TECHNICAL REPORT

A-3270-12-85

PILOT ASSESSMENT:

IMPACT OF AGING ON THE SEISMIC

PERFORMANCE OF SELECTED EQUIPMENT TYPES

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DECEMBER 1985

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SUMMARY

The USNRC has recently initiated a research program, under the support of the Nuclear Plant Aging Program (NPAR), to better understand the impact of equipment aging on plant safety and to recommend realistic operating and maintenance procedures to improve plant availability and enhance safety. Many research projects are in progress to address the various aging issues in the NPAR program. This pilot study was performed to investigate the feasibility of using plant experience data to assess the relationship between equipment aging and seismic performance capacity.

After a brief review of available plant experience data at many California sites for content and quality, data related to performance, maintenance, and failure history were collected for a sample set of equipment types. This pilot study selected four equipment types for investigation from the highest priority group in a previous NPAR program. The equipment types studied were:

- Electric motors
- Motor-operated valves (MOVs)
- Relays
- Circuit breakers
- Motor control centers (MCCs)

The acquired equipment data consisted of installation date, chronological listing of preventative and corrective maintenance activities, failed state and reason/cause of the activity, earthquake data (i.e., free-field acceleration, Richter magnitude, date), and equipment status before and after the earthquake. These data were acquired for all items belonging to the four equipment types in Units 2 and 4 of El Centro Steam Plant. This plant experienced the 1979 Imperial Valley earthquake which measured free-field accelerations of 0.49 and 0.35g for the two horizontal directions and 0.66g for the vertical direction. In addition, these plants have experienced six other earthquakes of smaller magnitude between 1953 and 1976.

The number of items studied in each equipment type, age at the time of earthquake and today, are presented Table 1.

Table 1

AGES OF SELECTED EQUIPMENT

Type	Number of Items	Age (Years) at Earthquake	Current Age (Years)
Electric Motors	58 (Unit 2)	27	33
	58 (Unit 4)	12	18
MOVs	3 (Unit 2)	27	33
	3 (Unit 4)	12	18
Relays	75-100 2400 V > 500 Total (Each Unit)	27 (Unit 2) 12 (Unit 4)	33 (Unit 2) 18 (Unit 4)
Circuit Breakers	75-100 2400 V > 500 Total (Each Unit)	27 (Unit 2) 12 (Unit 4)	33 (Unit 2) 18 (Unit 4)
MCCs	3 Assemblies 32 units	27 (Unit 2)	33 (Unit 2)
	3 Assemblies 32 units	12 (Unit 4)	18 (Unit 4)

The acquired equipment performance and maintenance data were studied to assess whether seismic performance is affected/degraded by aging and maintenance procedures. Each equipment data were reviewed for the following:

- Variations in corrective maintenance (CM) activity rate before and after the earthquake.
- Variations in preventative maintenance (PM) activity rate before and after the earthquake.
- Changes in failure states, or causes/reasons before and after the earthquake.
- Deviations from the average maintenance rate for the specific equipment in question.
- Modifications in PM procedures before and after the earthquake.

Based upon the limited collected data, the following can be inferred for the investigated equipment at the El Centro Plant:

- There is no variation in the type and frequency of CM and PM prior to and after an earthquake.
- The type and causes of equipment failures did not change following the earthquakes.
- There are no specific items (as identified by manufacturer, location, operating capacity, model number, etc.) within each equipment type that exhibited a higher CM rate after the earthquakes.
- No PM procedures were modified following the earthquake. Checking and adjusting the tightness of motor anchor bolts, panel and anchor bolts of MCCs, and bolts of circuit breakers were the only maintenance activities conducted following the earthquake to assure the continued integrity of equipment.

This pilot study was successful in demonstrating that experience data can be extracted and utilized to address the relationship between seismic performance capacity and aging of plant equipment. It is strongly recommended that future research be conducted to acquire experience data for other important equipment types and to investigate other California power plants. Such research will provide the maximum amount of actual experience data to address the aging-seismic relationship in a practical manner. Lessons learned from a review of these data can be used as input to develop practical maintenance and operating procedures to enhance safety and improve plant reliability.

1. INTRODUCTION

1.1 Background

The United States Nuclear Regulatory Commission (USNRC) has recently implemented a research program to investigate aging issues associated with equipment at nuclear plants in operation and under construction (Ref. 1). The operating lifetimes of several nuclear plants have exceeded fifteen years. As these facilities continue to advance in age, additional effort is necessary to assess the potential impact of time-related equipment degradation on plant safety. The original design life of these plants was 40 years, and the majority of the equipment were conservatively designed and qualified for the 40 year life. One of the purposes of the NPAR program is to estimate/assess the actual life that can be expected from these equipment.

There are many factors which may lead to the functional impairment of plant equipment. These factors include: natural chemical or physical processes, external stressors (radiation, humidity, chemical), service wear, excessive testing or improper installation, and maintenance. An understanding of the relationship between these conditions and aging is necessary to assure that the equipment when demanded, is capable of performing its intended function in order to minimize the potential consequences on plant safety. Good preventative maintenance (PM) procedures may reduce the need for future corrective maintenance (CM, i.e., repairs and other unscheduled activities).

Another recent advancement in equipment qualification is the use of actual plant seismic experience data to address the generic seismic adequacy of nuclear plant equipment. The Seismic Qualification Utilities Group (SQUG) has gained the approval of the USNRC to use extensive performance data collected at various power and industrial facilities (database facilities) during past earthquakes to resolve USI A-46 (Ref. 2). This approach is based on the assumption that actual

data provide a credible and cost effective method of evaluating the performance of typical power plant components and structures.

The SQUG also demonstrated the similarities between nuclear and non-nuclear database equipment on the basis of manufacturer, model and age, size, and structural characteristics including anchorage. In general, nuclear equipment is newer, better maintained, and better anchored than database equipment (Ref.2).

A number of SQUG database facilities in California have been subjected to earthquakes with peak ground accelerations greater than 0.25g and as high as 0.60g. In addition to the earthquake performance, detailed records including operating logs and maintenance work orders are typically stored at the fossil power plants in this data base. These facilities contain power plant units constructed in the early 1940's to the mid 1970's. Some of the equipment has therefore been in operation longer than the anticipated forty year life of a nuclear plant. These data are studied in this pilot program to investigate the correlation between seismic performance capacity and aging for selected equipment based on actual plant experience data.

Extensive data are available on power plant equipment performance during and after earthquakes. A typical utility also keeps detailed operating and maintenance records. These records were reviewed to determine trends in equipment performance. This study demonstrates that the use of experience data provides a simple, reliable, and inexpensive alternative to current research efforts evaluating the effect of aging on the seismic performance capacity of selected equipment. Further, these studies assess whether PM activities required to maintain the seismic capacity of equipment can be derived from actual plant maintenance data of California plants.

1.2 Objective

The Nuclear Plant Aging Research (NPAR) program was initiated by the USNRC to meet three objectives:

- Identify and characterize aging and service wear effects which if not addressed could cause degradation of structures, components, and systems.

- Identify methods of inspection, surveillance, and monitoring structures, components, and systems to assure the timely detection of significant aging effects prior to loss of safety function.

- Evaluate the effectiveness of storage, maintenance, and repair and replacement practices in mitigating the rate and extent of degradation caused by aging and service wear.

The NPAR program is intended to provide a better understanding of the impact of equipment aging on plant safety. The results of the research may lead to recommendations for code revisions and standardization of current industry practices, improved plant availability/reliability, and enhanced safety.

The specific objective of this pilot study is to investigate selected equipment types to assess whether the seismic capacity is affected (degraded or enhanced) by aging effects. This can be achieved through a comprehensive review of equipment performance and maintenance histories from installation prior to and following an earthquake. It is also the objective to identify maintenance activities that are essential to maintain the seismic capacity of the item throughout its life.

If this study is successful in demonstrating that the experience data is a useful tool, then a detailed research program could address equipment types in several database facilities to address the relationship between aging and seismic capacity and to identify specific maintenance activity to maintain the seismic capacity of equipment. Such a study could provide valuable data and information to the NPAR Program.

1.3 Overview of Pilot Study

The purpose of this report is to examine and document the correlation between seismic and aging issues associated with typical nuclear plant equipment. After a brief review of available experience data for content and quality in selected California power plants (Section 2.1), the history of selected equipment in one California fossil plant was studied. The plant and equipment selection rationale are described in Section 2.2. Equipment history data were collected as described in Section 2.3 via interviews with plant personnel and detailed research of plant logs and work orders. Installation, major overhaul, and replacement dates were noted in determining the age of the equipment. Maintenance records are presented in Section 2.4 and Appendices A and B.

The pilot study findings and conclusions are presented in Section 3. Equipment are categorized based on observed trends of seismic performance and age degradation. Each item exhibits positive, negative, or potential seismic-aging correlation. Potential correlations include equipment for which insufficient data were collected in the pilot study. This section also contains the recommendations for the extension of this pilot study to available data at other database plants/sites and additional equipment types.

2. AGING - SEISMIC EXPERIENCE DATA

2.1 Available Experience Data

As a part of this pilot study, some of the power plants in the SQUG database (Ref. 2) were contacted to explore the content, quality, and accessibility of their aging/maintenance data. Non-nuclear and nuclear plants listed below were queried for this purpose:

- SMUD - Rancho Seco Nuclear Plant
- PG & E - Humboldt Bay Nuclear Plant
- SCE - San Onofre Nuclear Plant
- Imperial Irrigation District - El Centro Steam Plant
- LADWP - Valley Steam Power Plant
- City of Burbank - Burbank Power Plant
- City of Glendale - Glendale Power Plant
- SCE - Ormond Beach Power Plant
- SCE - Solar One

Nuclear plants, in general, keep a computerized summary of corrective and preventative maintenance activities. Other sources of data include licensee event reports, in-plant reliability systems, plant work orders, and in-service inspection reports. Maintenance data at non-nuclear plants are generally handwritten and organized by unit. Separate files are kept on several of the larger pieces of equipment. Although no specific storage system has been implemented for the records, a computerized database management system is being planned at many non-nuclear plants.

The plant work order database at a typical power plant includes operating logs and work orders with the following information:

- Equipment identifier
- Chronological data
- Problem description

- Actions taken
- Cost

Work orders are generally the best source of these data. Operating logs note the time and location of equipment malfunctions but provide little other detail.

The equipment identifier is usually a tag number, manufacturer, and model number. Such data are sufficient to uniquely identify the equipment in the plant. Chronological data include the date of failure detection, date action was taken, outage, duration, and priority (i.e., an assessment of how critical the equipment is to safe plant operation). Problem descriptions identify symptoms, failed state, and probable cause. A description of the action taken may provide insight into the nature of the failure cause/mechanism. Maintenance may be preventative, surveillance, inspection, calibration, or repair. The first four categories are considered preventative maintenance. Repairs and any unscheduled activities are classified as corrective maintenance.

2.2 Plant and Equipment Types Selection

Seismic performance data and maintenance records for components and systems are available at several fossil power plants in California. Approximate dates of commercial operation, number of units, and known experienced free-field earthquake levels are shown in Table 2-1 for selected plants.

The El Centro Steam Plant was selected for review based on the peak ground acceleration, age range of the individual units, access to available records, and input from Brookhaven. This plant has been investigated by SQUG Utilities and the U.S. Nuclear Regulatory Commission (Refs. 2 and 3). It is located approximately 16 miles from the epicenter of the Imperial Valley earthquake of 1979.

There are four units at El Centro Steam Plant. Electric power rating, first date of construction, and date of commercial operation for each of these units are shown in Table 2-2.

Table 2-1

CALIFORNIA DATABASE FACILITIES

Plant	Number of Units	Date of Commercial Operation	Free-field Peak Ground Acceleration
Burbank Power Plant	7	1940-1960	0.35g (1971)
Glendale Power Plant	5	1941-1964	0.30g (1971)
Valley Steam Power Plant	4	1954-1956	0.40g (1971)
Humboldt Bay Power Plant	3	1956-1963	0.25g (1980)
Ormond Beach Power Plant	2	1970-1973	0.20g (1973)
El Centro Steam Plant	4	1948-1968	0.50g (1979)

Table 2-2

AGES AND OPERATING CAPACITIES OF INDIVIDUAL UNITS

Unit	Rating (Mw)	Date of Operation	Age to Date (Years)	Comments
1	20	1948	37	--
2	32	1952	33	Investigated
3	50	1957	28	--
4	80	1968	17	Investigated

Units 3 and 4 were in operation during the earthquake. Units 1 and 2 were shut down for scheduled maintenance. The age range of the units was 12 to 30 years at the time of the 1979 earthquake. Known damage to equipment in the plant was minimal (Refs. 2 and 3).

From the recommendations of a previous NPAR study (Ref. 1), four equipment types were selected for review in this pilot study:

- Motors
- MOVs
- MCCs
- Circuit breakers
- Relays

These items represent a sampling of the equipment of current interest to the NPAR program. This selection is also consistent with ongoing research at BNL. When the study was started, battery chargers and inverters were included as the fifth equipment type, but these were dropped during the initial phases of the study because there are no inverters at El Centro that had experienced the earthquake (see Section 2.4.7 for additional detail).

2.3 Data Collection

Data collection at El Centro Steam Plant consisted of three activities. The first was the establishment of a contact at the site. The maintenance and operations personnel then arranged for access to the facility. During the site visit, data collection activities included conducting interviews with plant staff and reviewing maintenance records on the equipment of interest.

All pertinent history data for the following equipment types were acquired:

- Electric motors (including MOVs)
- Circuit breakers
- Relays
- MCCs (cabinets)

The nameplate data (manufacturer, model, tag number, etc.), location, and environmental data were collected for each item. Sample pages from preventative maintenance, repair, and operator logs are shown in Appendix B. For each equipment item, the preventative maintenance summary books were reviewed from the date of installation to the present to extract pertinent activities. The repair logs were reviewed to gather data about corrective maintenance. Operator logs were also reviewed to supplement (or verify/check) the other data. The acquired data consisted of date, activity type and description, failed state, and reason/cause for the activity.

These data gathered in the field were organized by "date" (i.e., for each date, all activities on selected equipment were listed). These data were sorted to organize the activities by equipment. The corrective and preventative maintenance activities were combined in a chronological order to obtain the maintenance history of the equipment item.

In addition to the equipment history data, general information and data regarding ambient weather conditions (humidity and temperature) were collected. Plant operating logs were used to obtain data on the number of hours of operation for each unit.

2.4 Maintenance Experience Summaries

The acquired data were sorted and compiled to obtain information regarding the maintenance history and seismic performance of the equipment. The hours of individual unit operation and local environmental conditions were also reviewed. These data are summarized in the following subsections.

2.4.1 General Information. El Centro is located in a dry, desert area approximately 16 miles from the epicenter and three miles from the causative fault of the Imperial Valley earthquake of Richter magnitude 6.6 (Figure 2-1). Several other earthquakes have affected this area since 1952, the initial operating date of Unit 2 (Refs. 4 and 5). These earthquakes are summarized in Table 2-3. Of the six earthquakes listed in Table 2-3, only the 1979 earthquake produced accelerations of 0.49 and 0.35g for the horizontal directions and 0.66g for the vertical direction (Refs. 2 and 3). The estimated/measured ground motions at the plant were smaller for the other earthquakes listed in the table.

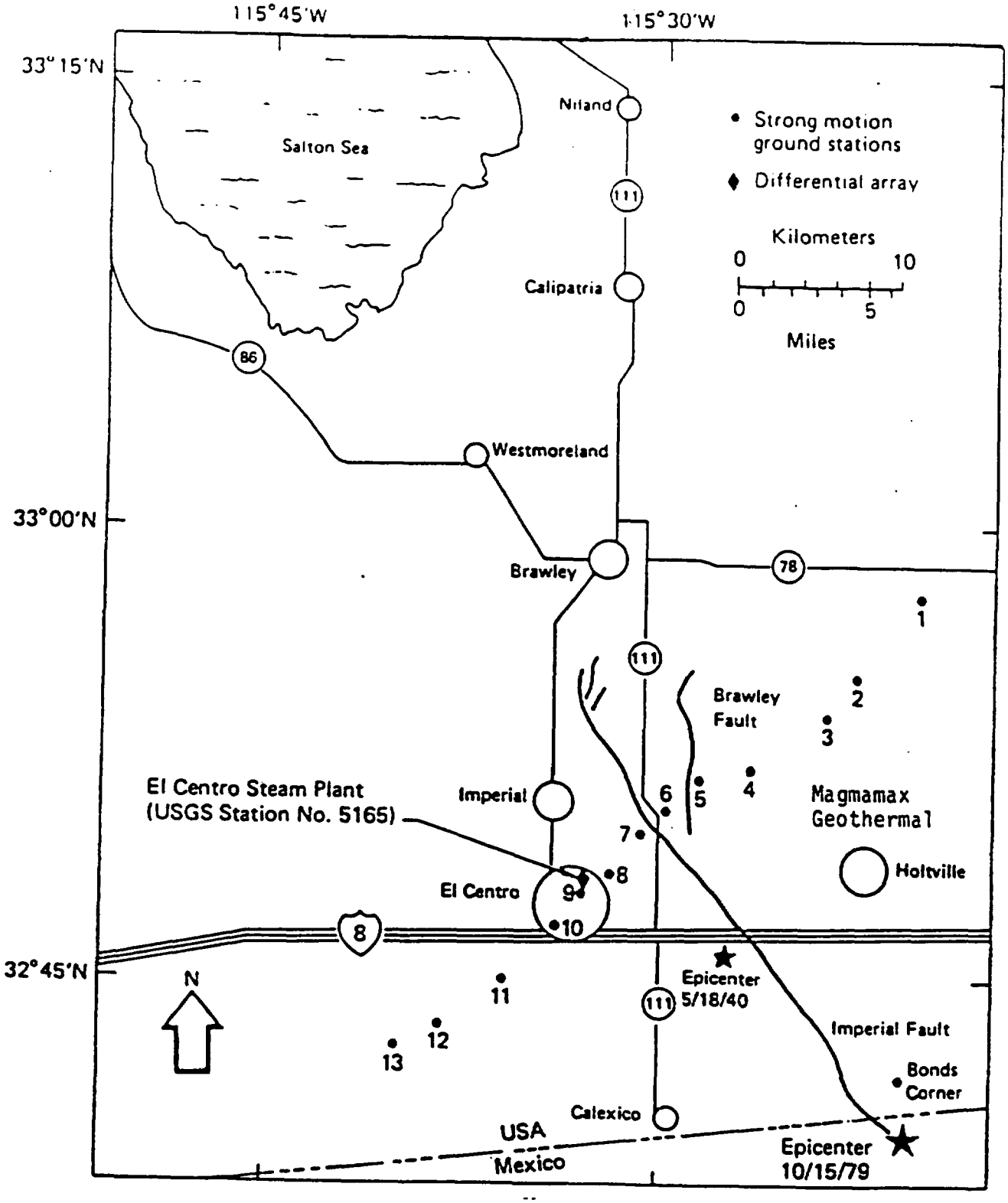

Figure 2-1: Map of the Imperial Valley, California, showing the ruptured segments of the Imperial fault, and the El Centro Steam Plant.

Table 2-3

EARTHQUAKES IN IMPERIAL VALLEY
SINCE 1953

Date	Location	Magnitude	Maximum Intensity*
6-13-53	Imperial Valley	5.5	VII
12-16-55	Near Brawley	5.4	VII
5-22-63	Imperial Valley	4.7	VI
3-4-66	Near Imperial	3.6	VI
4-8-68	South of Ocotillo Wells	6.5	VII
	Calexico Area (Aftershock)	4.7	VI
11-4-76	Imperial Valley	5.5	VI
10-15-79	Imperial Valley	6.6	VII

* These maximum intensities were not always near the plant.

The average temperature is between 50° F in February to 105° F in August, and the humidity is between 10% and 30% of RH. The typical swing in temperature between daytime high and nighttime low is 20° F, but at least a few times a year, the swing may be as high as 35° F. A histogram showing average temperature and humidity is presented in Figure 2-2.

Unit 2, constructed in 1950, started to produce power in 1952 and Unit 4, constructed in 1967, went on-line in 1968. The power production hours varied from year to year for each unit. Figure 2-3 shows the distribution of hours of operation since 1970.

2.4.2 Electric Motors. Because all the motors at the El Centro Plant are routinely used to produce power, they are well maintained. Excellent records are available for CM and PM activities on these items. A separate and more detailed file is kept on the large motors (i.e., greater than or equal to 100 hp). Several of these larger motors were selected for review based on the critical nature of their service and the detailed maintenance history information available. Selected motor CM and PM histories are presented in Appendix A.

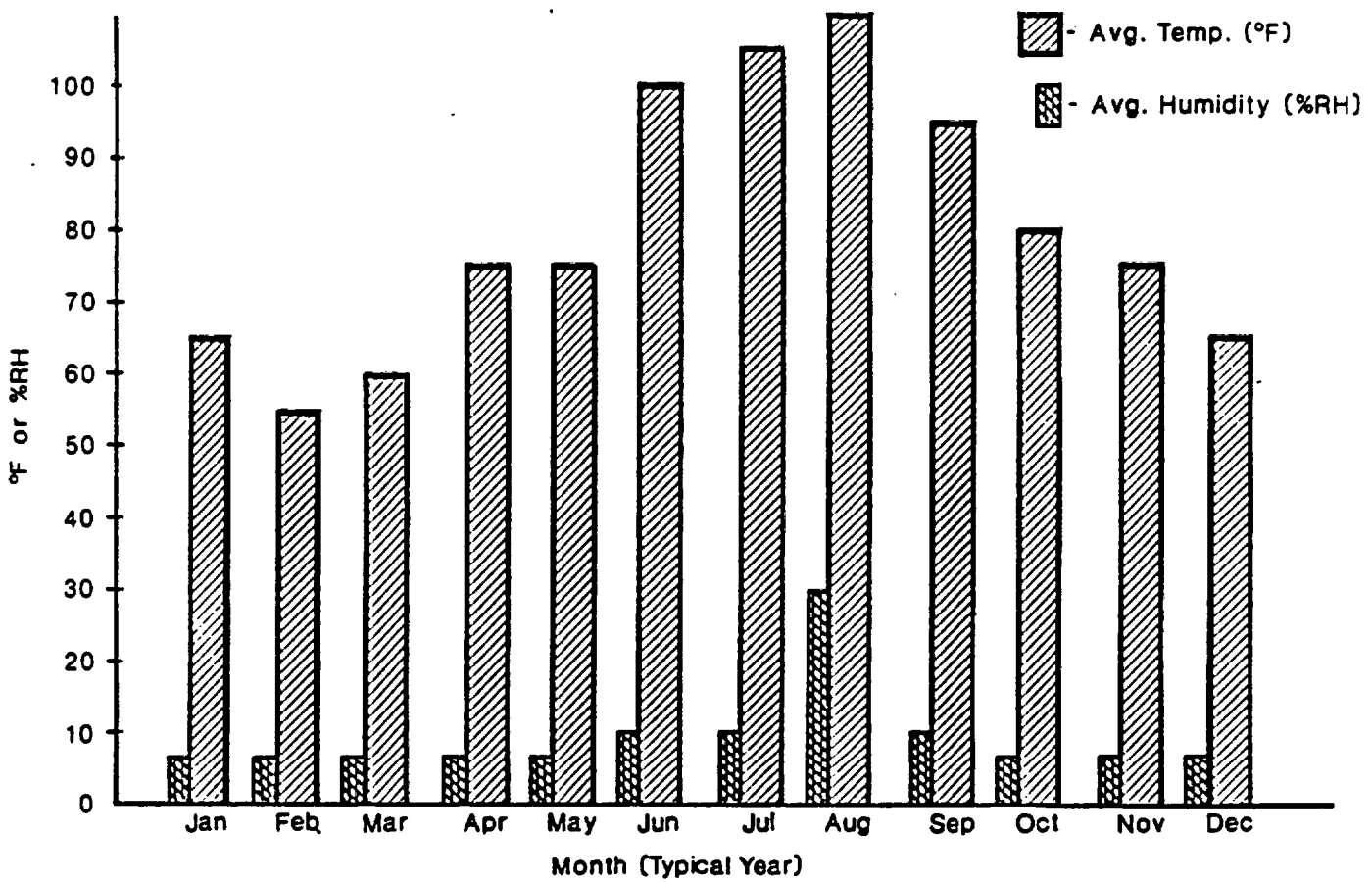

Figure 2-2: Average temperatures and humidities during a typical year at El Centro Steam Plant.

