	15.5	23.5	64.0	4.0	6.3	58.4
COOK 1	08/75	76.1	3.0	3.9	92.6	62.7	4.0	6.4	57.2	64.0	3.0	4.7	77.9
COOK 2	06/78	70.6	3.0	4.2	85.9	76.9	5.0	6.5	56.1	78.0	6.0	7.7	47.5
COOPER STATION	07/74	71.2	1.0	1.4	259.9	84.6	4.0	4.7	77.2	63.0	3.0	4.8	76.7
DRESDEN 2	07/70	60.1	4.0	6.7	54.8	92.4	5.0	5.4	67.5	58.0	6.0	10.3	35.3
DRESDEN 3	10/71	94.3	5.0	5.3	68.8	63.5	4.0	6.3	57.9	73.0	6.0	8.2	44.4
DUANE ARNOLD	05/74	69.8	6.0	8.6	42.5	74.7	4.0	5.4	68.2	63.0	4.0	6.3	57.5
FARLEY 1	12/77	41.4	7.0	16.9	21.6	79.2	7.0	8.8	41.3	78.0	2.0	2.6	142.4
FARLEY 2	07/81					79.2	10.0	12.6	28.9	88.0	5.0	5.7	64.2
FITZPATRICK	07/75	74.7	0.0	0.0	0.0	75.0	4.0	5.3	68.4	71.0	3.0	4.2	86.4
GINNA	07/75	82.1	0.0	0.0	0.0	58.8	2.0	3.4	107.3	75.0	2.0	2.7	136.9
HADDAM NECK	01/68	84.3	3.0	3.6	102.6	93.4	4.0	4.3	85.2	78.0	1.0	1.3	284.7
HATCH 1	12/75	50.1	9.0	18.0	20.3	49.3	4.0	8.1	45.0	71.3	9.0	12.6	28.9
HATCH 2	09/79	78.5	14.0	17.8	20.5	63.8	8.0	12.5	29.1	65.9	3.0	4.6	80.2
INDIAN POINT 2	07/74	46.0	6.0	13.0	28.0	65.4	5.0	7.6	47.7	84.0	9.0	10.7	34.1
INDIAN POINT 3	08/76	59.8	8.0	13.4	27.3	22.5	2.0	8.9	41.1	2.6	2.0	76.9	4.7
KEWAUNEE	06/74	86.7	2.0	2.3	158.2	87.6	2.0	2.3	159.9	83.7	4.0	4.8	76.4
MCGUIRE 1	12/81					80.0	14.0	17.5	20.9	56.0	17.0	30.4	12.0
MILLSTONE 1	12/70	51.6	5.0	9.7	37.7	79.9	3.0	3.8	97.2	95.6	4.0	4.2	87.2
MONTICELLO	07/71	72.6	3.0	4.1	88.3	63.3	1.0	1.6	231.0	96.3	1.0	1.0	351.5
NINE MILE POINT 1	12/79	66.0	1.0	1.5	240.9	21.4	0.0	0.0	0.0	56.0	1.0	1.8	204.4
NORTH ANNA 1	06/78	65.1	6.0	9.2	39.6	34.6	4.0	11.6	31.6	72.0	1.0	1.4	262.8
NORTH ANNA 2	12/80	77.8	12.0	15.4	23.7	57.0	3.0	5.3	69.4	81.0	6.0	7.4	49.3
OYSTER CREEK	12/69	59.8	3.0	5.0	72.8	62.5	2.0	3.2	114.1	12.0	0.0	0.0	0.0
PEACH BOTTOM 2	07/74	79.3	4.0	5.0	72.4	58.1	2.0	3.4	106.0	51.0	2.0	3.9	93.1
PEACH BOTTOM 3	07/74	36.6	2.0	5.5	66.8	95.6	1.0	1.0	348.9	31.0	3.0	9.7	37.7
PILGRIM 1	12/72	65.9	3.0	4.6	80.2	63.9	6.0	9.4	38.9	87.0	8.0	9.2	39.7
POINT BEACH 1	12/70	78.0	3.0	3.8	94.9	81.8	2.0	2.4	149.3	74.0	1.0	1.4	270.1
POINT BEACH 2	10/72	89.2	0.0	0.0	0.0	86.8	1.0	1.2	316.8	71.0	2.0	2.8	129.6
PRAIRIE ISLAND 1	12/73	89.1	1.0	1.1	325.2	90.0	1.0	1.1	328.5	87.0	3.0	3.4	105.9
PRAIRIE ISLAND 2	12/74	71.9	4.0	5.6	65.6	89.6	5.0	5.6	65.4	87.0	1.0	1.1	317.6
QUAD CITIES 1	08/72	94.1	7.0	7.4	49.1	68.0	7.0	10.3	35.5	94.0	3.0	3.2	114.4
QUAD CITIES 2	10/72	68.0	0.0	0.0	0.0	83.9	6.0	7.2	51.0	64.0	1.0	1.6	233.6