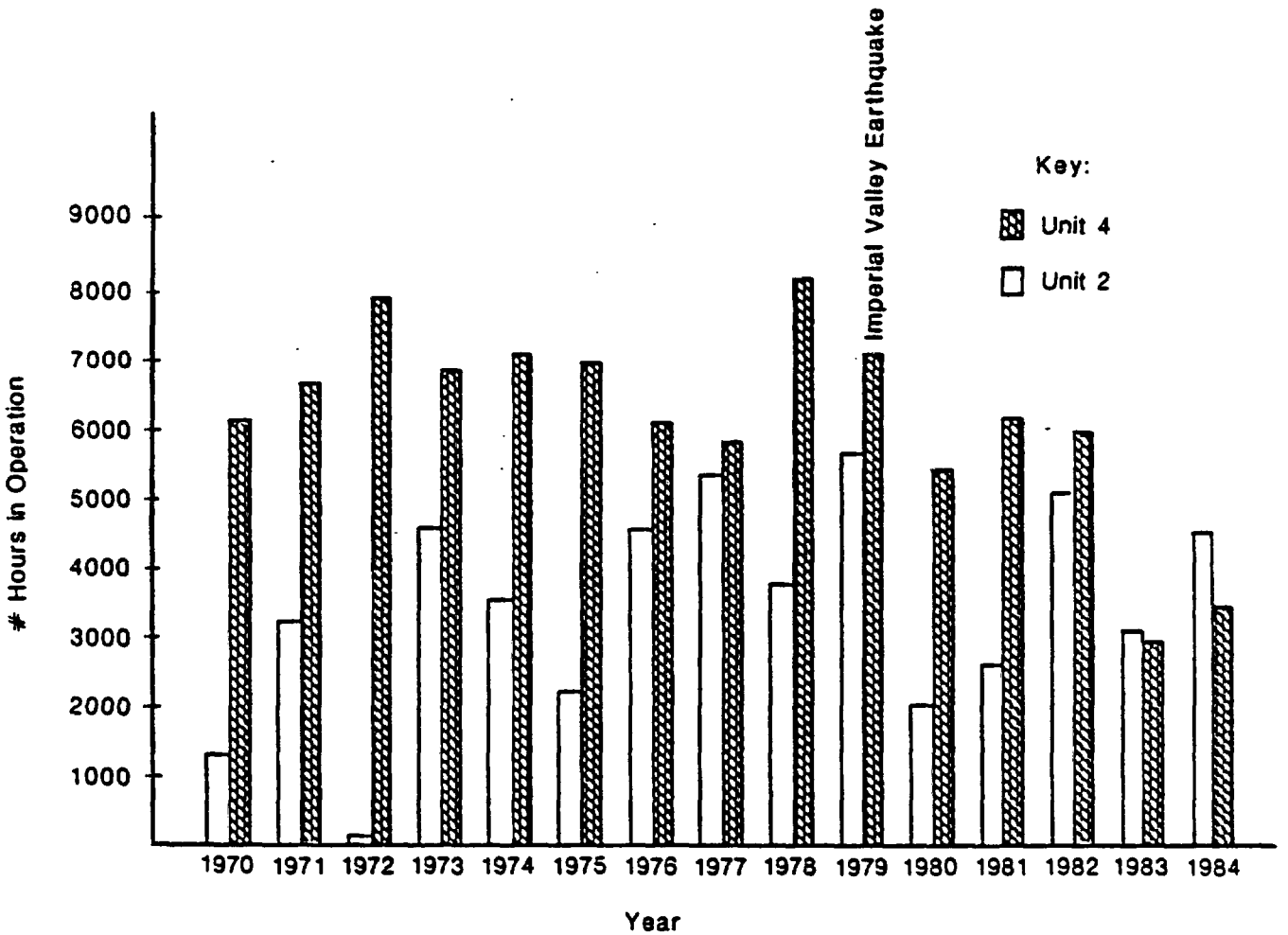

Figure 2-3: A comparison of operating hours for Units 2 and 4 at El Centro Steam Plant.

The majority of the large horsepower motors in Units 2 and 4 were manufactured by Allis Chalmers. Most of the motors on the site range from fractional to 100 hp and were primarily manufactured by GE and Fairbanks Morse. Units 2 and 4 contain 58 motors each. Figures 2-4 and 2-5 show the distribution of motors by HP for Units 2 and 4.

PM procedures conducted most frequently include: bearing inspections, alignment checks, and lubrication. All rotating equipment on the site is checked on an hourly basis for oil level, bearing temperature, and gland leakage. The shift supervisor logs all problems in a journal which is later reviewed by the plant superintendent. Significant plant operating problems or nuisances such as oil leakage, are flagged for action by the maintenance department.

The collected data showed that the 2300 volt motors such as the Forced Draft and Induced Draft Fans are generally subjected to more PM than smaller motors. Motors have demonstrated the highest CM rate of all equipment reviewed during this study. These activities have included: rewinding, re-alignment, and replacement of bearings. A motor is typically rewound when the windings are loose or burned up. The electrical shop on site rewinds motors less than 100 hp. Re-alignment is necessary for pump-motor and fan-motor sets due to excessive vibration and bumping which may later cause more extensive damage. Burned out bearings are replaced as required.

No motor failures occurred during any of the earthquakes. Eight out of fifty-nine instances of CM were noted within six months of a seismic event for all motor histories reviewed in detail (see Table 2-4).

Table 2-4

MOTOR CM WITHIN SIX MONTHS
OF AN EARTHQUAKE

Earthquake Date	Corrective Maintenance	Description of Corrective Maintenance	Equipment Identification
6-13-53	10-9-53	Replace inboard bearing	Boiler Feed Pump 2-1
12-16-55	4-24-56	Replace lower guide bearing	Circulating Water Pump 2-2
5-22-63	6-11-63	Install shim under outboard foot	Boiler Feed Pump 2-1
3-4-66	None	None	None
4-8-68	8-27-68	Cut new keyway in outboard fan hub	Boiler Feed Pump 4-1
	8-27-68	Repair rotor, reason unknown	Boiler Feed Pump 4-2
	8-27-68	Repair rotor, reason unknown	Boiler Feed Pump 4-3
11-4-76	None	None	None
10-15-79	10-19-79	Replace motor bearing shim	Forced Draft Fan 4-1
	12-10-79	Install shim under outboard foot	Forced Draft Fan 4-1

A previous study by the Electric Power Research Institute (Ref. 7) has found that seismic effects are minimal provided that motors are adequately maintained. The results of the Wylie phase two study on aging-seismic correlation also found that there is no correlation between aging and the seismic performance of motors (Ref. 7, the phase two report will be published in early 1986). This conclusion is further supported by this investigation and the BNL experience database (Ref. 8).

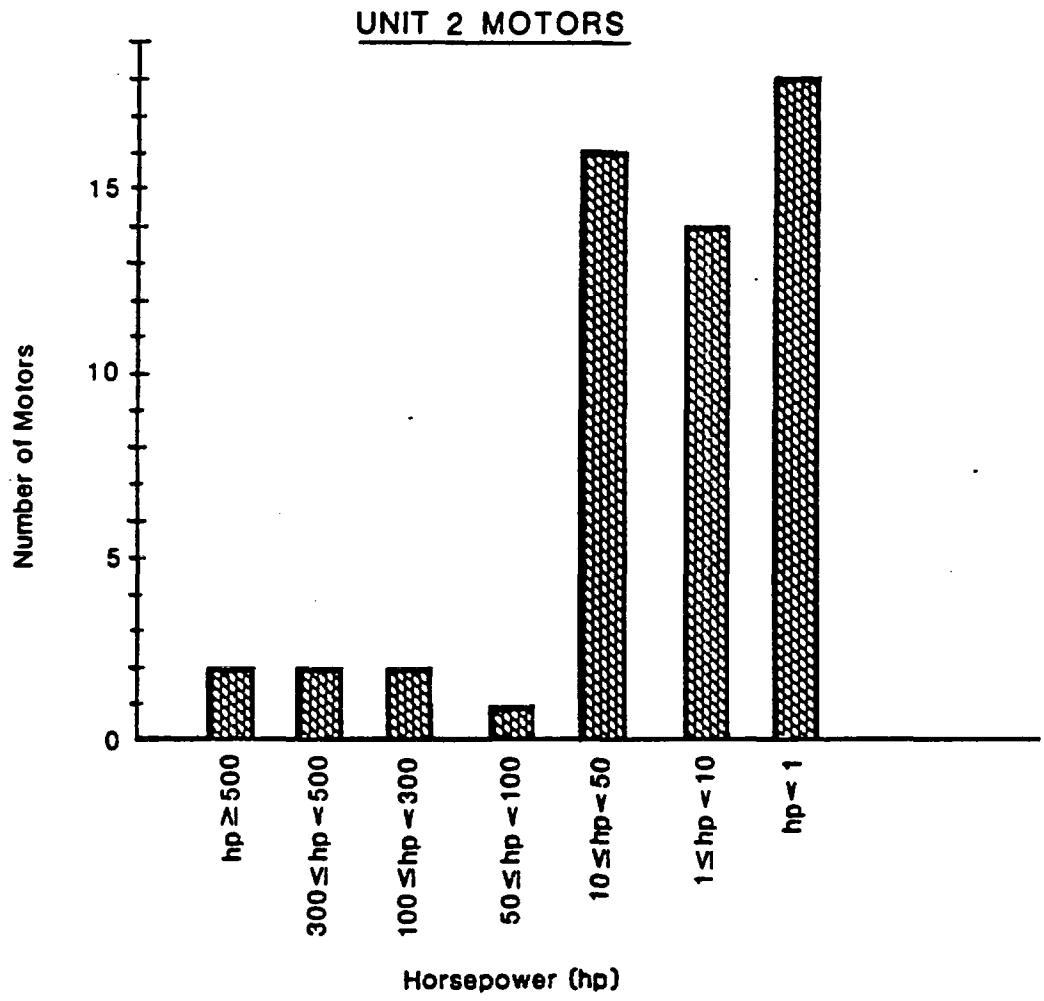

Figure 2-4: Horsepower ratings for Unit 2 motors at El Centro Steam Plant.

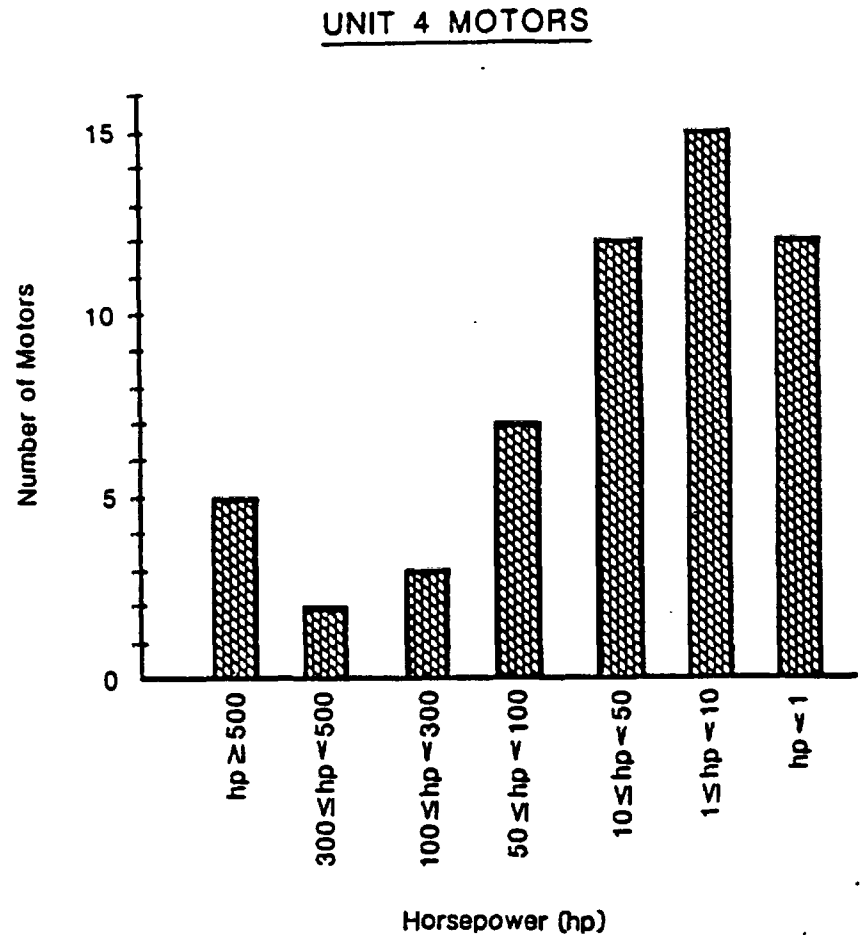

Figure 2-5: Horsepower ratings for Unit 4 motors at El Centro Steam Plant.

The annual PM performed on motors up to 33 years old at the El Centro Steam Plant is sufficient to prevent seismic failure due to age degradation.

Table 2-4 lists the motor CM activities within six months of the earthquakes felt at the site. Corrective maintenance activities conducted in 1953 and 1955 may be associated with initial plant operation and not the earthquake. Because these motors were basically new at that time, the failures were attributed to operational start-up problems. In three cases shims were replaced or installed. A clearance inspection and anchor bolt tightness check are therefore recommended following an earthquake. Four months following the 1968 earthquake, three maintenance activities were performed. One activity is an equipment modification and the other two are related to rotor. Because the two incidents occurred on two and not on all motors and only after one earthquake, these isolated incidents do not provide a basis for inferring aging-seismic correlation for motors.

CM activities were very limited in the years following the Imperial Valley earthquake. The six year period from the time of the earthquake to present is much shorter than from the installation date to 1979 for Units 2 and 4.

No specific motors demonstrated a higher CM rate than the average for all motors. It was observed that the type and frequency of PM did not change prior to and following the earthquake.

2.4.3 MOVs. A limited number of motor-operated valves are used at this site. Units 2 and 4 contain a total of six valves. Each unit includes a main steam stop valve and two circulating water discharge valves. All motor-operators were manufactured by Limitorque.

PM is conducted on a scheduled basis at approximately one-year intervals and generally includes inspection, cleaning, repacking, and lubrication. Corrective maintenance is typically performed on the valve, not the

motor operator. The Circulating Water Discharge Valve 2-1 was the only MOV repaired within six months of an earthquake (See Table 2-5). No CM was performed on the motor operator at that time. MOV CM and PM histories are presented in Appendix A.

No MOV failures occurred during the earthquake. The collected data showed that the type and frequency of CM and PM did not change prior to and following the seismic event.

TABLE 2-5

MOV CM AFTER AN EARTHQUAKE

Earthquake Date	Corrective Maintenance	Description of Corrective Maintenance	Equipment Identification
6-13-53	None	None	None
12-16-55	11-12-62	Repair valve leak	Main Steam Stop Valve #2
5-22-63	None	None	None
3-4-66	4-21-66	Grind edges on circumference of valve to relieve tight fit. Reassemble gear.	Circulating Water Discharge Valve 2-1
	10-16-67	Install new rubber seat, cast iron holding segments, butterfly, and shaft. Rewind motor. Reset Limitorque.	Circulating Water Discharge Valve 2-1
	1-24-68	Check safety and try to reset popping pressure	Main Steam Stop Valve #4

TABLE 2-5 (cont.)

MOV CM AFTER AN
EARTHQUAKE

Earthquake Date	Corrective Maintenance	Description of Corrective Maintenance	Equipment Identification
	3-67	Replace rubber seal and cast iron segments. Grease fittings installed in stem bushings. Reset Limitorque.	Circulating Water Discharge Valve 2-2
4-8-68	2-17-69	Lapped seat and disc and reassembled.	Main Steam Stop Valve #4
	1-6-72	Repair due to failure to close electrically.	Main Steam Stop Valve #2
	9-20-75	Replace disc.	Circulating Water Discharge Valve 2-1
11-4-76	None	None	None
10-15-79	10-81	Remove and replace valve.	Main Steam Stop Valve #4
	9-27-84	Free gear.	Circulating Water Discharge Valve 4-2

2.4.4 Circuit Breakers. The majority of the circuit breakers at El Centro were manufactured by GE. Very few were replaced since the initial operation of Units 2 and 4. Typical PM activities include an inspection of all contacts, cleaning, and a check of the manual and

electrical operation at one year intervals. Maintenance dates are noted on the exterior of the cabinet.

Isolated instances of CM include the replacement of a solenoid winding and an electrical coil. No CM activities were noted within six months of an earthquake (See Table 2-6).

TABLE 2-6

CIRCUIT BREAKER CM
AFTER AN EARTHQUAKE

Earthquake Date	Corrective Maintenance	Description of Corrective Maintenance	Equipment Identification
6-13-53	None	None	None
12-16-55	None	None	None
5-22-63	None	None	None
3-4-66	None	None	None
4-8-68	10-8-71	Tighten bolts on pallet switches.	Boiler Feed Pump 4-1 CB
	1-6-72	Replace winding in solenoid operation mechanism.	#2-13 CB in Pumphouse
	10-26-73	Clean and repair all breaker pallet switches.	Boiler Feed Pump 4-1 CB
11-4-76	5-15-79	Replace electrical coil.	Service Water Return Pump 4-2 CB
10-15-79	5-80	Repair CB because it wouldn't close.	Fuel Oil Transfer Pump 4-1 CB

Sample circuit breaker CM and PM histories are presented in Appendix A. This sampling was selected based on those items exhibiting CM activities.

2.4.5 Relays. Most of the relays on site were manufactured by GE. Very little maintenance has been necessary on these items. They are typically inspected and cleaned on an annual basis. At that time the operability is also checked. An index card indicating the last service date is placed inside the glass enclosure of each relay. No CM activities occurred within six months of an earthquake (See Table 2-7).

TABLE 2-7

RELAY CM AFTER
AN EARTHQUAKE

Earthquake Date	Corrective Maintenance	Description of Corrective Maintenance	Equipment Identification
6-13-53	None	None	None
12-16-55	None	None	None
5-22-63	None	None	None
3-4-66	None	None	None
4-8-68	8-19-70	Replace.	Boiler Feed Pump 4-1 Bearing Oil Pressure Relay
11-4-76	None	None	None
10-15-79	None	None	None

Several mercoid switches on high level alarms for the 2-4 and 4-3 Feedwater Heaters were repaired before the Imperial Valley earthquake. The type and frequency of CM and PM did not change prior to and following the earthquake. Sample relay CM and PM histories are presented in Appendix A.

2.4.6 MCCs. The majority of the MCC cabinets were manufactured by Square D and GE. These cabinets are cleaned and inspected on an annual

basis. The tightness of panel/cabinet and anchor bolts were checked and adjusted once after each earthquake. No other maintenance was performed on the panel/cabinets. All the PM and CM were performed on the relays and circuit breakers contained within the MCCs. These are addressed in their respective sections.

2.4.7 Battery Chargers and Inverters. No record of PM for the Unit 4 battery charger exists. No CM is recorded to date. Unit 2 utilizes a motor generator set and hence is included in Section 2.4.2.

There is one inverter at El Centro which was installed subsequent to the 1979 earthquake. Our brief survey of other California plants showed that the Glendale Power Plant, for example, has two inverters, both of which experienced the 1971 San Fernando earthquake. The brief survey showed that these inverters performed satisfactorily. Further investigation at other sites for this particular item is recommended.

3. CONCLUSIONS AND RECOMMENDATIONS

This pilot study was conducted to investigate the feasibility of using experience data for assessing the impact of aging on the seismic performance of equipment. Based upon the acquired data, inferences on the effect of age-degradation and maintenance activities on the seismic performance of sample equipment types were made. In addition, recommendations for expanding this successful pilot study to include other equipment types and plants/sites are presented.

3.1 Assessment on the Use of Experience Data

The pilot study collected actual plant aging and maintenance experience data for selected equipment types in a sample power plant. This plant had experienced an earthquake with a free-field peak acceleration of 0.49 and 0.35g (horizontal) and 0.66g (vertical) in 1979. Two of the four units investigated in this pilot study were approximately 12 years and 27 years old. Pertinent preventative and corrective maintenance and seismic performance data were gathered and utilized to infer the relationship between aging (degradation/enhancement) and the seismic performance of selected equipment.

Based upon this pilot study, it is concluded that reliable equipment experience data can be acquired. Further, the study demonstrated that these data can be utilized to assess the relationship between aging, maintenance practices, and seismic performance of equipment. This study also demonstrated that PM is practical and essential for maintaining the seismic capacity of plant equipment based on actual plant experience data.

Representatives of many nuclear and non-nuclear plants in California were queried and it was concluded that all power plants maintain pertinent equipment data in an organized auditable manner (i.e., reliable data regarding the seismic performance of equipment and maintenance procedures can be extracted).

3.2 Findings on Seismic-Aging Correlation

Sample equipment types were investigated in this pilot study to assess whether aging and PM practices affect the seismic capacity of equipment. The ages of these items at the time of the earthquake and at present are tabulated in Table 3-1.

Table 3-1

SEISMIC-AGING CORRELATION ASSESSMENT

Type	Number of Items	Age in Years at Time of Earthquake	Current Age
Electric Motors	116	12 (Unit 4) 27 (Unit 2)	18 (Unit 4) 33 (Unit 2)
MOVs	6	12 (Unit 4) 27 (Unit 2)	18 (Unit 4) 33 (Unit 2)
Relays	75-100 2400V > 500 Total (Each Unit)	12 (Unit 4) 27 (Unit 2)	18 (Unit 4) 33 (Unit 2)
Circuit Breakers	75-100 2400V > 500 Total (Each Unit)	12 (Unit 4) 27 (Unit 2)	18 (Unit 4) 33 (Unit 2)
MCCs	3 Assemblies 32 Units 3 Assemblies 32 Units	12 (Unit 4) 27 (Unit 2)	18 (Unit 4) 33 (Unit 2)

The acquired equipment history data consisting of installation date, first operation date, corrective and preventative maintenance activity histories, seismic performance, local environmental conditions, and inferences on the relationship between equipment age and seismic performance capacity were assembled by considering the following:

- The corrective maintenance (CM) activity rate before and after the earthquake
- The types of failure states before and after the earthquake
- The PM activity rate before and after the earthquake

- The average PM and CM activity rate of an equipment type versus the specific equipment activity rate

Based upon a study of the data collected for the selected equipment types, it is inferred that aging does not affect the seismic capacity of motors, circuit breakers, relays, MOVs, and MCCs at the El Centro Power Plant as long as the routine PMs are performed. The pilot study also identified that a bolt tightness check and clearance inspection are essential to PM in order to maintain the seismic capacity of equipment throughout their life.

3.3 Recommendations for Future Research

This pilot study has demonstrated the usefulness of the actual plant experience data in addressing the aging-seismic relationship of plant equipment. Additional research would be cost beneficial in resolving the aging-seismic issues of a large number of plant equipment types.

To maximize the benefits from future research efforts, an organized approach is recommended. Based upon a review of available literature on aging-seismic issues and availability of experience data, it is recommended that the future efforts focus on the following equipment types:

- Electro-mechanical switches (snap acting type)
- Snubbers
- MOVs
- Pumps
- Protective relays
- Inverters
- Batteries
- Solenoid valves
- Check valves

Additional data on MOVs and inverters should be collected at other sites in order to expand the limited selection at El Centro Plant.

It is further recommended that the future research investigate equipment in all California sites affected by earthquakes greater than 0.3g. These facilities may include:

- Sylmar Converter Station
- Valley Steam Power Plant
- Burbank Power Plant
- Glendale Power Plant
- Humboldt Bay Power Plant
- Las Ventanas Power Plant

Our investigation found that each of these sites keeps CM and PM records on most equipment.

4. REFERENCES

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2. Yanev, Peter I. and Swan, S.W., "Program for the Development of an Alternative Approach to Seismic Equipment Qualification", Prepared for the Seismic Qualification Utilities Group by EQE Incorporated, September 1982.

3. Nelson, T.A., et al, "Responses of El Centro Steam Plant Equipment During the October 15, 1979 Imperial Valley Earthquake", NUREG/CR-1665, September 1980.

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5. Gere, John M., "Earthquake Tables", Stanford University, California, August 1982.

6. Clay, H.R., et al, "Life Expectancy of Motors in Mild Nuclear Plant Environments", Published by Electric Power Research Institute, EPRI/NP 3887, February 1985.

7. Gleason, J.F., "Correlation Between Aging and Seismic Qualification for Nuclear Plant Electrical Components", EPRI Report, Project PRI 1707-4.

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APPENDIX A

Table A-1

Standard Motor Preventative Maintenance

Abbreviation	Description
PM1	Lubricate motor (drain, flush, and renew oil).
PM2	Install asbestos gaskets on bearing seal faces to prevent oil leakage.
PM3	Remove rotor, clean and wash out windings.
PM4	Clean coils.
PM5	Paint stator windings with Glyptal.
PM6	Check inboard and outboard clearances.
PM7	Check vibration.
PM8	Check alignment of pump and motor.
PM9	Check motor sight glass.
PM10	Check shaft.
PM11	Inspect motor thrust bearing.
PM12	Check rotor for trueness.
PM13	Paint motor.
PM14	Check alignment of motor and fan.
PM15	Check and align motor and gear box shaft coupling.
PM16	Overhaul (i.e. complete list).
PM17	Lower pitch.
PM18	Use Loc-Tite between bushing and motor shaft to prevent separation between fan and shaft.
PM19	Inspect all bearings.
PM20	Inspect outboard bearing.
PM21	Inspect inboard bearing.
PM22	Inspect both boiler fans and fan duct work. Check condition of drive linkage and all pivot points.
PM23	Inspect, clean, and repack drive couplings and motor bearings for air preheater.
PM24	Inspect cooling tower fans. Clean and repair fan motors, shafts, shaft couplings, gear boxes, and fan blades as required.

TABLE A-1 (Continued)

Abbreviation	Description
PM25	Clean and inspect motor generator set on battery charger and stone commutator as necessary.
PM26	Remove inspection plates and blow out large motors on boiler fans.
PM27	Check windings.
PM28	Check oil for foreign particles.
PM29	Check upper bearing.
PM30	Blow out motor.
PM31	Repack coupling.
PM32	Clean bearings.

TABLE A-2

STANDARD MOTOR CORRECTIVE MAINTENANCE

Abbreviation	Description	Reason
CM1	Install new motor.	1. Unknown (amine pump only).
CM2	Rebuild motor.	1. Unknown (sootblower air motor only).
CM3	Rewind motor.	1. Motor burned up (burned out coils), 2. Windings loose, 3. Motor on fire.
CM4	Renew coupling.	1. Motor-pump coupling stripped, 2. Gear box drive coupling turned and froze to shaft.
CM5	Align motor and pump.	1. Bump, 2. Motor lower than pump.
CM6	Remove and revamp balancing drum.	1. Excessive vibration.
CM7	Replace all bearings.	1. Bearings rough, 2. Found water in both bearings.
CM8	Replace inboard bearing.	1. Bearing burn out, 2. Lower half of bearing with broken ear.
CM9	Replace outboard bearing.	1. Bearing wiped.
CM10	Replace seals in outboard bearing.	1. Seals curled (oil leak at seal joint).
CM11	Retie loose strings.	1. Coil strings broken and loose.
CM12	Install shim under outboard foot.	1. Clearance between footing and base.
CM13	Replace cooling coil.	1. Unknown.
CM14	Grind laminations on rotor.	1. Rotor rubbed stator.
CM15	Repair ground in cable to motor.	1. Unknown.
CM16	Repair electrical leads.	1. Leads burned during system upset.
CM17	Repair motor fan vanes.	1. Severe vibration indicated broken fan vanes.

TABLE A-2 (Continued)

Abbreviation	Description	Reason
CM18	Replace radial bearing.	1. Burned up due to low oil level.
CM19	Cut off inboard end of motor shaft.	1. Bump, 2. Vibration indicated motor shaft pushing against fan shaft.
CM20	Cut new keyway in outboard fan hub for motor.	1. Cooling fan came completely off rotor.
CM21	Repair key.	1. Motor shaft turning in coupling.
CM22	Use Loc-Tite between bushing and motor shaft.	1. Fan came loose.
CM23	Replace shaft hub.	1. Fan hitting housing.
CM24	Replace lower guide bearing.	1. Bearing, bearing housing and piping full of carbon (bearing dry)
CM25	Redowl and reshim.	1. Dismantled motor.
CM26	Repair seals in outboard bearing.	1. Damaged shim between upper end of shaft and drive sleeve.
CM27	Repair rotor.	1. Unknown.
CM28	Install new sight glasses on motor bearings.	1. Unknown.
CM29	Reposition inboard oil seal.	1. Excessive vibration and noise.
CM30	Modify motor to allow oil to drain.	1. Improper oil drainage.
CM31	Rewedge and relash rotor.	1. Excessive vibration and pulsating noise.
CM32	Shim and clamp down thrust bearing	1. Bearing rocking in housing.
CM33	Dismantle, wash windings, set for proper air gap.	1. Rotor dropped, causing excessive vibration and smoke due to rubbing between rotor and stator windings.

TABLE A-2 (Continued)

Abbreviation	Description	Reason
CM34	Replace upper guide bearing.	1. Bearing wiped.
CM35	Repair rotor and stator.	1. Clicking noise noted, 2. Evidence of rubbing such excessive temperature in stator and burned insulation smell.
CM36	Tighten bearing hold down screw.	1. Combat excessive vibration, 2. Bearing rocking in housing.
CM37	Align fan and motor.	1. Motor sent out for rewinding.
CM38	Install shim between bearing case and end bell.	1. Outboard bearing rotated
CM39	Replace motor bearing shim.	1. Shim had worked out. Use thicker shim.
CM40	Metal spray and remachine shaft.	1. Motor bearing frozen to shaft.
CM41	Metal spray and machine housing	1. Fan loose, rubbed housing.

Table A-3

Standard Circuit Breaker Corrective Maintenance

Abbreviation	Description
CM1	Replace winding in solenoid operation mechanism.
CM2	Replace electrical coil.
CM3	Repair breaker because it wouldn't close. Reason unknown.
CM4	Clean and repair all breaker pallet switches.
CM5	Tighten bolts on pallet switches.

Table A-4

Standard Circuit Breaker Preventative Maintenance

Abbreviation	Description
PM1	Remove from cubicle, remove and inspect arc chutes, inspect main contacts, inspect dash pots, inspect control contacts, clean and inspect entire mechanism, inspect throwover switch, check manual and electrical operation.
PM2	Clean and lubricate closing and trip mechanisms.
PM3	Check all connectors, nuts and bolts for tightness.
PM4	Lubricate pallet push rods with Molycote.

Table A-5

Standard MOV Corrective Maintenance

Abbreviation	Description	Reason(s)
CM1	Check safety and try to reset popping pressure. Internal inspection required.	After popping several times, it did not reseat.
CM2	Lapped seat and disc and and reassembled.	Seating surfaces of both disc and seat were slightly cut. Suspect that disc was not free of the valve stem.
CM3	Remove and replace valve.	Unknown.
CM4	Repair.	Failed to close electrically.
CM5	Repair valve leak.	Unknown.
CM6	Free gear.	Valve would not close, gear frozen.
CM7	Grind edges on circumference of valve to relieve tight fit.	Gear shaft had kink in it causing broken teeth.
CM8	Reassembled gear.	Gear shaft had kink in it causing broken teeth.
CM9	Install new rubber seat, cast iron holding segments, butterfly, and shaft.	Jagged edge of sem cut rubber seat and broke section of cast iron holding segments.
CM10	Replace disc.	Disc came loose from shaft.
CM11	Rewind motor.	Motor burned out.
CM12	Replace rubber seal and cast iron segments.	Unknown.
CM13	Grease fittings installed in the stem bushings.	Unknown.
CM14	Set Limitorque on minimum torque and to operate immediately after limit switch.	Unknown.

Table A-6

Standard MOV Preventative Maintenance

Abbreviation	Description
PM1	Lubricate.
PM2	Inspect, clean, repack, and note any unusual conditions.
PM3	Check operation.
PM4	Change oil in motor gear box.

Table A-7

Standard Relay Corrective Maintenance

Abbreviation	Description
CM1	Replace.

Table A-8

Standard Relay Preventative Maintenance

Abbreviation	Description
PM1	Inspect and check operation.
PM2	Clean and check operation.

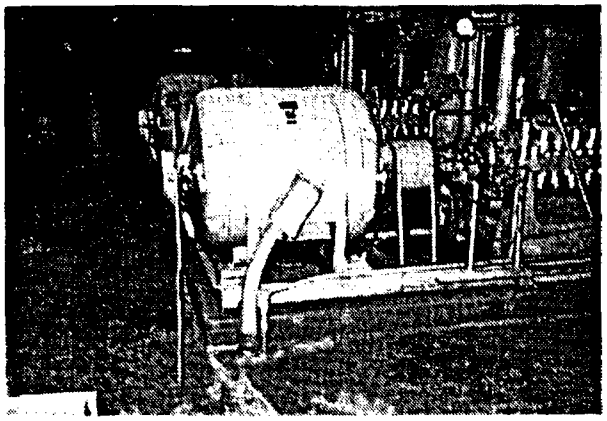
Table A-9

Standard MCC Preventative Maintenance

Abbreviation	Description
PMI	Clean and blow out cabinet. Tighten all bolts.

Table A-10

Maintenance Histories



BOILER FEED PUMP MOTOR #2-1

Allis Chalmers, 600 hp, 3650 rpm,
2300 V, 132 Amps, Serial # 1-5130-42170-1-2
Ground Floor

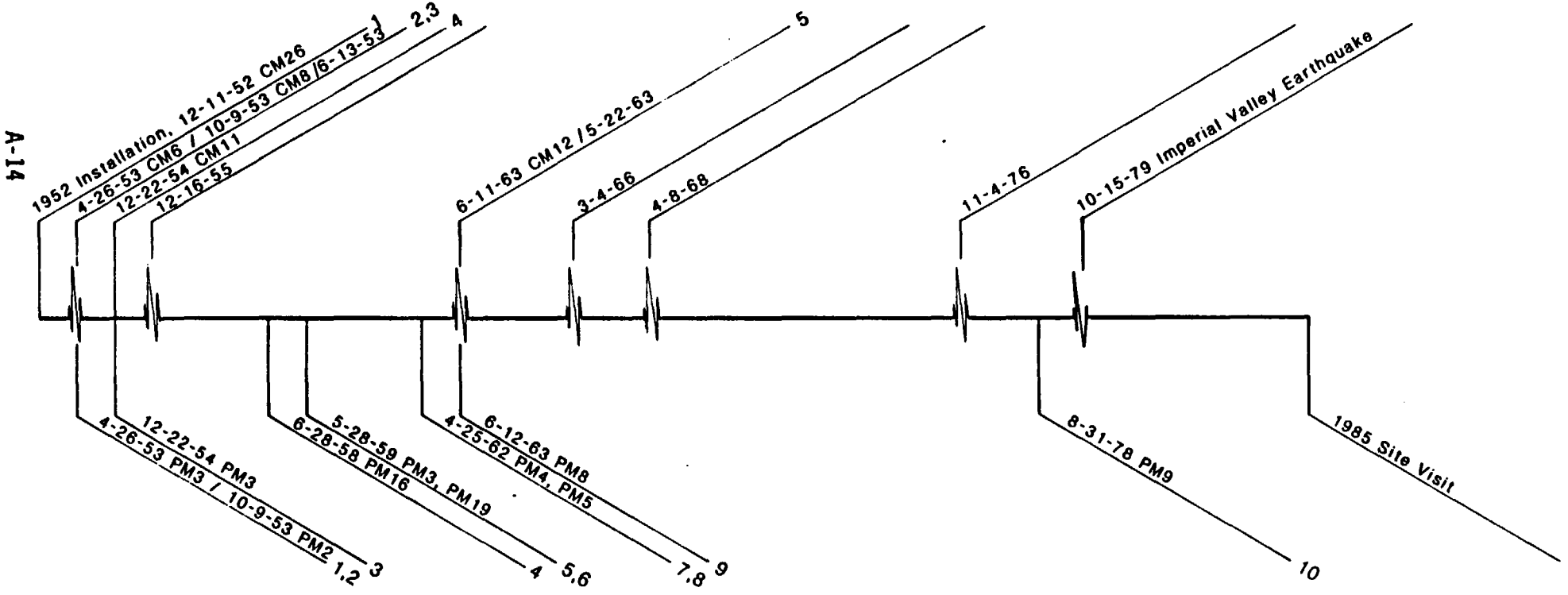
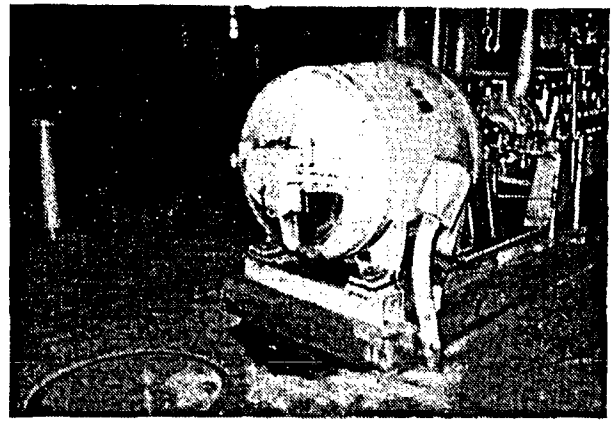


Figure A-1: Maintenance history for Boiler Feed Pump Motor #2-1 at El Centro Steam Plant.



BOILER FEED PUMP MOTOR #2-2

Allis Chalmers, 600 hp, 3650 rpm
2300 V, 132 Amps, Serial # 1-5130-42170-1-1
Ground Floor

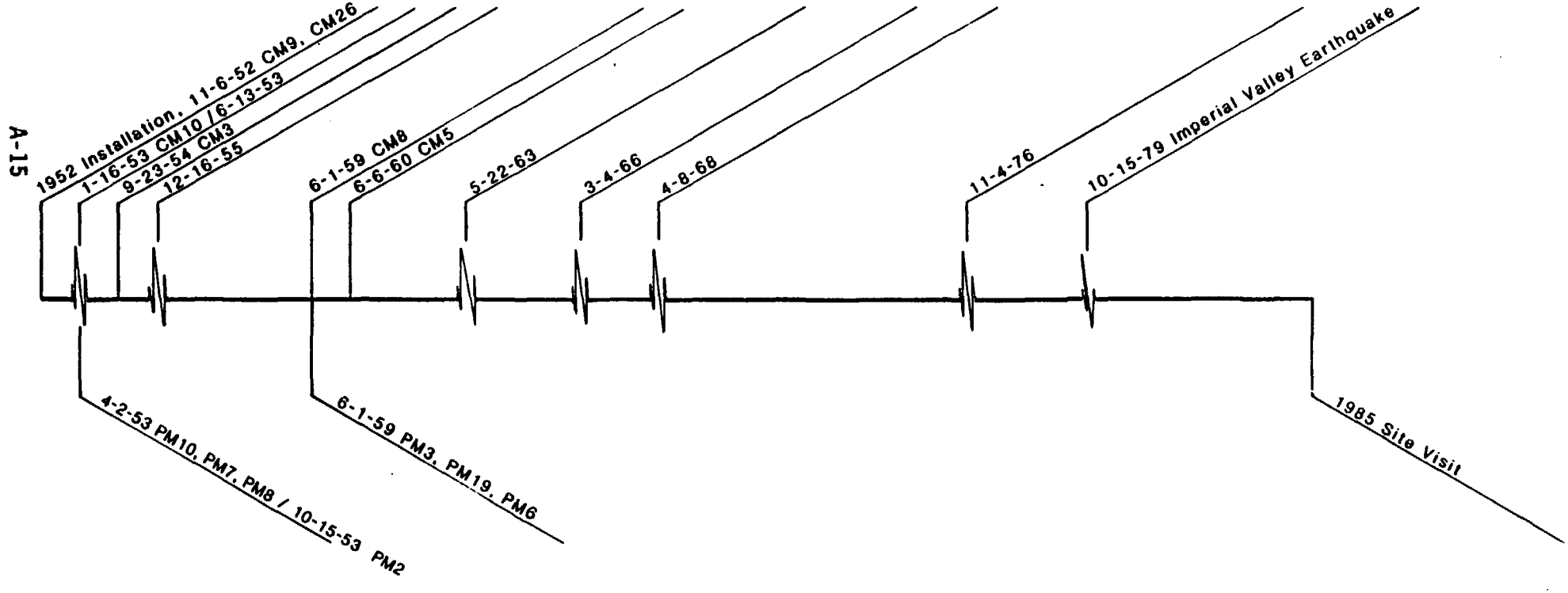
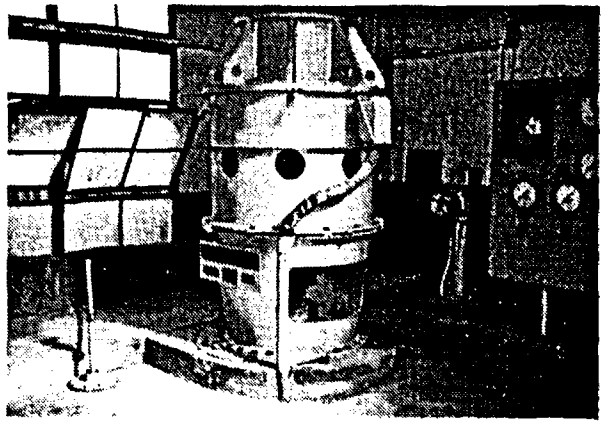


Figure A-2: Maintenance history for Boiler Feed Pump Motor #2-2 at El Centro Steam Plant.