TABLE A.1. (contd)

FACILITY	COMMERCIAL START-UP	1981 AVAIL. (%)	1981 AUTO TRIPS	1981 ADJUST. COUNT	1981 MTBE	1982 AVAIL. (%)	1982 AUTO TRIPS	1982 ADJUST. COUNT	1982 MTBE	1983 AVAIL. (%)	1983 AUTO TRIPS	1983 ADJUST. COUNT	1983 MTBE
ROBINSON 2	03/71	73.0	8.0	11.0	33.3	48.9	10.0	20.4	17.8	76.0	2.0	2.6	138.7
SALEM 1	06/77	78.1	10.0	12.8	28.5	47.9	5.0	12.5	29.1	59.0	5.0	8.5	43.1
SALEM 2	10/81					97.3	10.0	10.3	35.5	12.0	5.0	41.7	8.8
SAN ONOFRE 1	12/68	26.7	3.0	11.2	32.5	15.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEQUOYAH 1	07/81					52.8	9.0	17.0	21.4	78.0	10.0	12.8	28.5
SEQUOYAH 2	06/82									73.0	4.0	5.5	66.6
SURRY 1	12/72	38.9	7.0	18.0	20.3	88.8	17.0	19.1	19.1	57.0	10.0	17.5	20.8
SURRY 2	05/73	79.6	8.0	10.1	36.3	88.3	10.0	11.3	32.2	65.0	13.0	20.0	18.3
TROJAN	05/76	74.1	12.0	16.2	22.5	60.8	5.0	8.2	44.4	62.0	5.0	8.1	45.3
TURKEY POINT 3	12/72	15.8	0.0	0.0	0.0	64.1	10.0	15.6	23.4	73.0	1.0	1.4	266.5
TURKEY POINT 4	09/73	77.7	8.0	10.3	35.5	66.3	8.0	12.1	30.2	52.0	5.0	9.6	38.0
VERMONT YANKEE	11/72	84.6	2.0	2.4	154.4	96.0	3.0	3.1	116.8	69.0	3.0	4.3	84.0
YANKEE-ROWE	06/61	74.4*	1.0	1.3	271.6	73.4	3.0	4.1	89.3	91.0	4.0	4.4	83.0
ZION 1	10/73	71.9	1.0	1.4	262.4	59.1	2.0	3.4	107.9	66.0	5.0	7.6	48.2
ZION 2	09/74	72.7	12.0	16.5	22.1	69.4	9.0	13.0	28.1	73.0	2.0	2.7	133.2

Adjusted Count: # Auto Trips/Availability
MTBE: Mean Time Between Event, The number of days between auto trip events.
*: No events recorded

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13. ABSTRACT (200 words or less)

This report presents the results of a project designed to compare and contrast Japanese and United States nuclear power plant operating experience, preventive maintenance/surveillance requirements, and organization and management practices relating to maintenance. Findings are based on information obtained on the November-December 1983 and November 1984 visits to Japan by the NRC and representatives of Battelle's Pacific Northwest Division, and on various documents obtained from the Japanese (primarily the Ministry of International Trade and Industry--MITI) during and subsequent to the visits. U.S. data sources included NUREG-0020 (Greybook) and plant technical specifications. The study shows that Japanese plants experienced far fewer manual shutdowns, manual scrams, automatic scrams, and reduced loads than U.S. plants and that their mean-time-between-event (MTBE), even when adjusted for differences in average plant availability, was approximately 10 times greater than the U.S. MTBE. The report also points out significant differences in the Japanese approach to preventive maintenance, and in the Japanese regulatory approach to maintenance, their management and organizational context for maintenance, and other socioeconomic factors that may affect the performance of maintenance.

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