CIRCULATING WATER PUMP MOTOR #2-1

Allis Chalmers, 300 hp, 584 rpm
2300 V, 73.5 Amps, Serial # 154130
Pumphouse - Ground Level

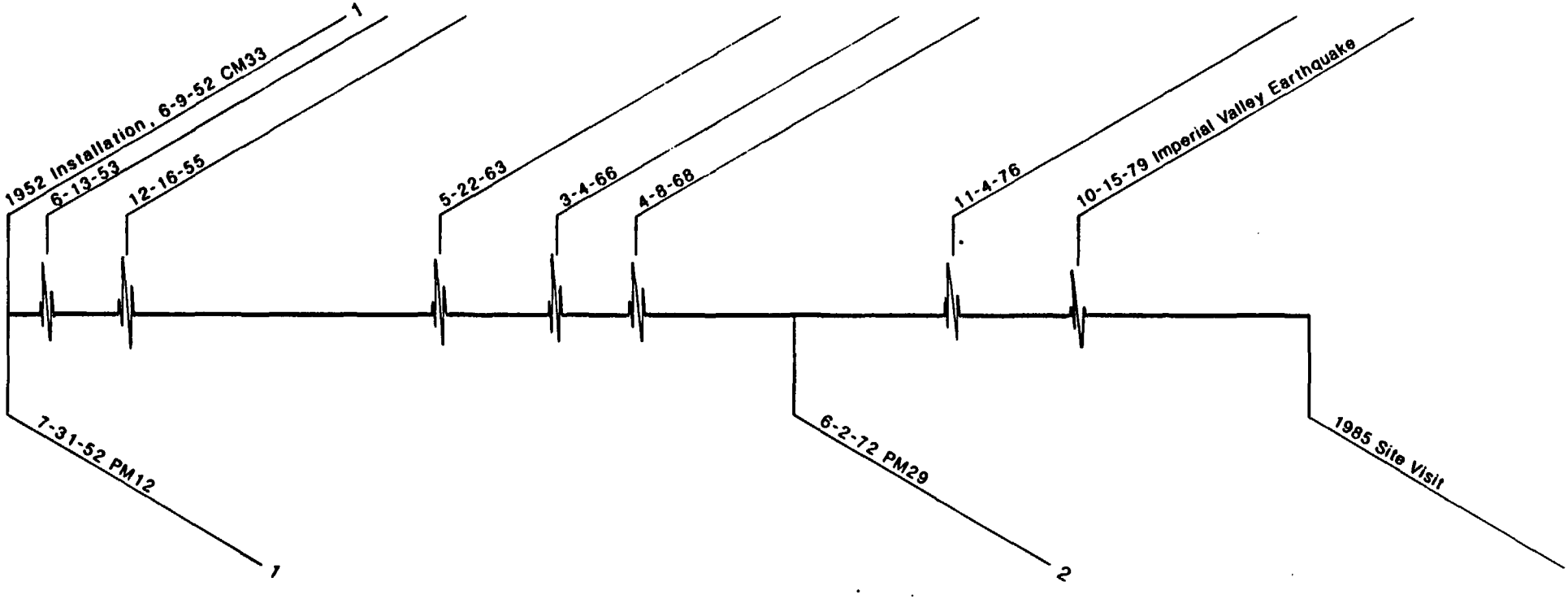
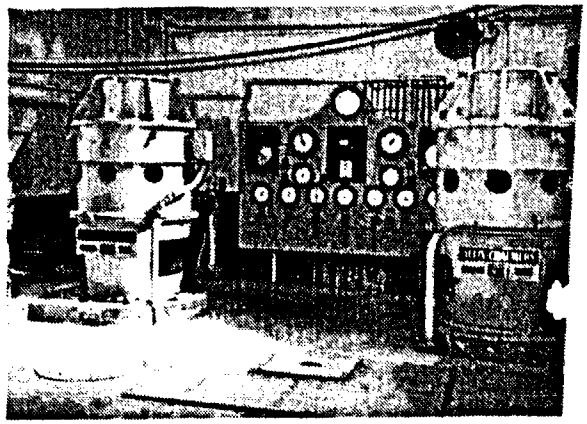


Figure A-3: Maintenance history for Boiler Circulating Water Pump Motor #2-1 at El Centro Steam Plant.



CIRCULATING WATER PUMP MOTOR #2-2

Allis Chalmers, 300 hp, 584 rpm
2300 V, 73.5 Amps, Serial # 154129
Pumphouse - Ground Level

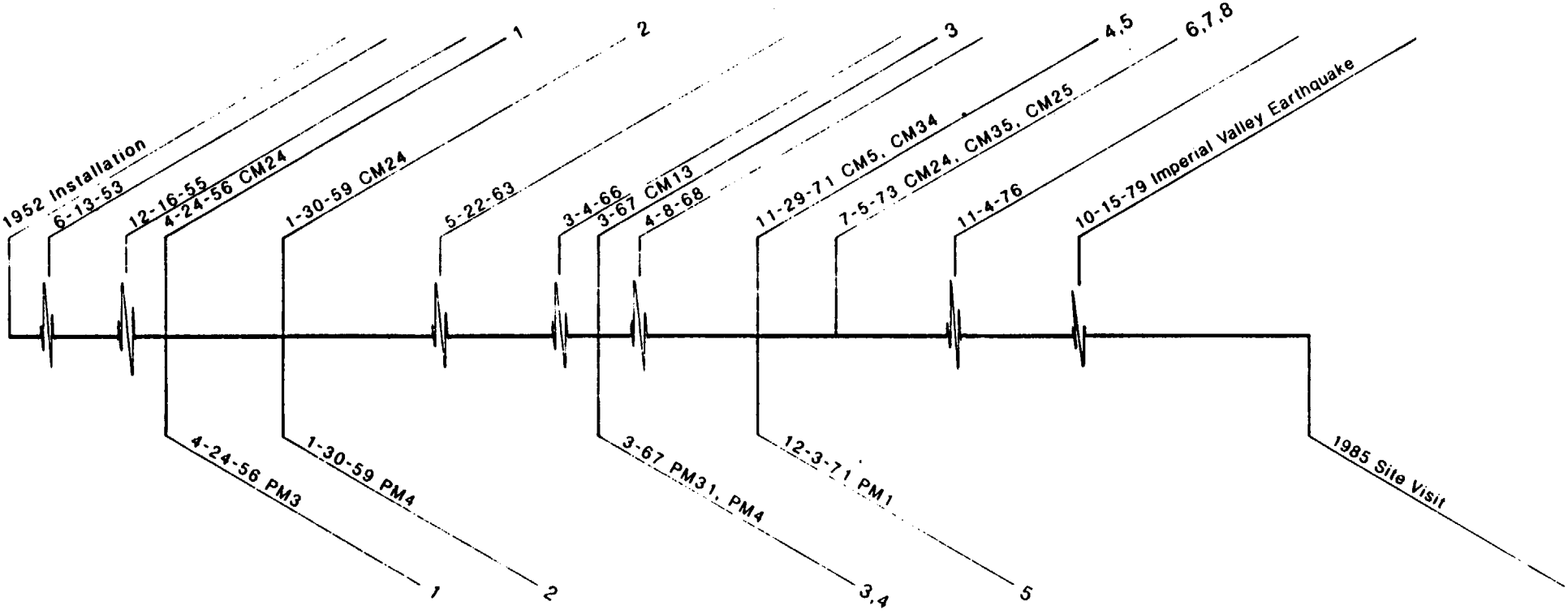


Figure A-4: Maintenance history for Boiler Circulating Water Pump Motor #2-2 at El Centro Steam Plant.

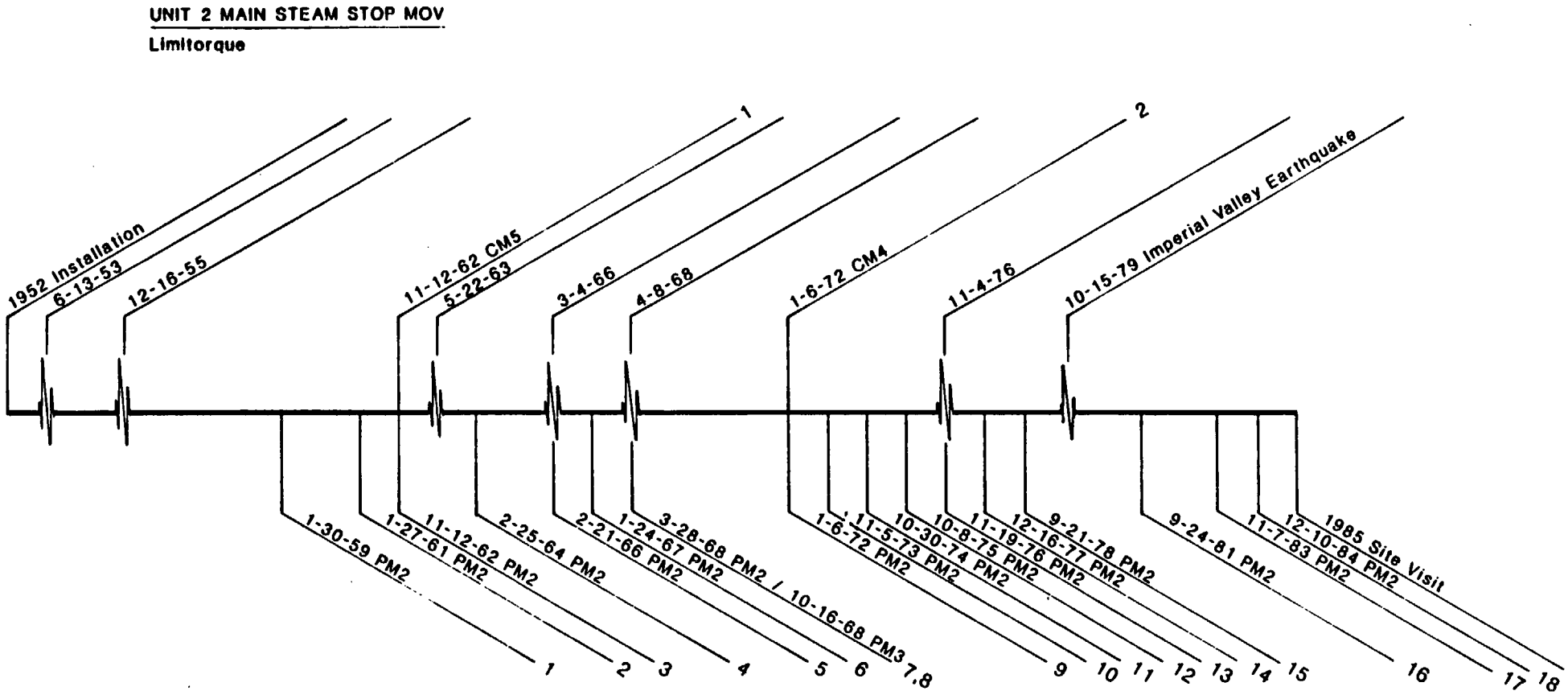


Figure A-5: Maintenance histoy for the Unit 2 Main Steam Stop MOV at El Centro Steam Plant.

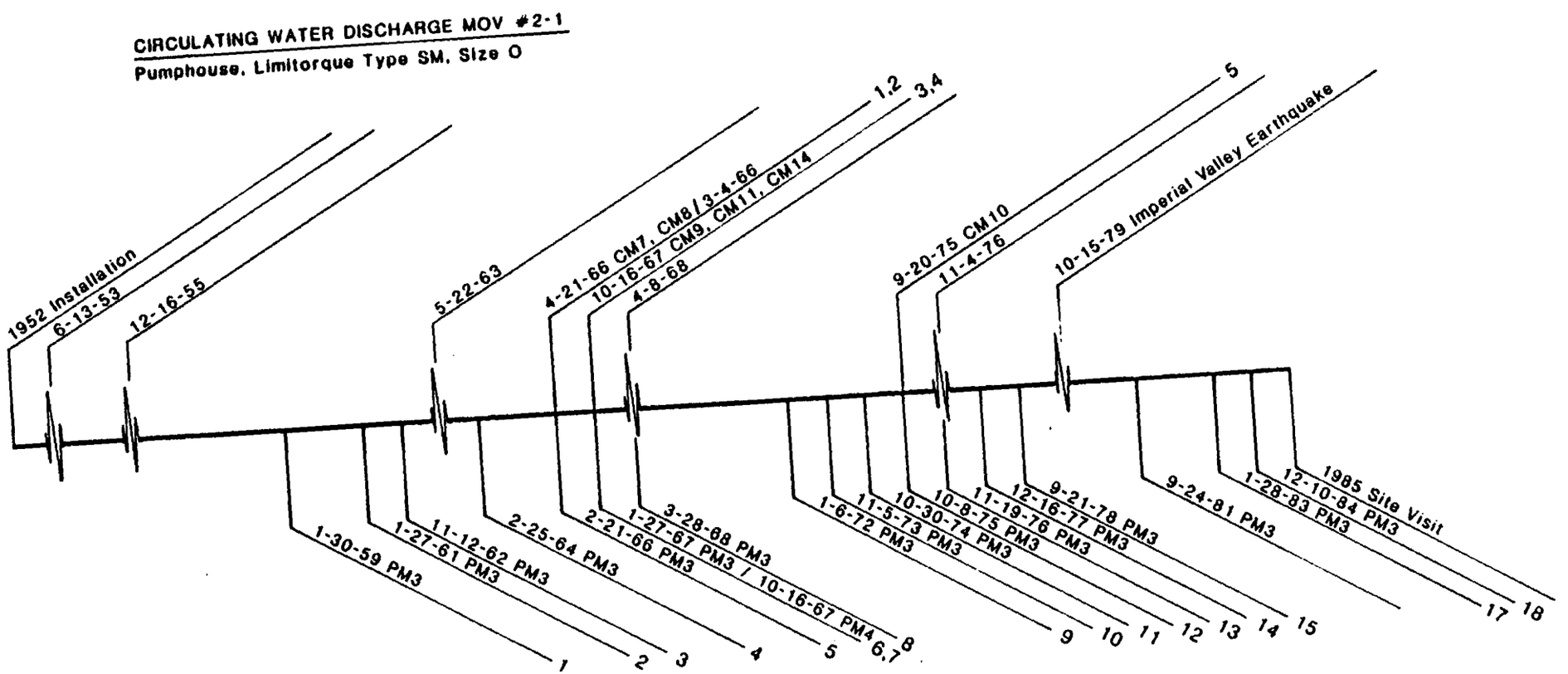
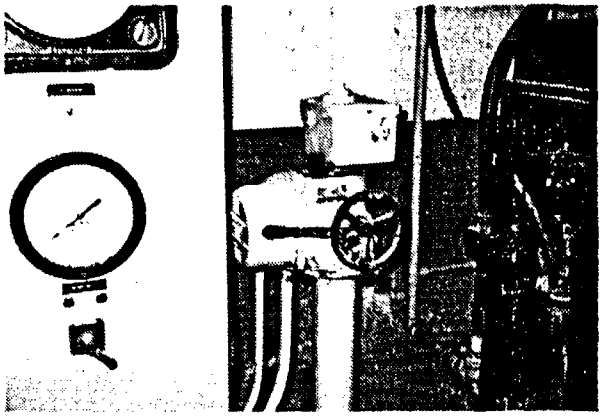


Figure A-6: Maintenance history for Circulating Water Discharge MOV #2-1 at El Centro Steam Plant.



CIRCULATING WATER DISCHARGE MOV #2-2

Pumphouse, Limitorque Type SM, Size O

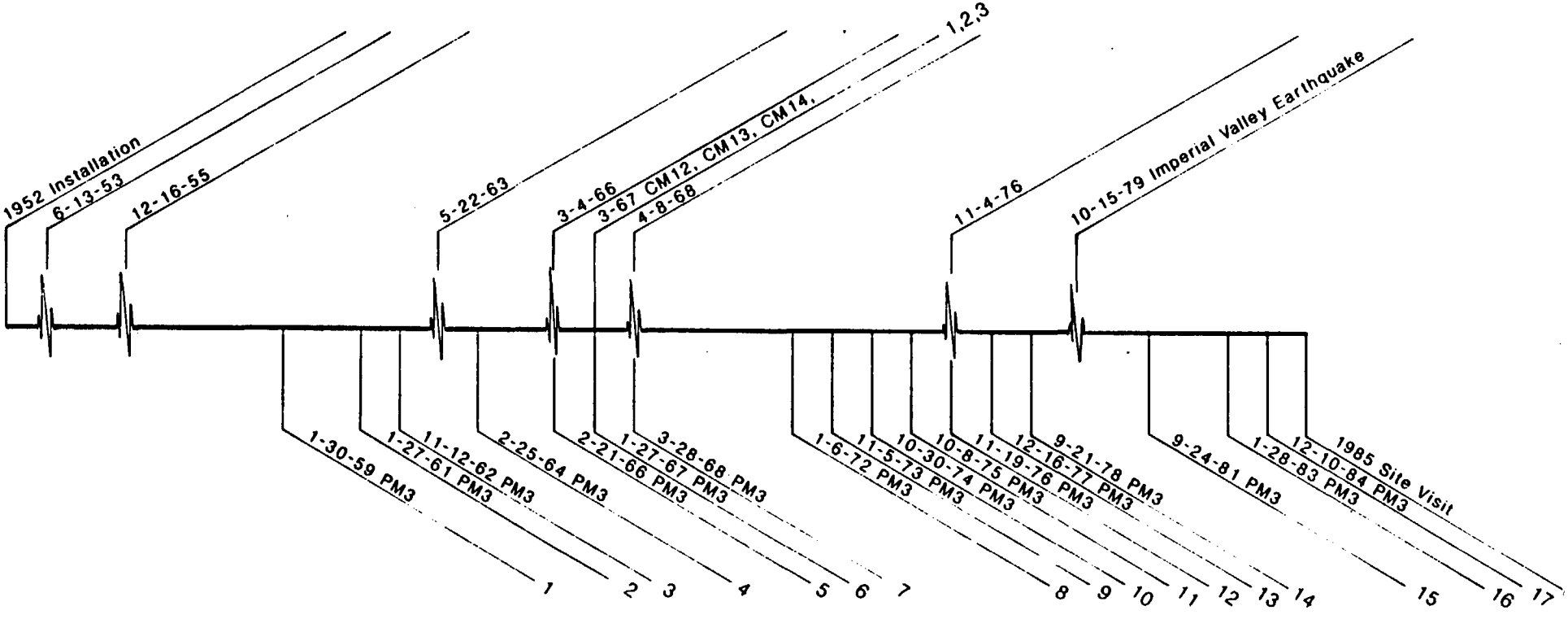
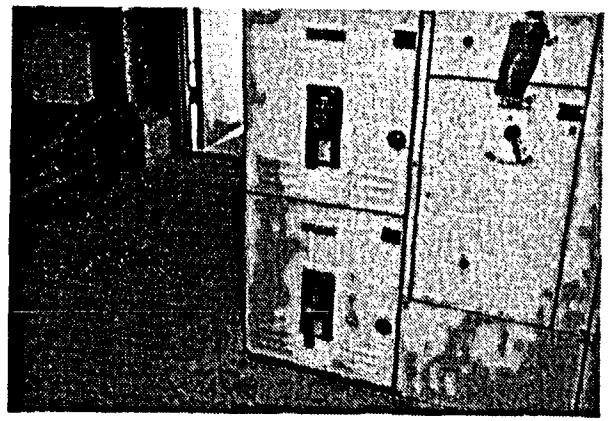


Figure A-7 Maintenance History for Circulating Water Discharge MOV #2-2 at El Centro Steam Plant.



#2-13 CIRCUIT BREAKER IN PUMPHOUSE

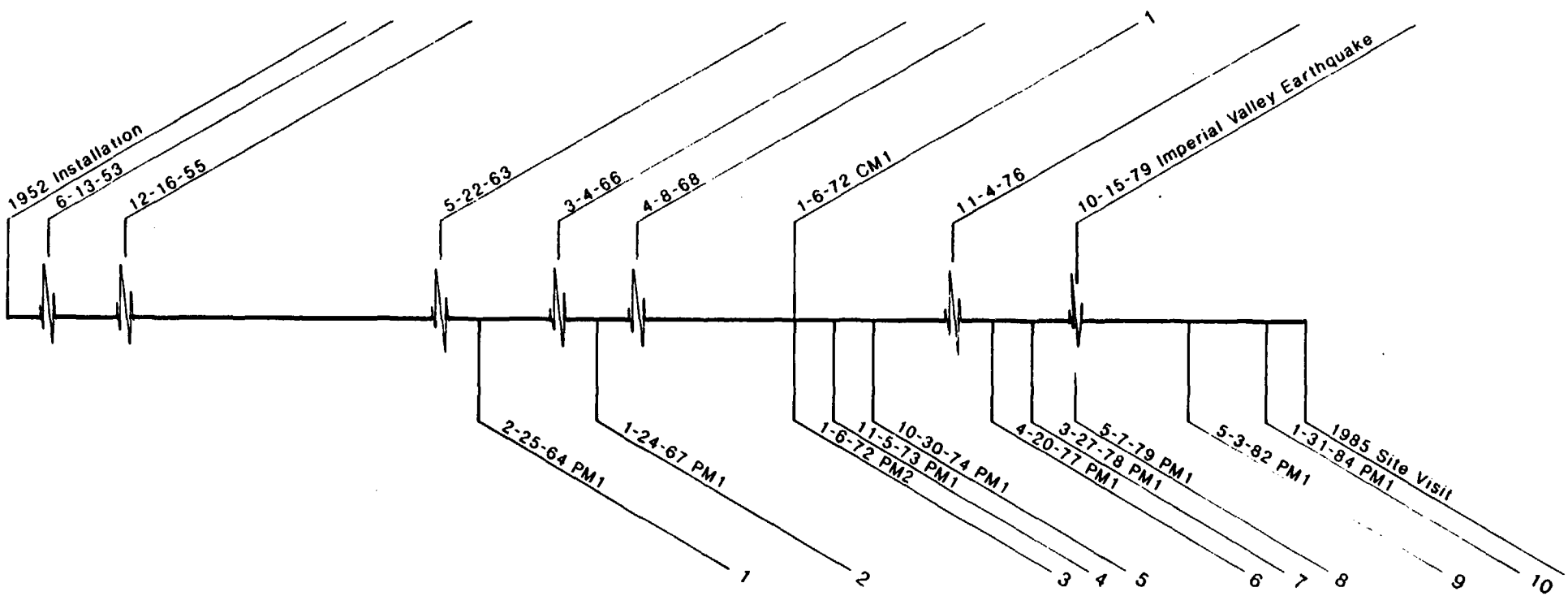
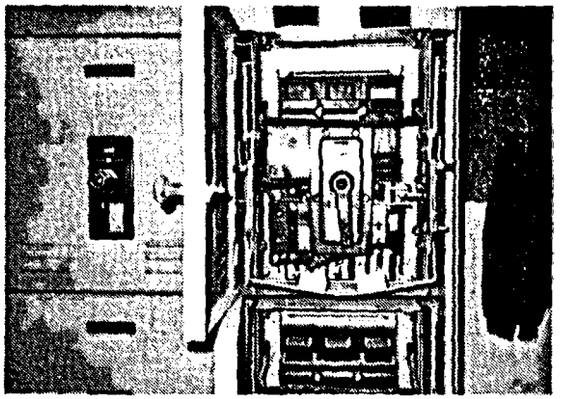


Figure A-8: Maintenance History for the #2-13 Circuit Breaker in the Pumphouse at El Centro Steam Plant.



480-V CONDENSATE PUMP 2-1 CIRCUIT BREAKER

Airbreaker, GE Switchgear, Type AK-1-25
#L-6418825-27,600 V, 60 cycles, 3 poles, 2500 Amps
Typical circuit breaker for Unit 2

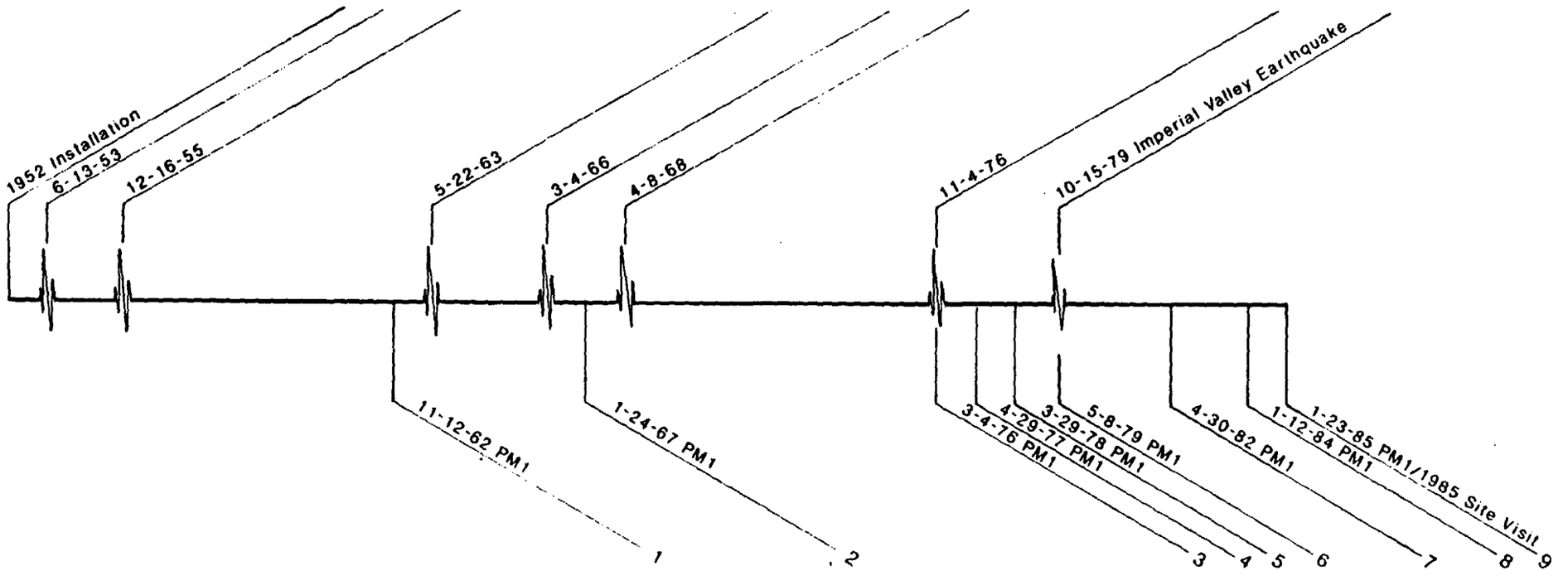


Figure A-9: Maintenance History for the Condensate Pump #2-1 Circuit Breaker at El Centro Steam Plant.

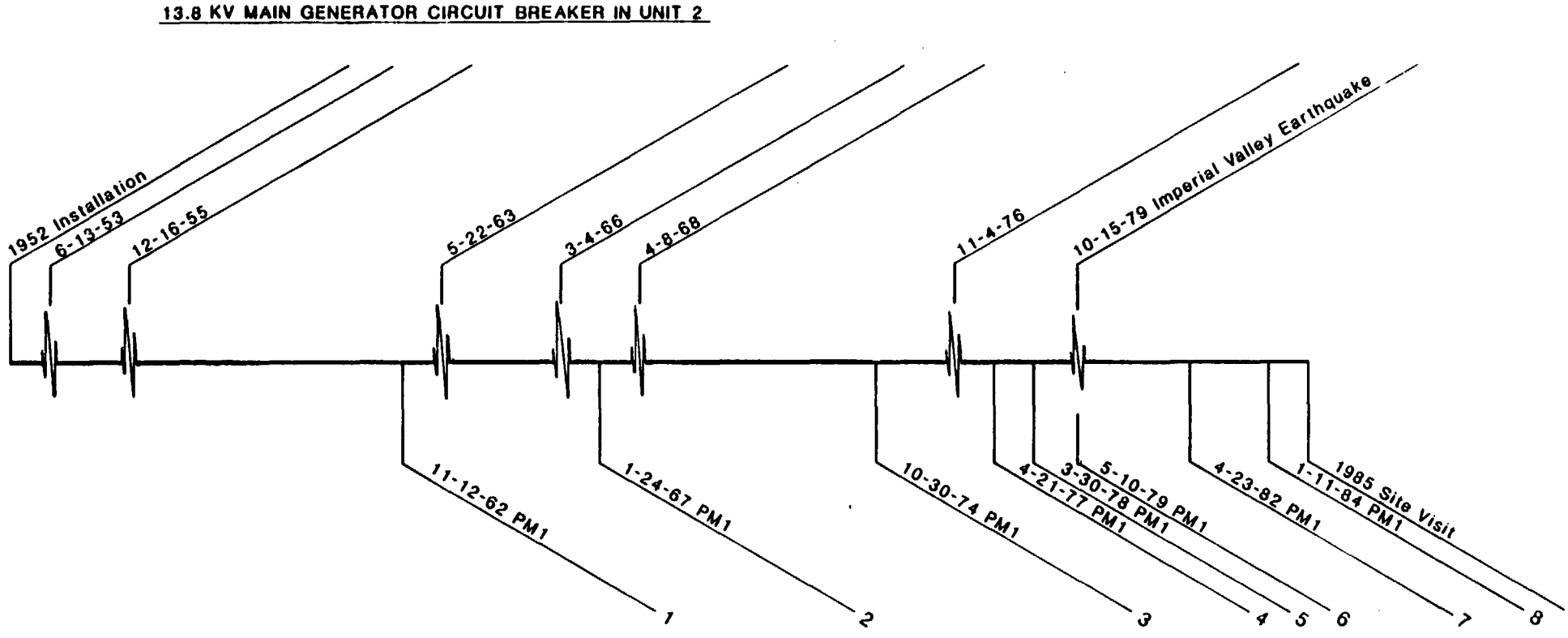
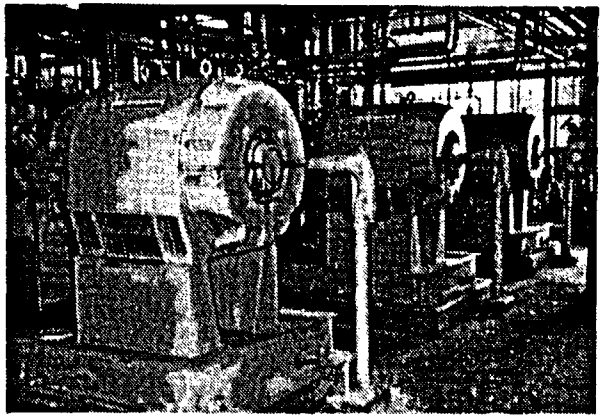


Figure A-10: Maintenance History for the Unit 2 13.8 kV Main Generator Circuit Breaker at El Centro Steam Plant.



BOILER FEED PUMP MOTOR #4-1

Allis Chalmers, 800 hp, 3560 rpm
2300 V, 172 Amps, Serial #1-5115-14468-1-1
Ground Floor

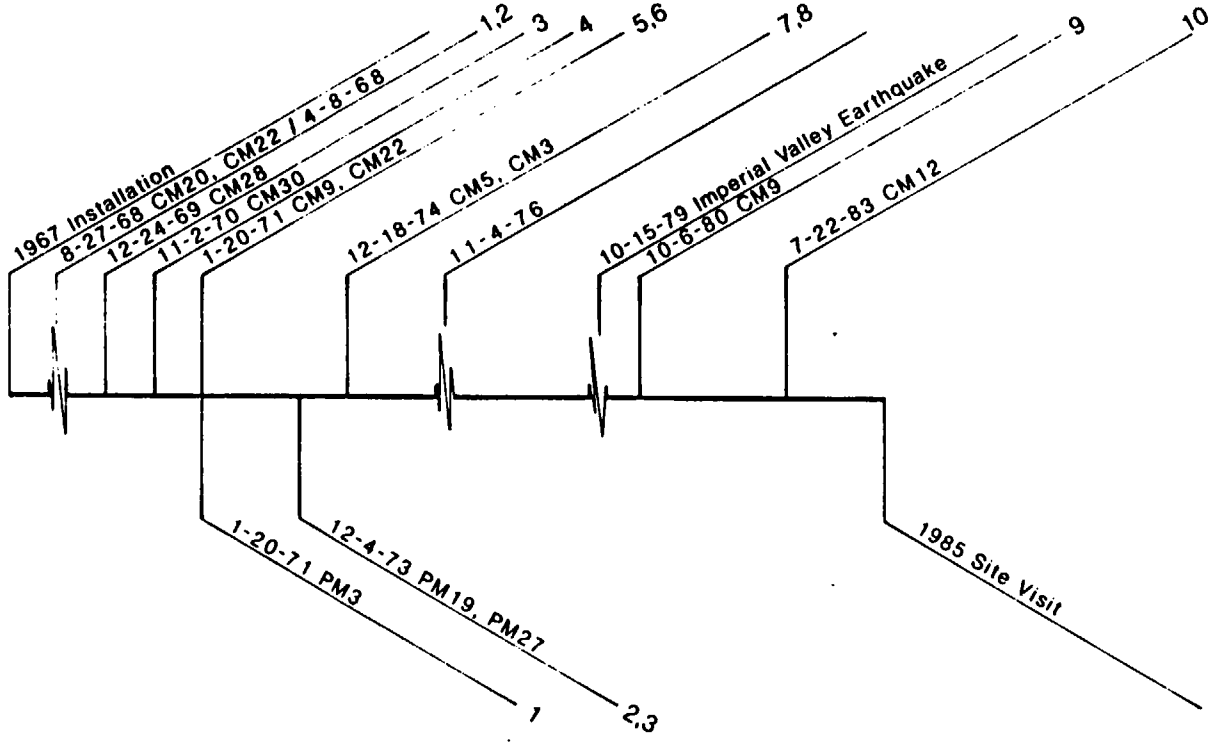


Figure A-11: Maintenance History for Boiler Feed Pump Motor #4-1 at El Centro Steam Plant.

BOILER FEED PUMP MOTOR #4-2

Allis Chalmers, 800 hp, 3560 rpm
2300 V, 172 Amps, Serial # 1-5115-14468-1-2
Ground Floor

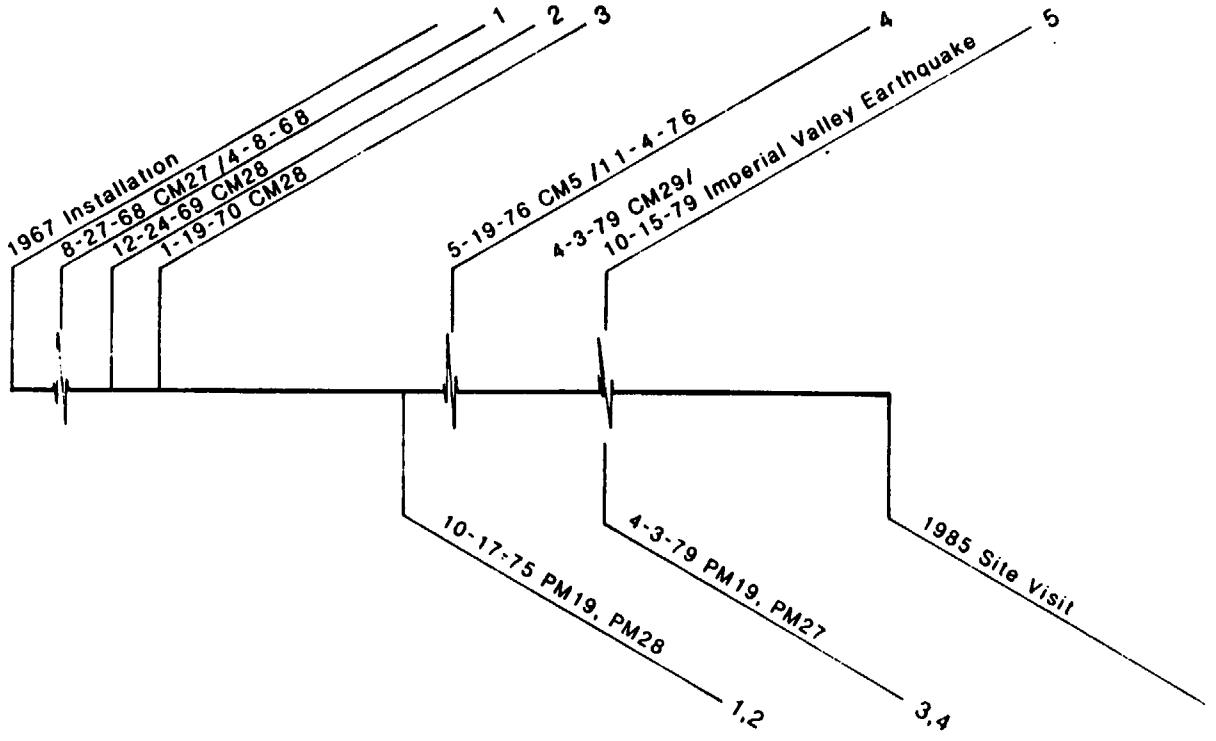
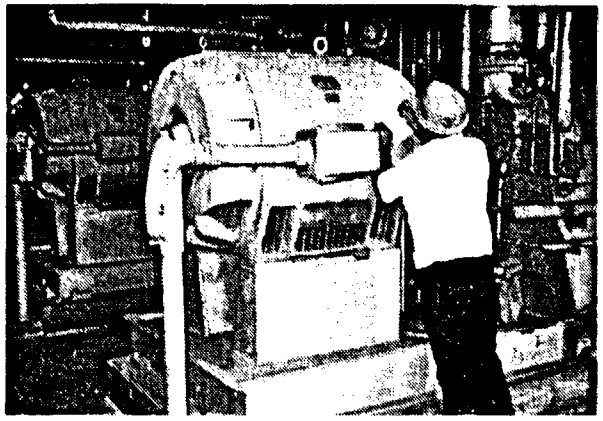


Figure A-12: Maintenance History for Boiler Feed Pump Motor #4-2 at El Centro Steam Plant.



BOILER FEED PUMP MOTOR #4-3

Allis Chalmers, 800 hp, 3560 rpm
2300 V, 172 Amps, Serial # 1-5115-14468-1-3
Ground Floor

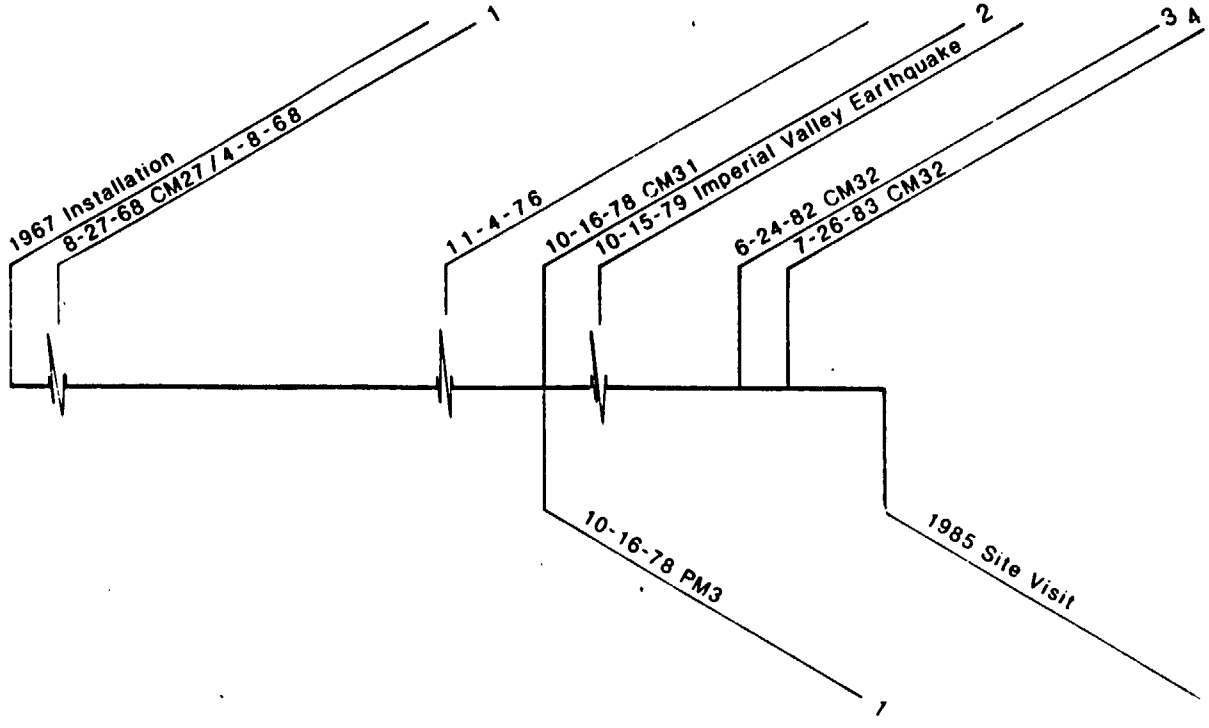


Figure A-13: Maintenance History for Boiler Feed Pump Motor #4-3 at El Centro Steam Plant.

Photo Not Available

CIRCULATING WATER PUMP MOTOR #4-1

Allis Chalmers, 450 hp, 709 rpm
2300 V, 112 Amps
Near Cooling Towers in Plant Yard

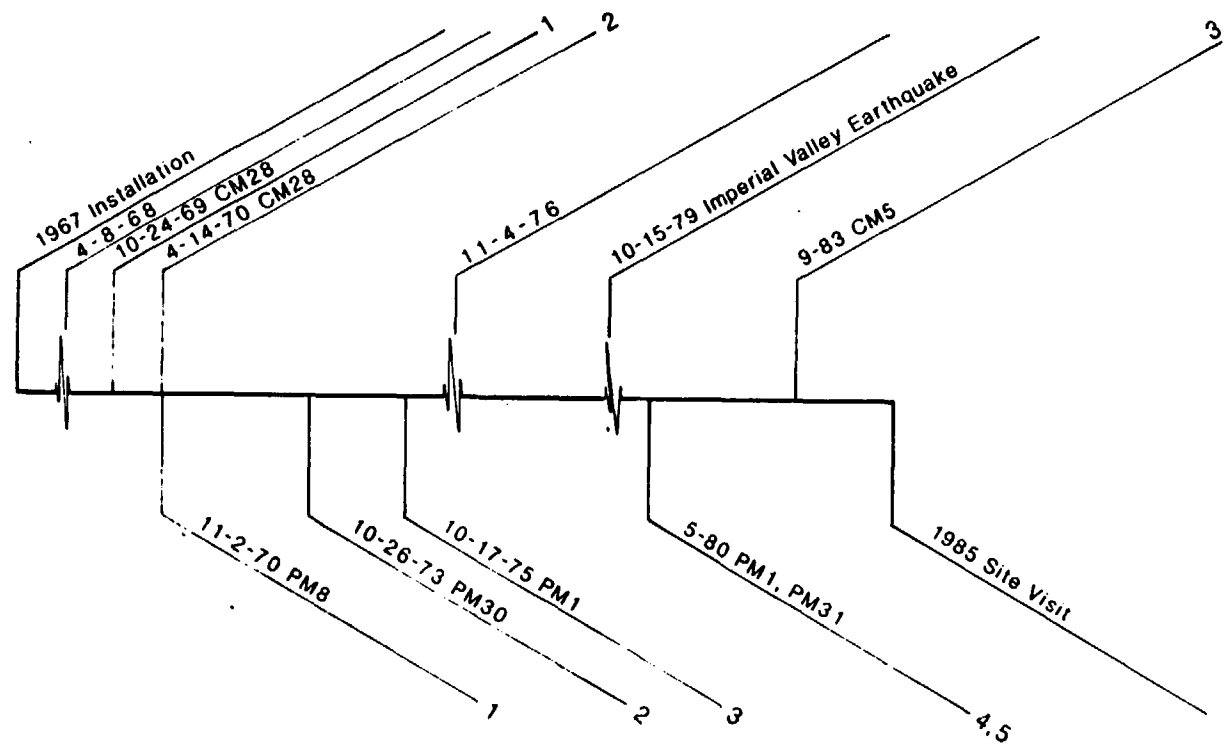
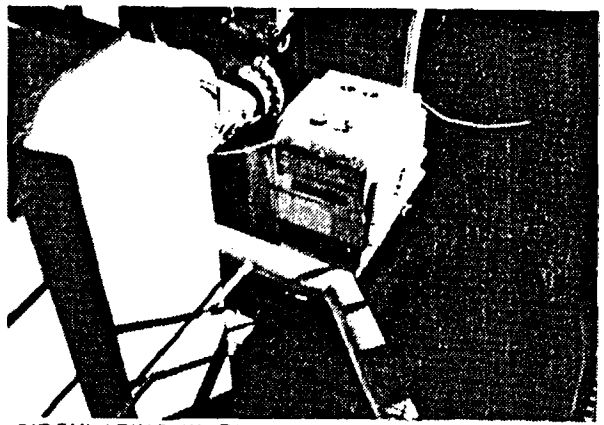


Figure A-14: Maintenance History for Circulating Water Pump Motor #4-1 at El Centro Steam Plant.



CIRCULATING WATER PUMP MOTOR #4-2

Allis Chalmers, 450 hp, 709 rpm
2300 V, 112 Amps, Serial # 38193-1
Near Cooling Tower in Plant Yard

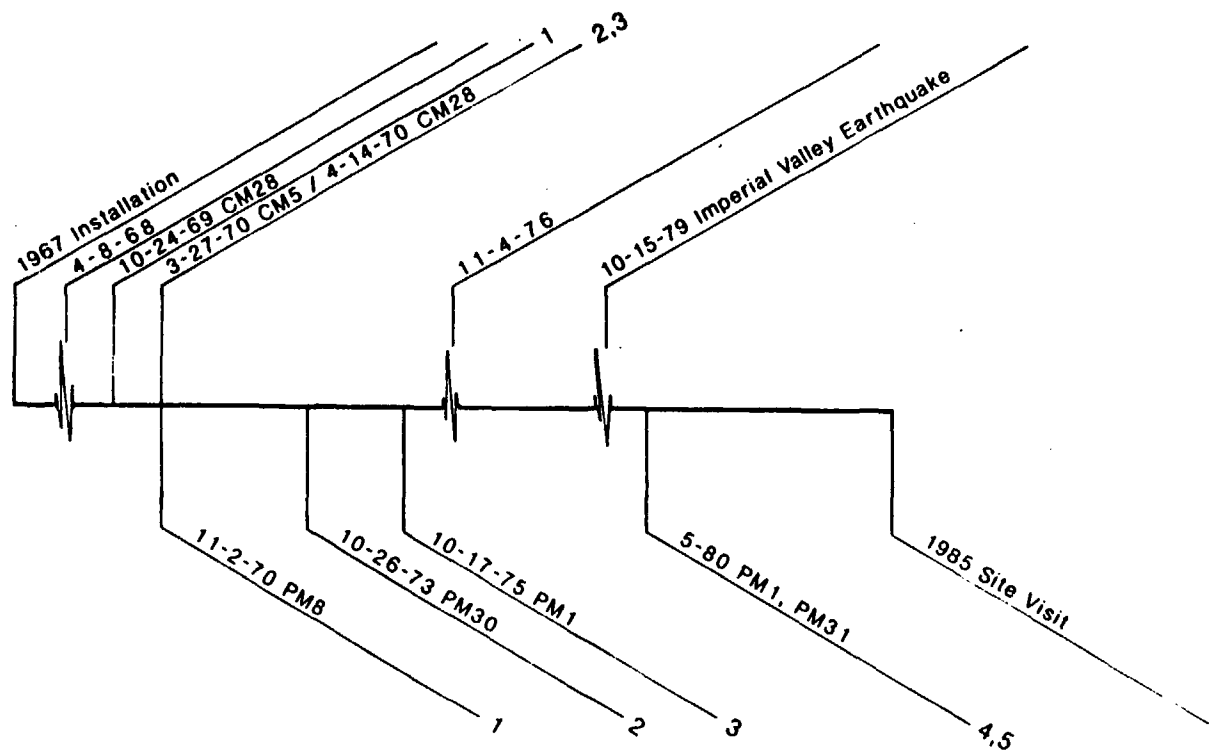
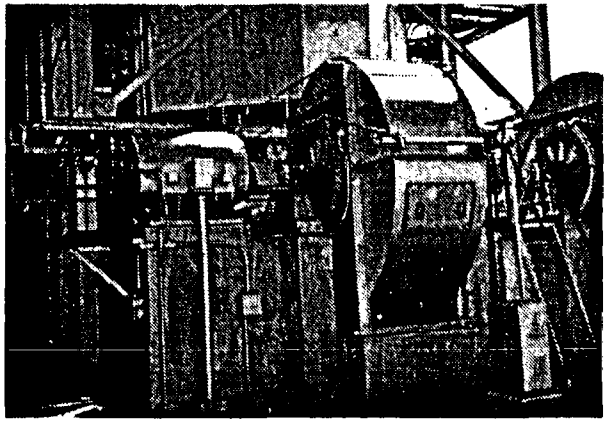


Figure A-15: Maintenance History for Circulating Water Pump Motor #4-2 at El Centro Steam Plant.



FORCED DRAFT FAN MOTOR #4-1

Allis Chalmers, 600 hp, 1180 rmp
230 V,136 Amps, Serial #1-5115-14608-1-1
Plant Yard

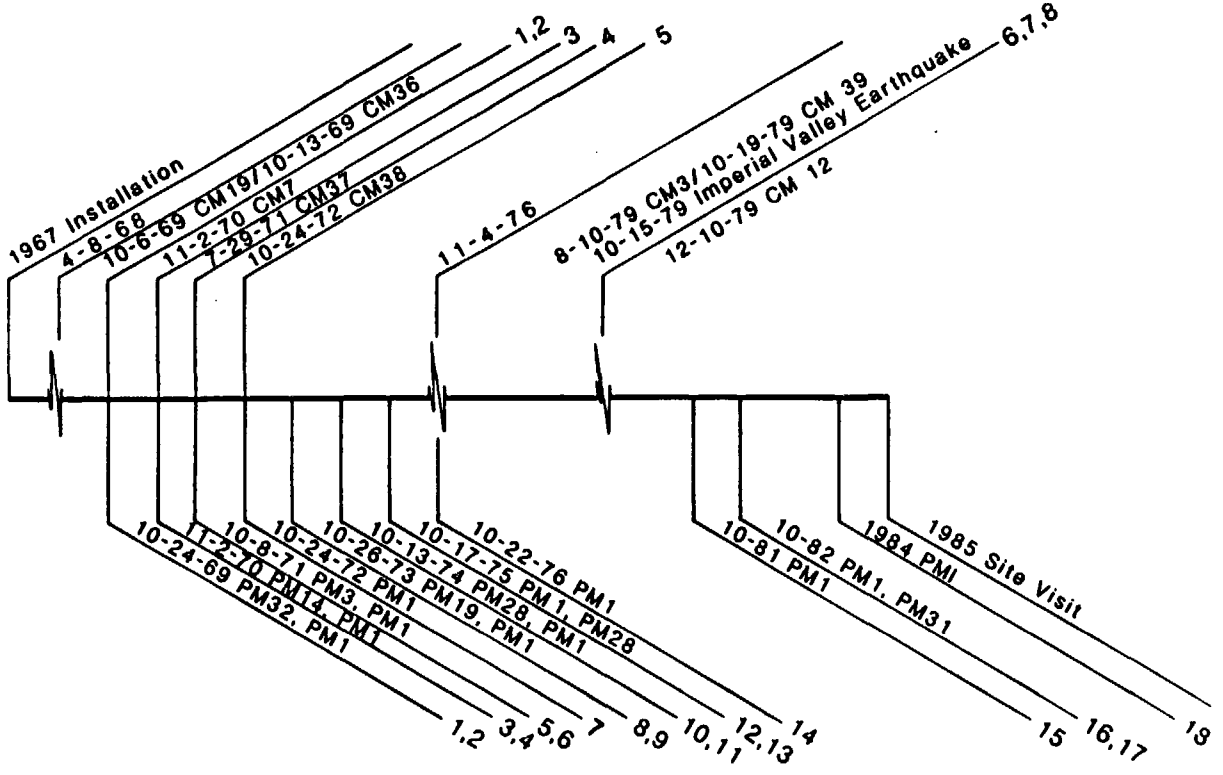
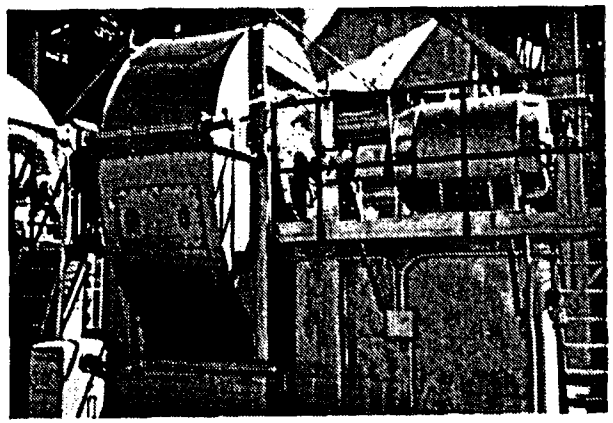


Figure A-16: Maintenance History for Forced Draft Fan Motor #4-1 at El Centro Steam Plant.



FORCED DRAFT FAN MOTOR #4-2

Allis Chalmers, 600 hp, 1180 rpm
2300 V, 136 Amps, Serial #1-5115-14608-1-2
Plant Yard

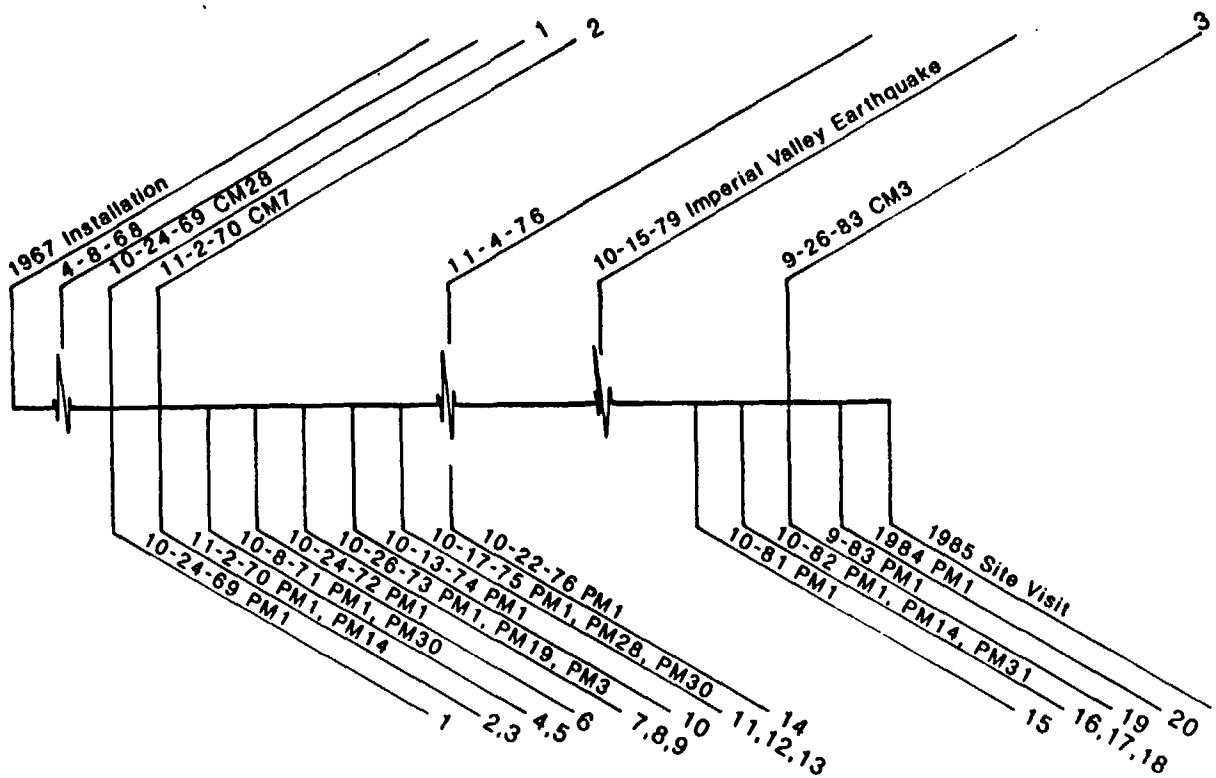


Figure A-17: Maintenance History for Forced Draft Fan Motor #4-2 at El Centro Steam Plant.

Photo Not Available

SERVICE WATER PUMP MOTOR #4-1

GE, 50 hp, 1765 rpm
460 V
Near Cooling Tower in Plant Yard

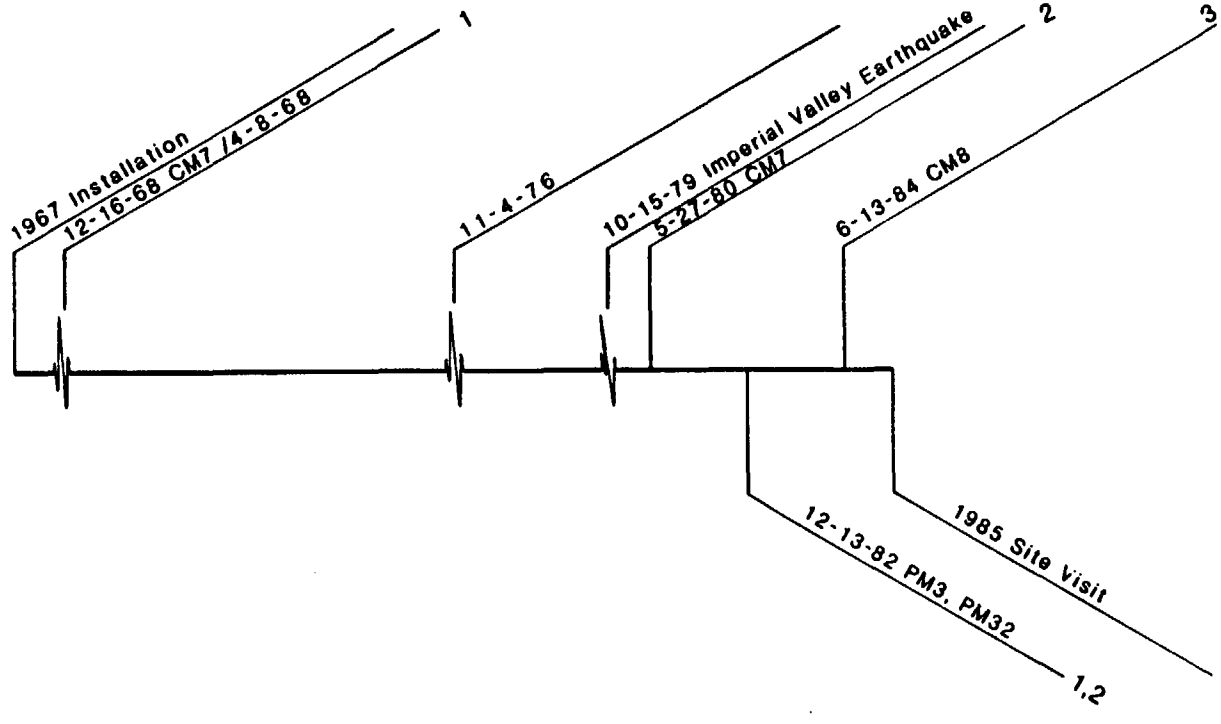
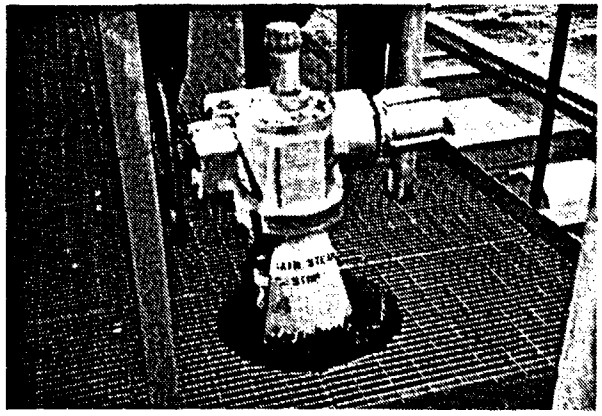


Figure A-18: Maintenance History for Service Water Pump Motor #4-1 at El Centro Steam Plant.



UNIT 4 MAIN STEAM STOP MOV
Limitorque

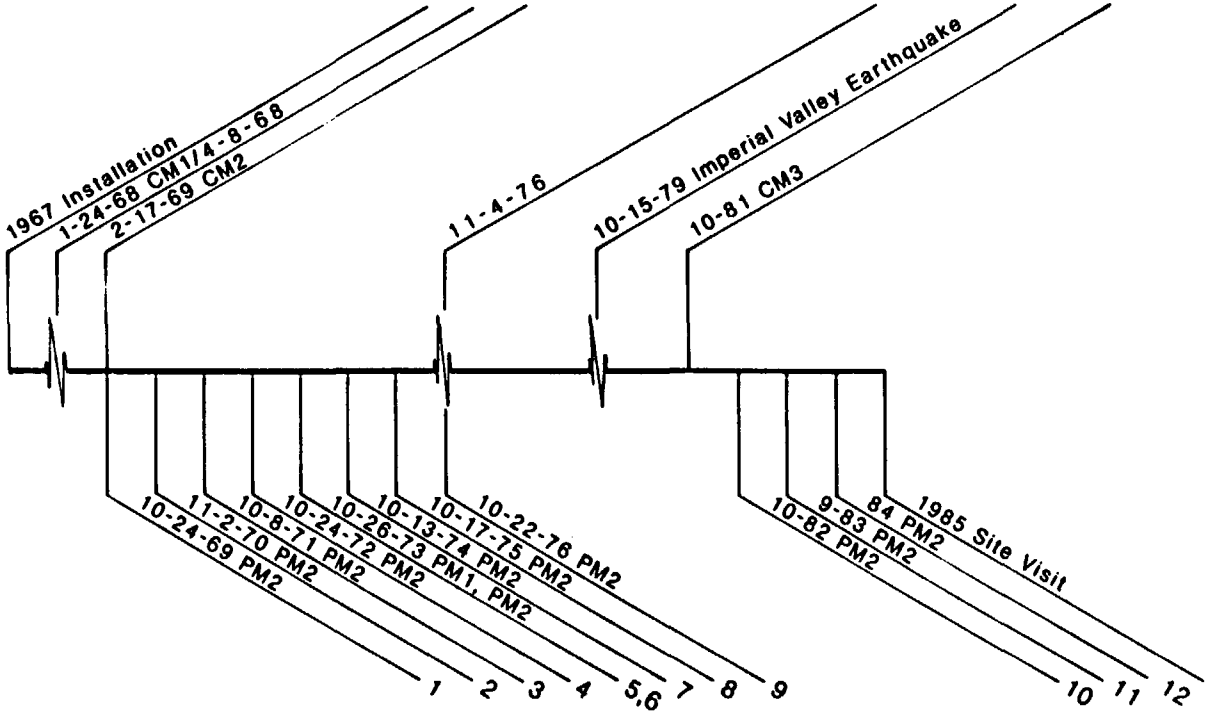


Figure A-19: Maintenance History for the Unit 4 Main Steam Stop MOV at El Centro Steam Plant.

Photo Not Available

CIRCULATING WATER DISCHARGE MOV #4-1

Limitorque

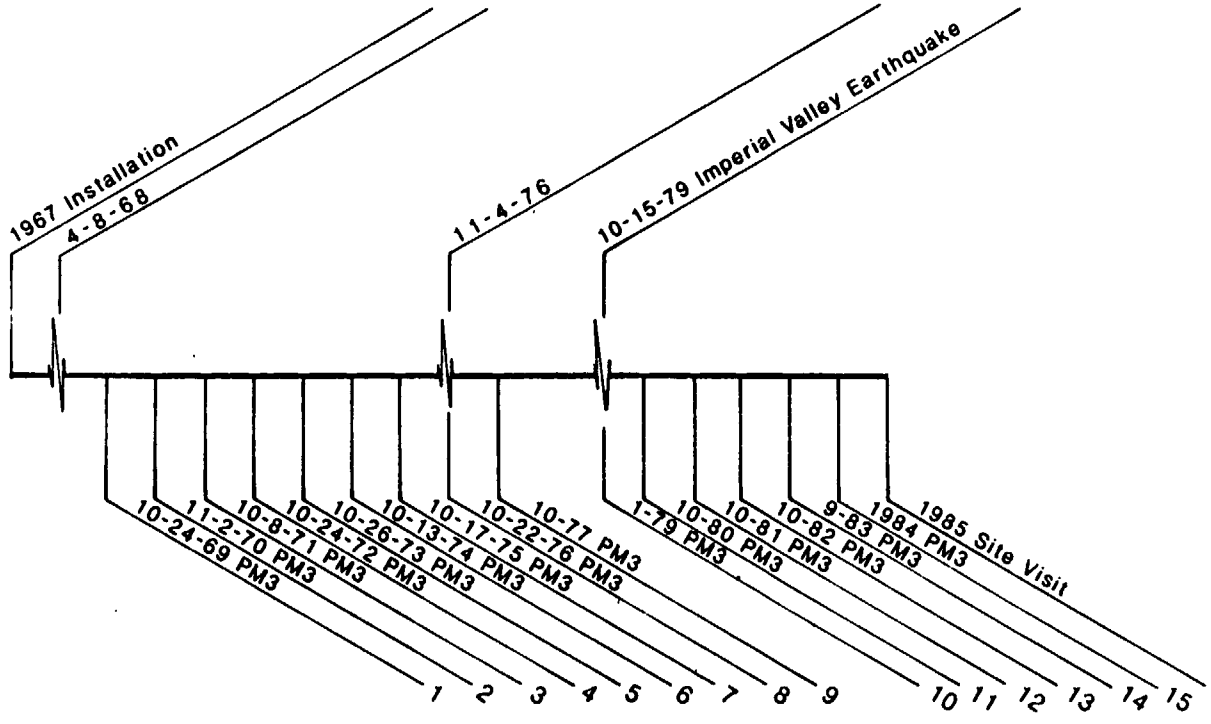
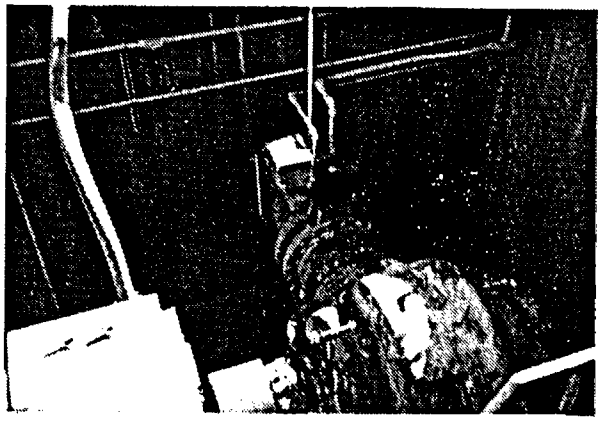


Figure A-20: Maintenance History for Circulating Water Discharge MOV #4-1 at El Centro Steam Plant.



CIRCULATING WATER DISCHARGE MOV #4-2

Limitorque

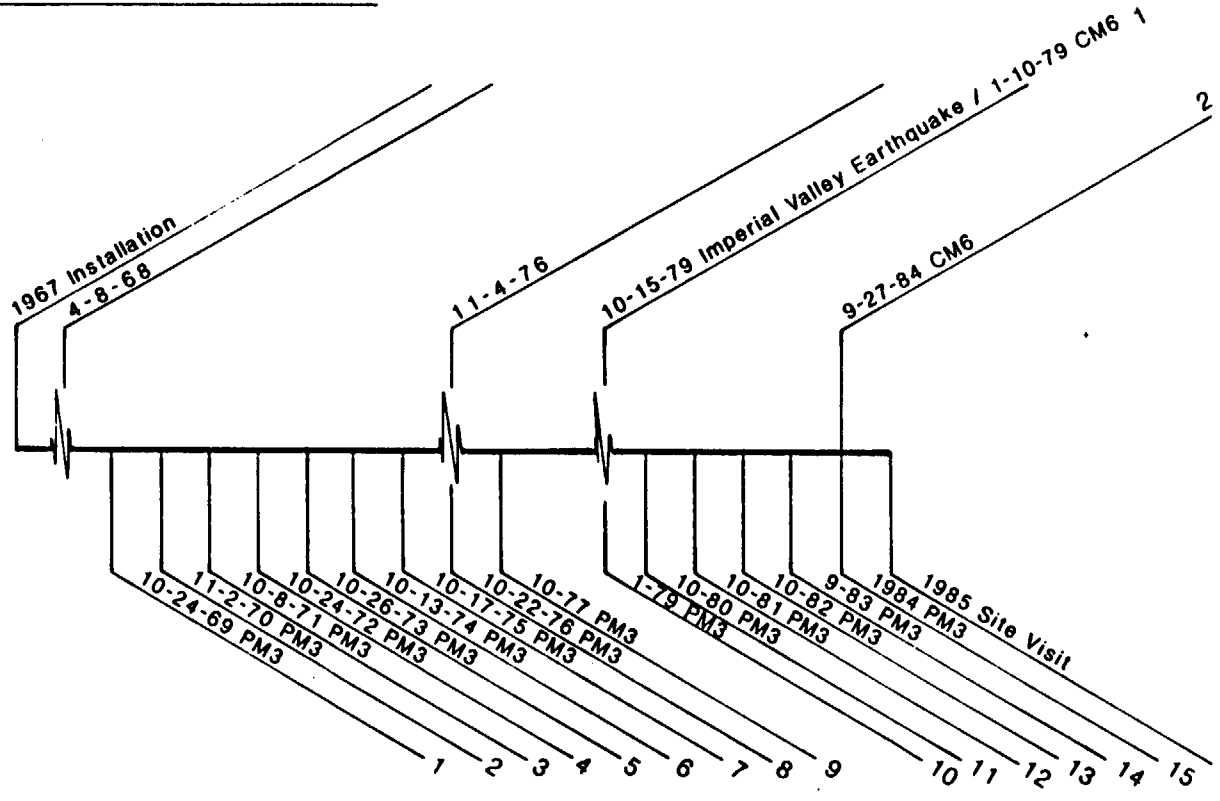


Figure A-21: Maintenance History for Circulating Water Discharge MOV #4-2 at El Centro Steam Plant.

Photo Not Available

2400 V BOILER FEED PUMP #4-1 CIRCUIT BREAKER

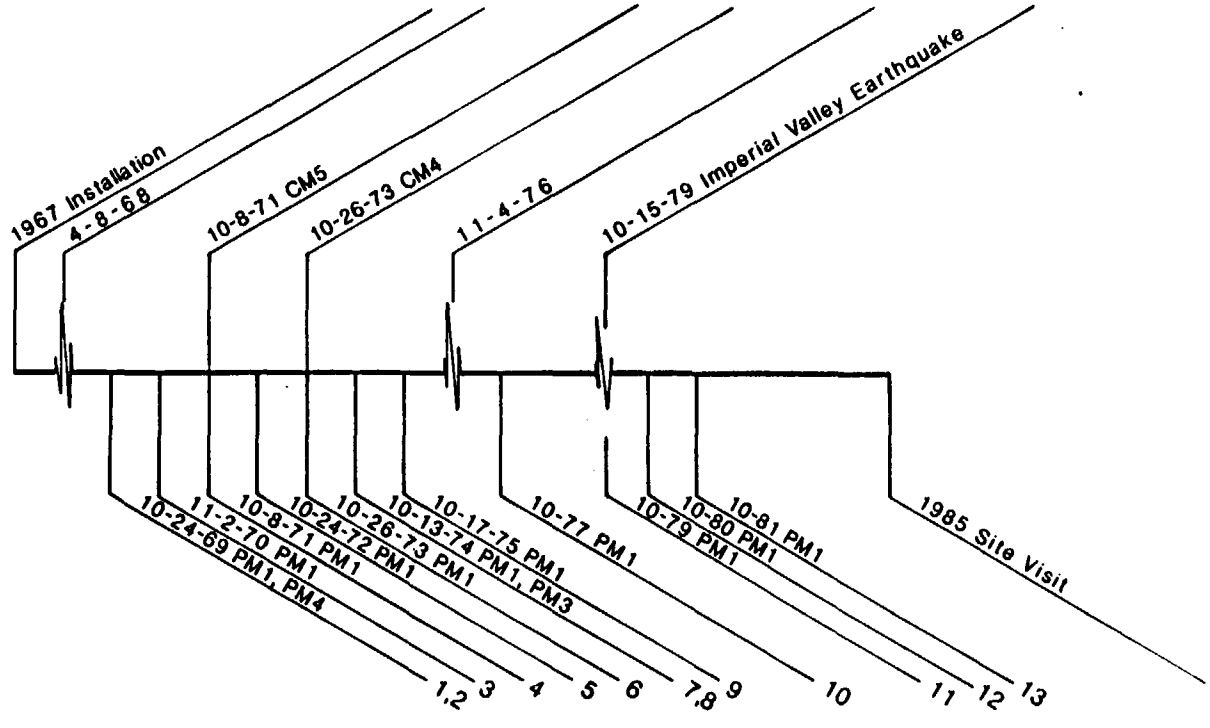


Figure A-22: Maintenance History for Boiler Feed Pump #4-1 Circuit Breaker at El Centro Steam Plant.

Photo Not Available

SERVICE WATER RETURN PUMP #4-2 CIRCUIT BREAKER

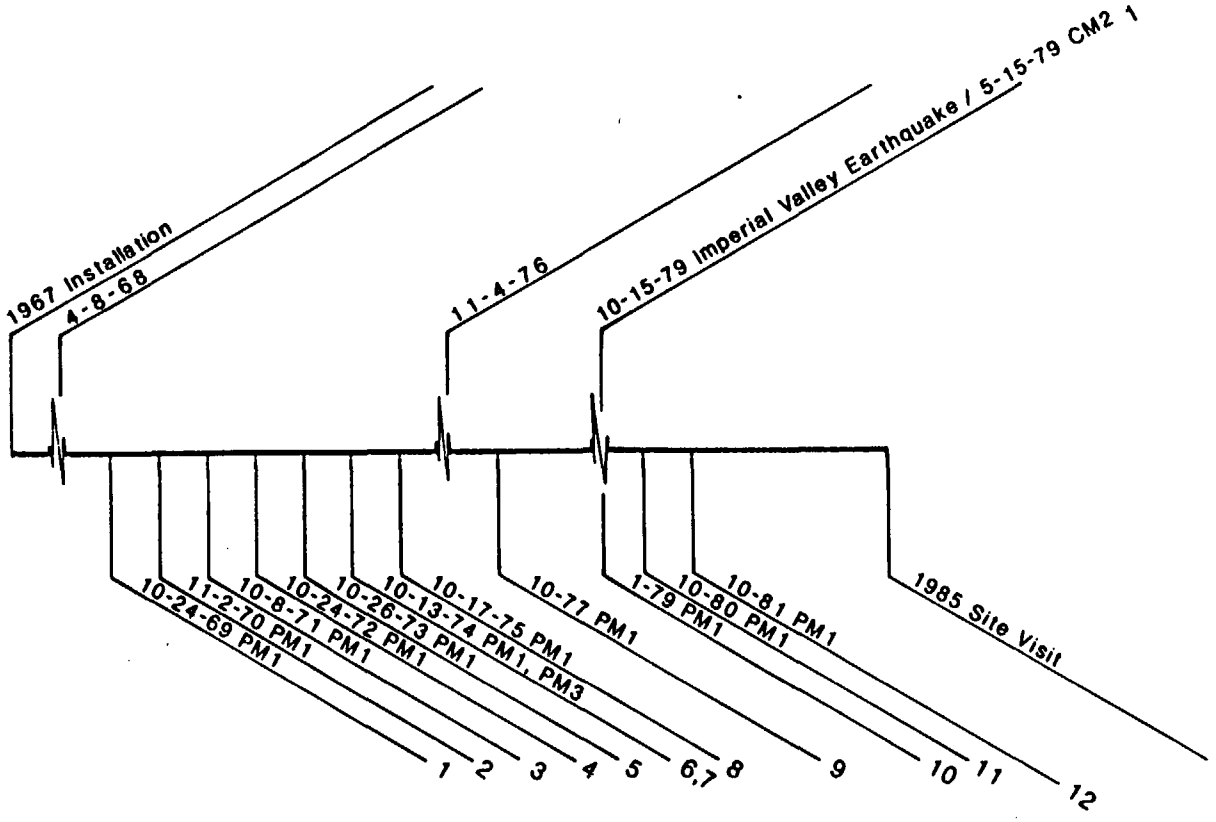
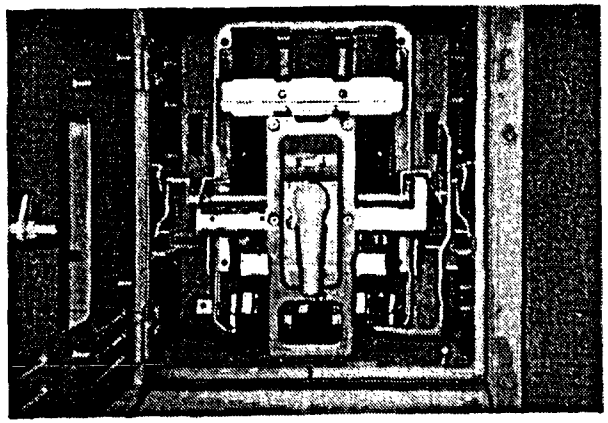


Figure A-23: Maintenance History for Service Water Return Pump #4-2 Circuit Breaker at El Centro Steam Plant.



FUEL OIL TRANSFER PUMP #4-1 CIRCUIT BREAKER

GE, #204A5589-304AD, Type AK-2-15-2
600 V, 60 cycles

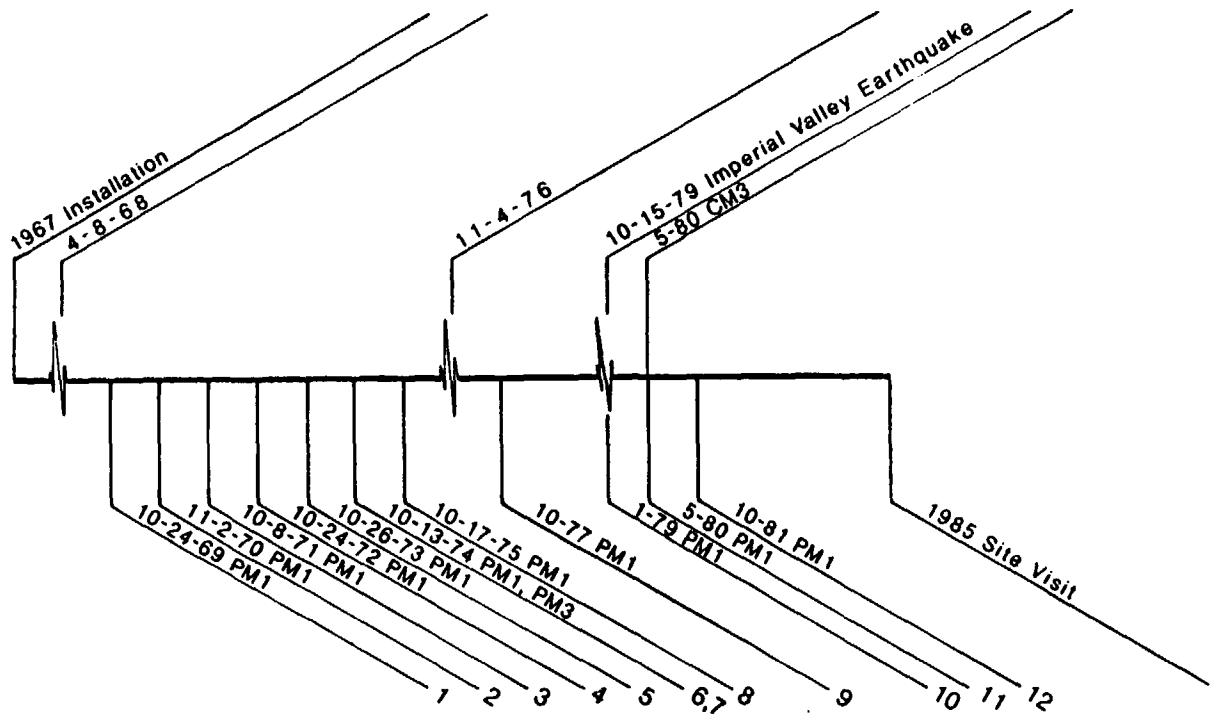
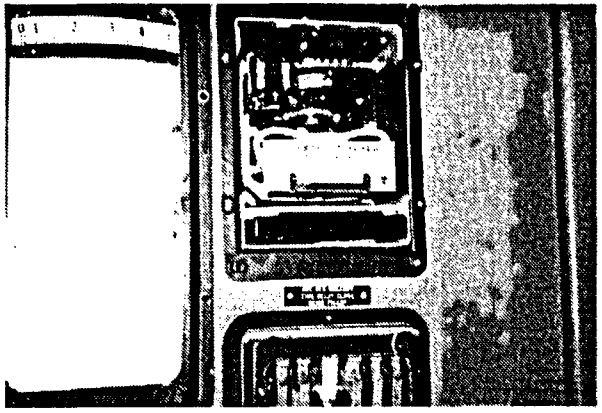


Figure A-24: Maintenance History for Fuel Oil Transfer Pump #4-1 at El Centro Steam Plant.



AUX. GEN. BREAKER QUICK PICKUP RELAY
Unit 4 GE Voltage Relay Model #121AV51A7A

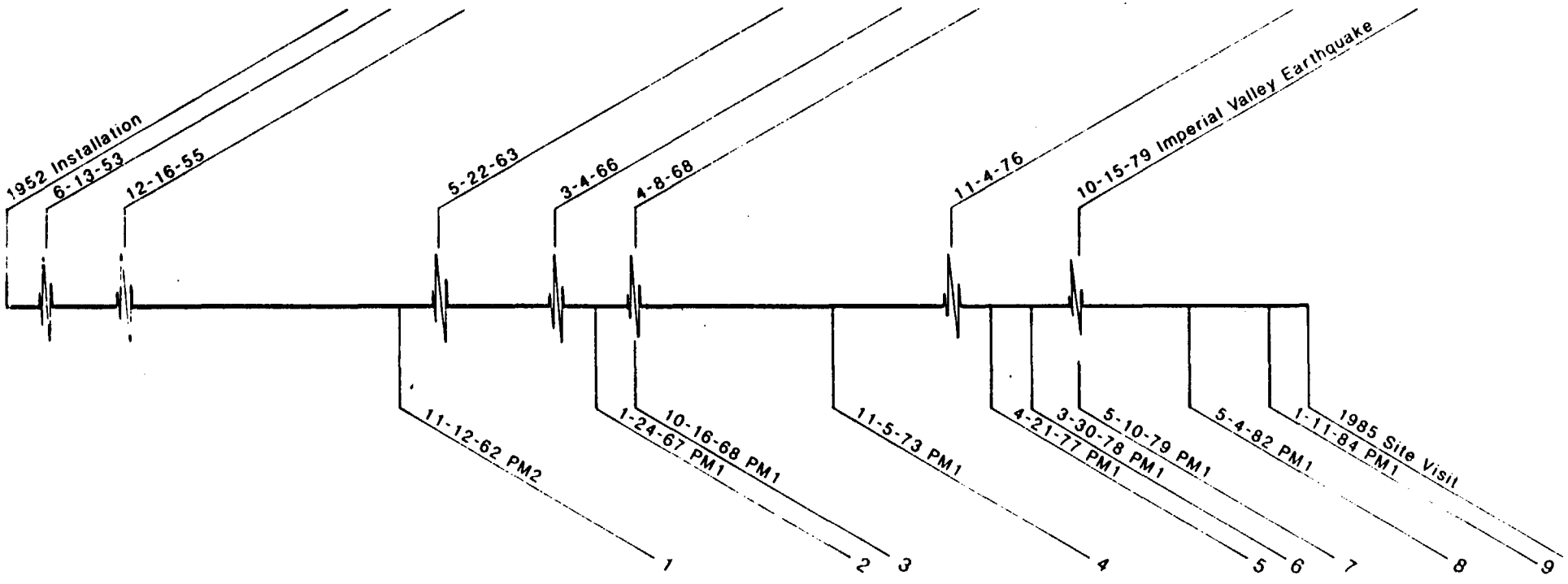


Figure A-25: Maintenance History for the Auxiliary Generator Quick Pickup Relay in Unit 4 at El Centro Steam Plant.

Photo Not Available

#4-1 BOILER FEED PUMP BEARING OIL PRESSURE RELAY

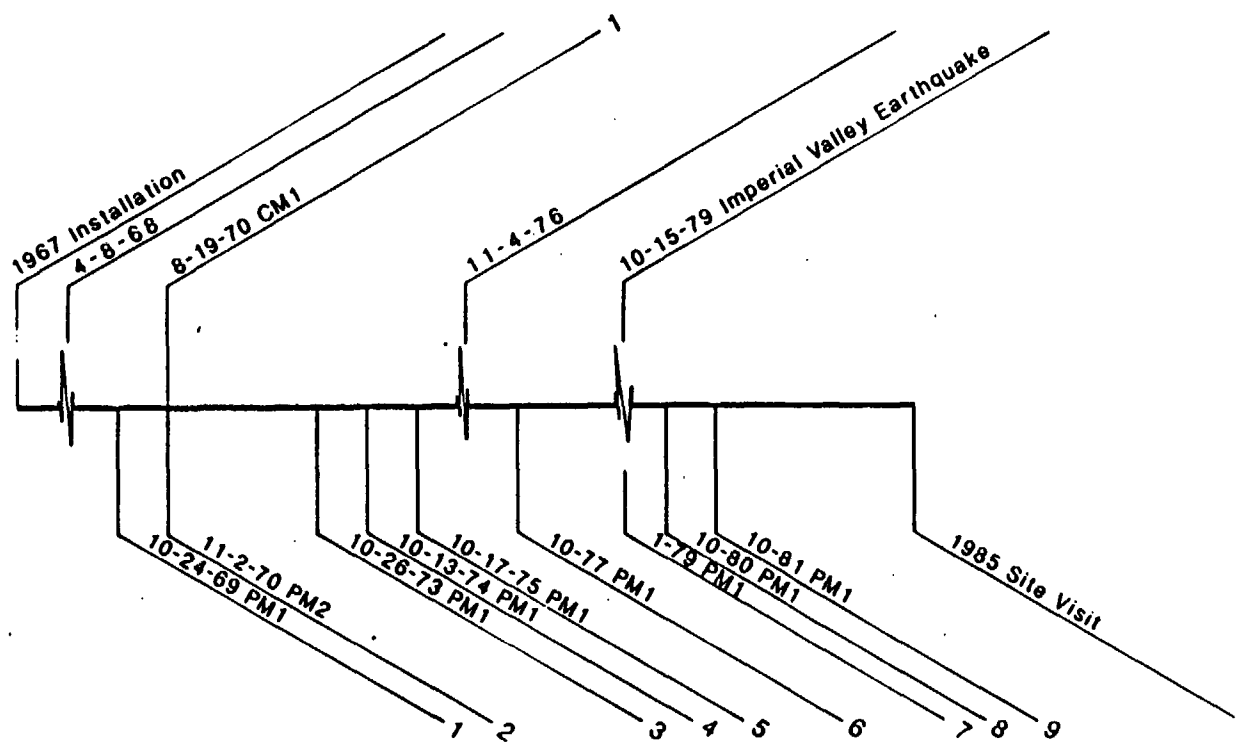


Figure A-26: Maintenance History for the #4-1 Boiler Feed Pump Bearing Oil Pressure Relay at El Centro Steam Plant.

Photo Not Available

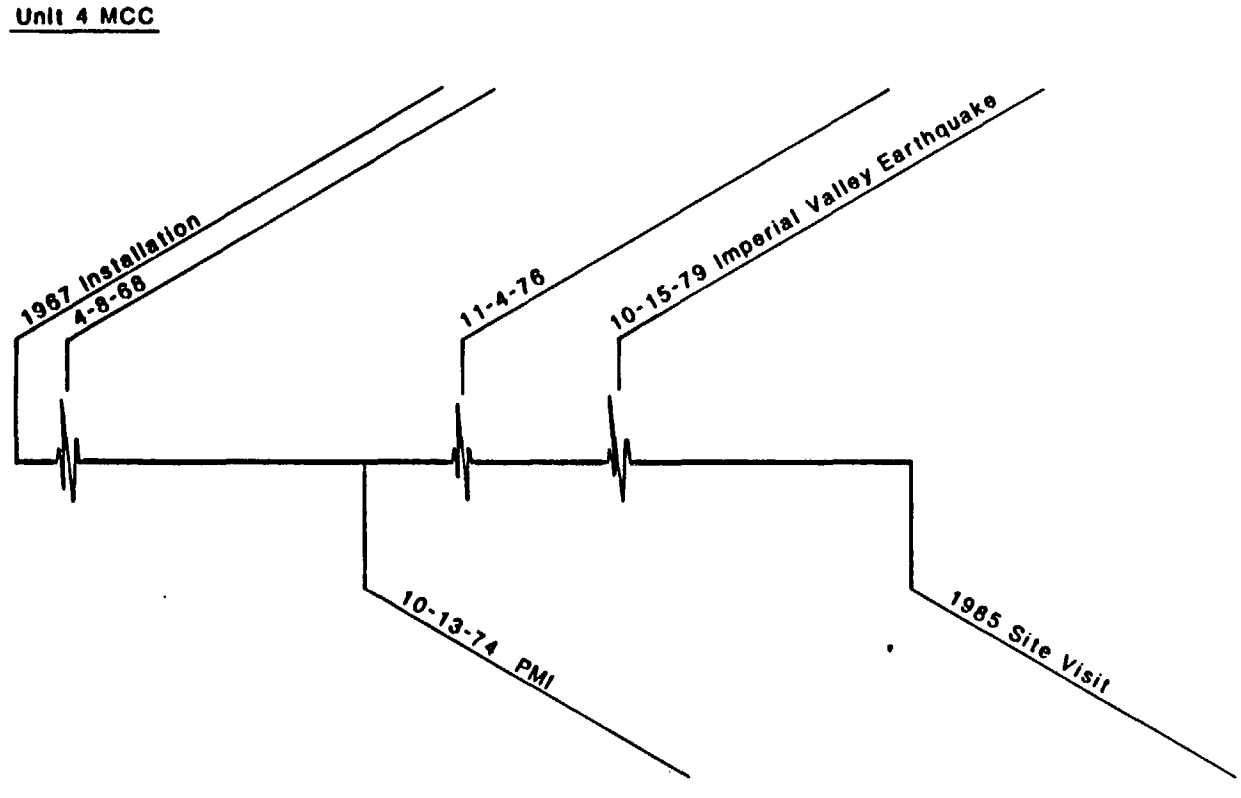


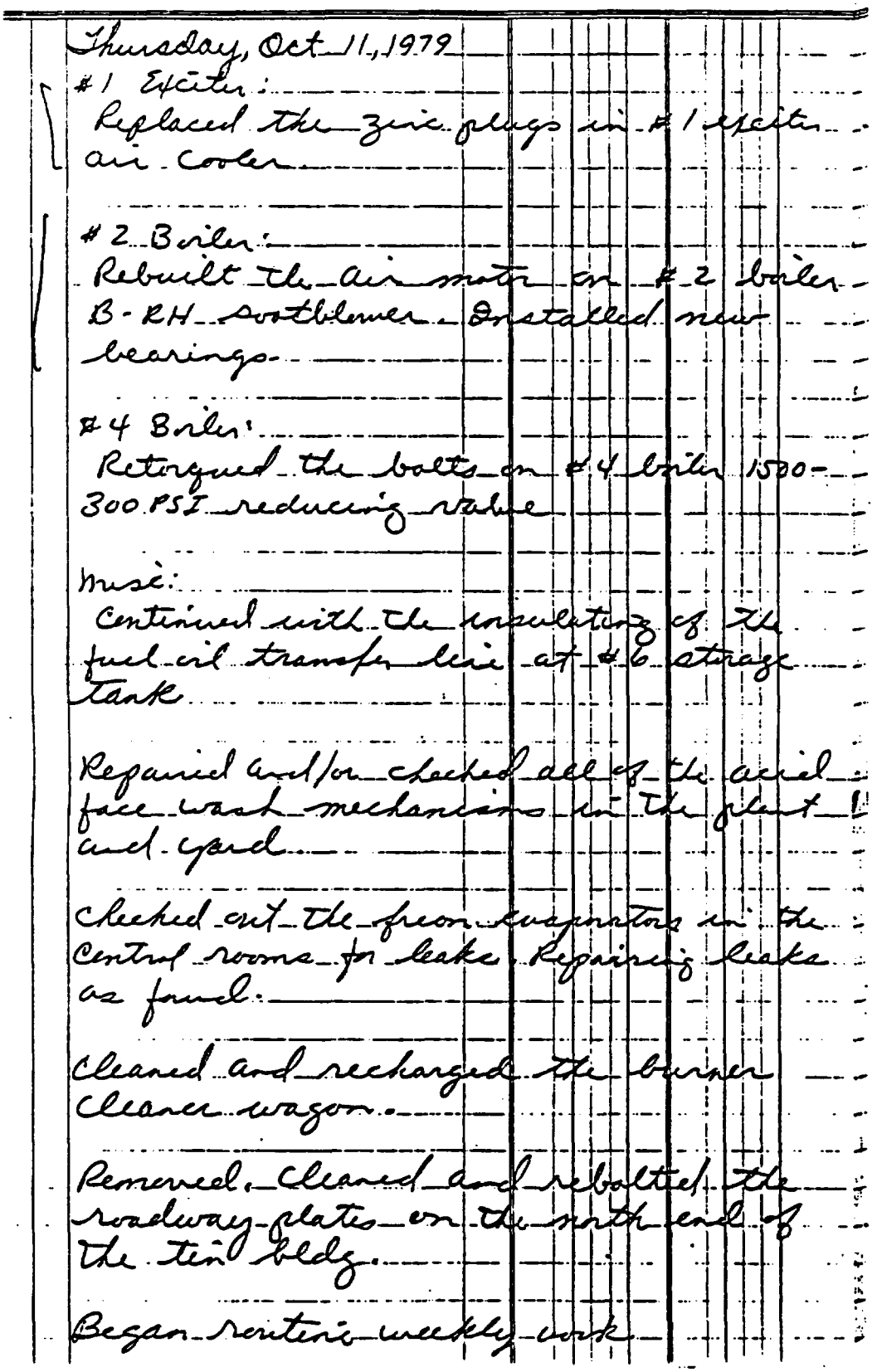
Figure A-27: Maintenance History for a Typical MCC at El Centro Steam Plant.

APPENDIX B

UNIT No. 4 BOILER FEED PUMPS

8-27-68	No. 4-1 Pump Motor: Cooling fan had come completely off the rotor. Pacific Pumps dispatched Mr. Bob Oswalt of Arnhart
	Electric Co: in San Diego. Cut a new key way in the otbd. fan hub. The rotor was sent to Arnhart's San Diego shop for
	final repairs and ballancing. Loc-Tite was used in seating the fans.
	No. 4-2 Pump Motor: Mr. Oswalt sent the rotor to a local machine shop for reballancing and repairs.
	No. 4-3 Pump Motor: Rotor was sent to Arnhart's shop for ballancing and repairs.
	All pump motors were reassembled and checked out by Mr. Oswalt.
9-6-68	No. 4-1 BFP Coupling: Repacked with Marfak "0".
4-15-69	Cleaned the lube oil coolers and renewed the magnesium plugs on all three pumps.
6-16-69	No. 4-3 Pump: Remounted the mercoid panel. Vibration had worn the switch linkage excessively.
12-24-69	No. 4 Boiler Feed Pumps: Installed new oil level sight glasses on the motor bearings of all three pumps.
1-19-70	No. 4-2 Pump Motor: Installed new sight glasses on the motor bearings.
4-1-70	No. 4-1 & 4-2 Pumps: Relocated the Mercoid switch mountings on each pump. The switches were damaged by vibration.
4-7-70	No. 4-3 Pump: Installed a rewound RCV controller solenoid coil.
8-19-70	No. 4-1 & 4-3: Installed zinc plugs and cleaned lube oil coolers. Changed bearing oil pressure relay
	on No. 4-1.
1-20-71	No. 4-1: Removed motor end bells to locate possible rub. Fan on outboard had moved $\frac{1}{8}$" toward shaft end, noted outboard lower
	half had wiped some. Clearances ranged from .006" to .010", rotor removed. Fan set screws not tight, fan removed.
	Cleaned motor wingings, drilled one more set screw hole, mounted O. B. fan using Loc-Tite. Installed new O. B. bearing.
9-19-72	Renewed zinc anodes in all of the lube oil coolers.
~~9-20-72~~	~~Installed bracing to eliminate vibration in compressor head and after cooler.~~
10-10-72	Replaced coil in 4-3 boiler feed pump discharge valve air supply.
12-4-73	No. 4-1 BFP: Motor windings free of oil and grime. Bearings and seals OK. Seal,felt, out of place inbd. brg. Reassembled.
12-7-73	Completed checking all BFP motors and all in good condition.
12-10-73	No. 4-2 BFP: Installed new outboard pump seal. THRUST CLEARANCE - 0.026" BEARING CLEARANCE - 0.004",
12-12-73	No. 4-2 BFP: Renewed pump end plate gasket (0.016") with 0.006" gasket. Thrust clearance from 0.026" to 0.016".
	No. 4-1 BFP: Replaced otbd pump seal. Thrust = 0.013". Otbd bearing inbd. = 2.379", otbd.= 2.379"
	Shaft inbd. = 2.374", otbd.= 2.3745"
	Clearances = 0.005" 0.0045"
12-31-73	No. 4-1 BFP: Installed new Inbd. pump seal.
7-9-74	No. 4-2 BFP: Cleaned lube oil cooler.

Figure B-1: Sample Maintenance Card Kept on Larger (i.e., Greater than 100 hp) Motors at El Centro Steam Plant.



Thursday, Oct 11, 1979

#1 Exciter:

Replaced the zinc plugs in #1 exciter air cooler

#2 Boiler:

Rebuilt the air motor on #2 boiler B-RH sootblower. Installed new bearings.

#4 Boiler:

Retorqued the bolts on #4 boiler 1500-300 PSI reducing valve

Misc:

Continued with the insulation of the fuel oil transfer line at #6 storage tank

Repaired and/or checked all of the acid face wash mechanisms in the plant and yard

Checked out the freon evaporators in the control rooms for leaks. Repaired leaks as found.

Cleaned and recharged the burner cleaner wagon.

Removed, cleaned and rebolted the roadway plates on the north end of the tin bldg.

Began routine weekly work

Figure B-2: Sample Operating Log Kept Daily by the Plant Supervisor at El Centro Steam Plant.

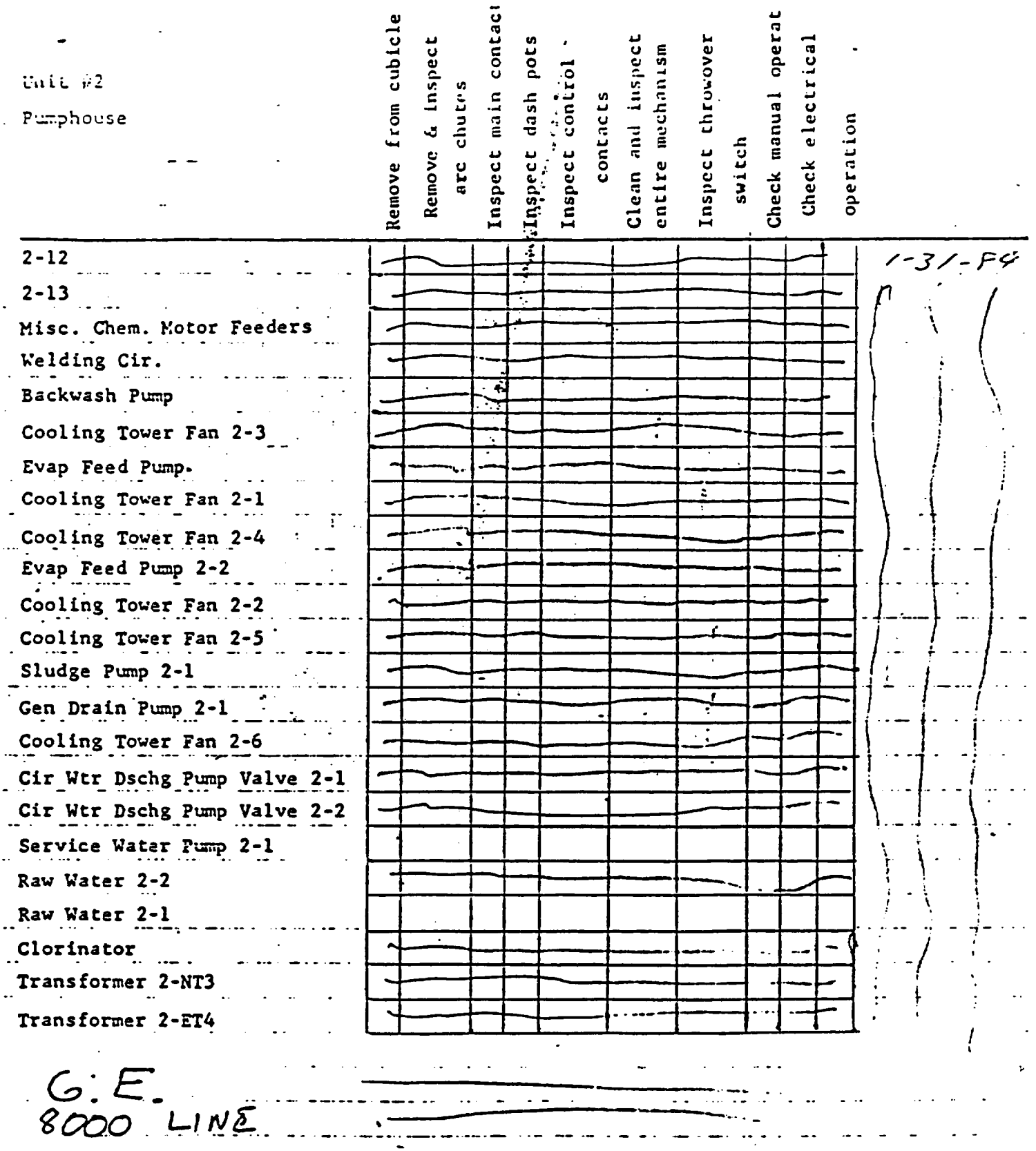


Figure B-3: Sample Circuit Breaker Maintenance Record at El Centro Steam Plant.

nit #2
480 Volt Section

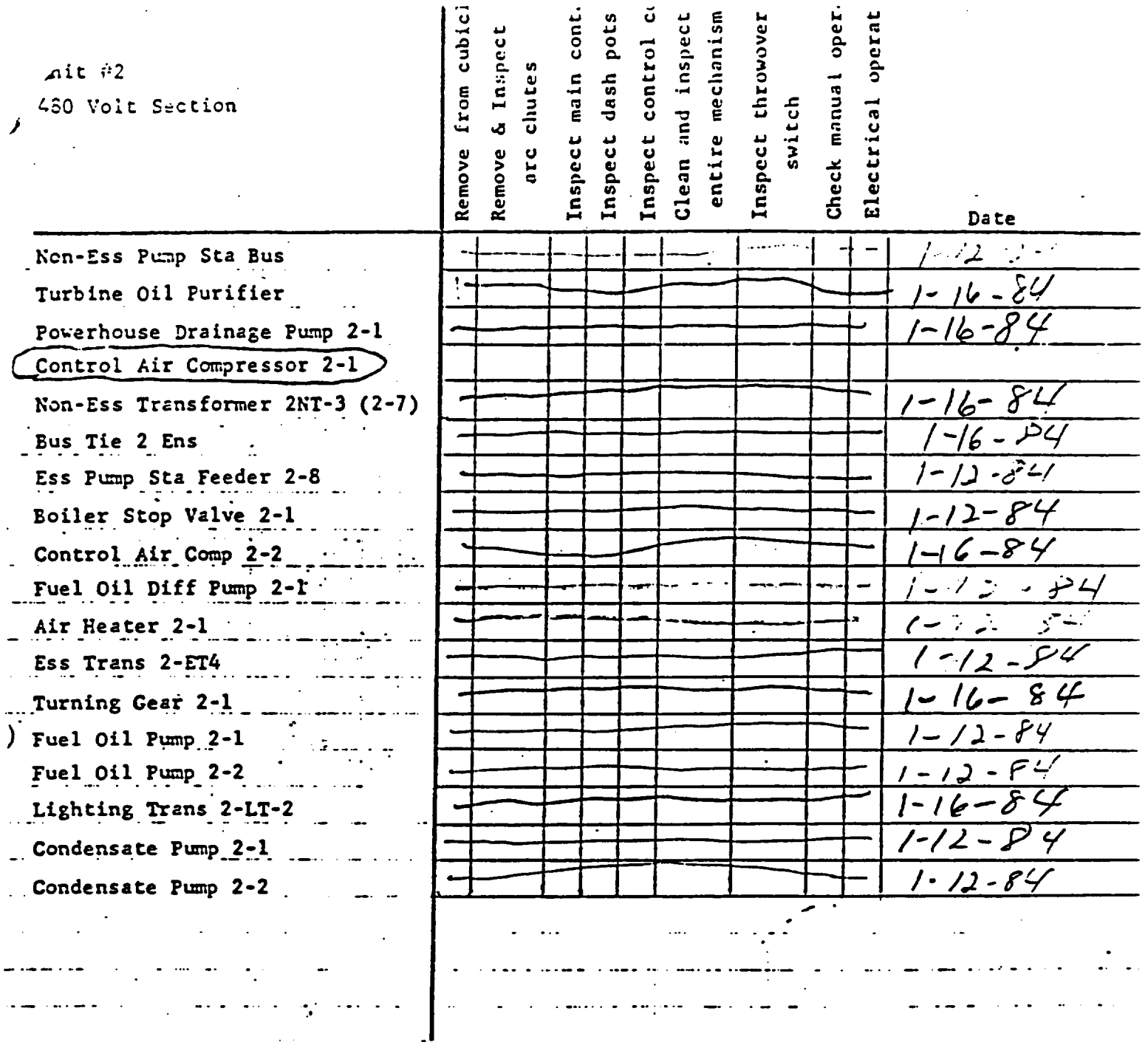


Figure B-4: Sample Circuit Breaker Maintenance Record at El Centro Steam Plant.

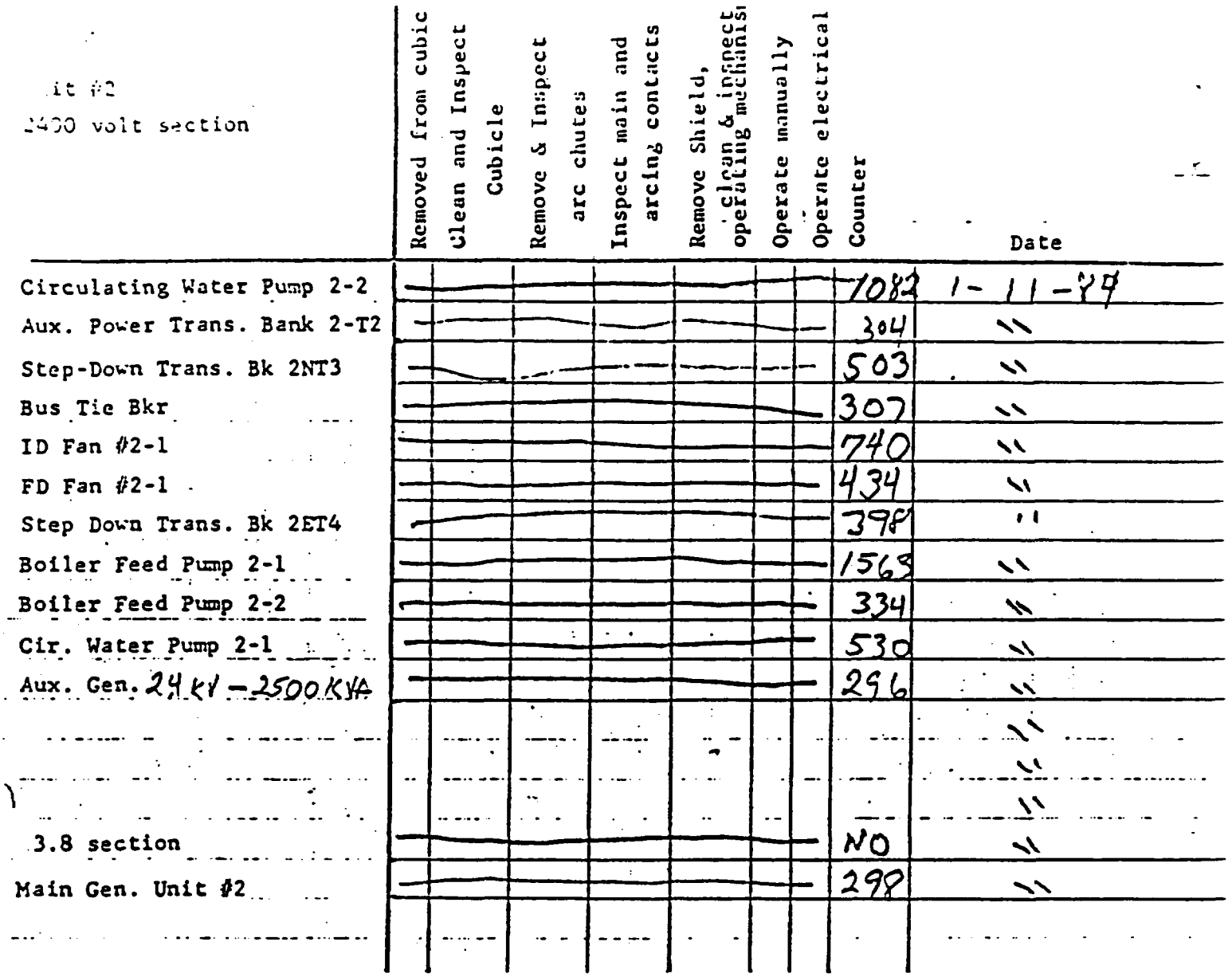


Figure B-5: Sample Circuit Breaker Maintenance Record at El Centro Steam Plant.

ELECTRICAL MAINTENANCE

1. A few days prior to shutdown, the Electrical Crew should move down and set up 37.5-kva transformer for bolt heaters.

2. Remove lagging, clean, vacuum and inspect the two dry-type 2400 to 480-volt station service transformers. Be sure to lubricate cooling fans.

   REMARKS:

3. Vacuum, clean and make inspection of main unit voltage regulator. Check all contacts.

   REMARKS:

4. Clean and inspect main field breaker and all contacts.

   REMARKS:

5. Check relays and contacts on all controls on three speeds of boiler fans.

   REMARKS:

6. Clean and inspect voltage regulator, field breaker and main breaker on auxiliary house generator after first obtaining clearance from Operator.

   REMARKS:

Figure B-6: Sample Electrical Maintenance Check List at El Centro Steam Plant.

7. Make thorough inspection of brush rigging, collector rings, exciter and all related equipment. Clean and blow out all parts and repair as required. Use Turco-Solv solution around all electrical windings. Dress down exciter commutator and collector rings, if necessary, and renew brushes. Set brushes to proper tension.

REMARKS:

8. Test generator and transformer differential relays.

REMARKS:

9. Megger and record generator field and stator windings.

REMARKS:

	Present	Previous
Field	_____	_____
Stator	_____	_____

10. Drop all breakers (essential and non-essential) on 13,800, 2400 and 480-volt buses in powerhouse and in pump house, including bus tie breakers. Clean, inspect and check operation.

REMARKS:

Figure B-7: Sample Electrical Maintenance Check List at El Centro Steam Plant.

11. Clean insulators and bushings in substation, at the same time clean behind gear at pump houses.

REMARKS:

12. Clean and inspect motor-generator set on battery charger and stone commutator as necessary.

REMARKS:

13. Remove inspection plates and blow out large motors on boiler fans.

REMARKS:

14. Remove and check tubes in all amplifiers behind combustion and turbine boards.

REMARKS:

Figure B-8: Sample Electrical Maintenance Check List at El Centro Steam Plant.

Date _____ ELECTRICAL MAINTENANCE Unit No. __

Test: Breaker 4T1 COV. and Diff. Relays. (Dispatcher's area)

Remarks:

Test: 13.8 Generator Relays.

Remarks:

Test: 2.4 Relays and Alarms.

Remarks:

Test: 480 Relays.

Remarks:

Test: Indoor and Outdoor low voltage transfer relays.

Remarks:

Megger and record generator field and stator windings.

Remarks:	Hot ____	Present	Cold ____	Present
Field	_____	_____	_____	_____
Stator	_____	_____	_____	_____
Pilot	_____	_____	_____	_____
Main	_____	_____	_____	_____

Check: Diodes.

Remarks:

Check: Base Adjuster.

Remarks:

Clean: Generator Temperature Switches.

Remarks:

Figure B-9: Sample Electrical Maintenance Check List at El Centro Steam Plant.

No.___Boiler Date:_____ 1-1

Inspect all drums and drum internals. Check the baffles and all line flanges. Check the cleanliness of the drum and note any deposits and their composition.

No.___Boiler Date:_____ 1- 2

Check the drum tubes, the furnace tubes, and the generating tubes. Note scale deposits or any other unusual conditions.

No.___Boiler Date:_____ 1-3

Collect a sample from the drum for analysis.

Figure B-10: Sample Maintenance Work Orders at El Centro Steam Plant.