EQE

A COMPARISON OF THE MAINE YANKEE ATOMIC POWER PLANT WITH THE SQUG SEISMIC EXPERIENCE DATA BASE

September 1985

EQE INCORPORATED / 121 SECOND STREET / SAN FRANCISCO, CA 94105 / (415) 495-5500 TELEX 296166

A COMPARISON OF THE MAINE YANKEE ATOMIC POWER PLANT WITH THE SQUG SEISMIC EXPERIENCE DATA BASE

EQE Project No. 8414-02

September 1985

Prepared for:

YANKEE ATOMIC ELECTRIC COMPANY
1671 Worcester Road
Framingham, MA 01701

Prepared by:

EQE Incorporated
121 Second Street
San Francisco, CA 94105

EQE

CONTENTS

CONTENTS (Continued)

TABLES

FIGURES

CONTENTS (Continued)

FIGURES (Continued)

CONTENTS (Continued)

FIGURES (Continued)

CONTENTS (Continued)

FIGURES (Continued)

EQE

EXECUTIVE SUMMARY

This report is an evaluation of the seismic durability of critical equipment* at the Maine Yankee Atomic Power Plant. The method of evaluation is based upon seismic experience data collected from eight major California earthquakes under the auspicies of the Seismic Qualification Utilities Group (SQUG). Eight specific types of equipment representing essential mechanical and electrical components are addressed. The eight types of equipment focused upon in this report are as follows:

- Motor Control Centers
- Low Voltage Switchgear
- Unit Substation Transformers
- Metal Clad Switchgear
- Horizontal Pumps and their Motors
- Vertical Pumps and their Motors
- Air-Operated Valves
- Motor-Operated Valves

The seismic experience data were compiled through a study of the effects of several strong motion earthquakes in California. These earthquakes affected dozens of facilities that contain equipment that are the same as those found in nuclear power plants. The study generally focused on the most heavily shaken areas of each earthquake. The product of the ongoing study is a description of the performance of a large inventory of various types of equipment, installations and structures that have experienced seismic loads comparable to or in excess of those for which the Maine Yankee plant is designed. Based on a review of this seismic experience data base, an appointed panel of experts in earthquake engineering has developed a set of response spectra below which explicit seismic qualification is unnecessary for certain types of equipment.

---

* Includes hot, safe shutdown plus, on a sampling basis, cold shutdown and accident mitigation equipment.

The NRC staff has reviewed the experience data base and has endorsed the following conclusions:

- Seismic damage to equipment is rare, even in earthquakes much stronger than the design basis for most nuclear plants.
- The few instances of equipment damage are usually related to inadequate equipment anchorage.
- Equipment in nuclear plants is generally similar to, and at least as rugged as, equipment in non-nuclear facilities that have survived strong motion earthquakes.
- There is a sufficiently large experience data base to waive the requirement of seismic qualification for many types of equipment.

The seismic adequacy of the eight types of equipment at Maine Yankee was examined by comparison with the performance of similar equipment at conventional power plants and industrial facilities during past earthquakes (seismic experience data). Walkdowns of critical plant equipment were performed to establish the similarity of each equipment type to that which formed the basis for the criteria developed by SQUG, and to assure appropriate anchorage.

The evaluation of the seismic adequacy of selected critical equipment at the Maine Yankee plant by comparison to the seismic experience data base and the criteria developed by SQUG leads to the conclusion that the Maine Yankee equipment possesses an inherent seismic ruggedness well beyond that required for a re-evaluation earthquake based on the USNRC Regulatory Guide 1.60 ground motion spectrum at 0.10g. Empirical seismic data find essential equipment maintaining post-earthquake function at several times this level of motion provided its anchorage has been properly engineered and installed.

1. INTRODUCTION

This report presents the results of a study of the Maine Yankee Atomic Power Plant to determine the capability of critical equipment to withstand a maximum credible earthquake for the site.

The maximum credible earthquake that would constitute a reasonable design basis for the Maine Yankee plant is a subject of current study. The original seismic design for the plant was based on a Housner-type ground motion response spectrum with a peak ground acceleration (PGA) of 0.10g. The NRC Staff has suggested that this may not be sufficiently conservative to represent the seismic potential of the plant location. However, it is generally recognized that conventional procedures in the nuclear industry for the seismic design of structures and equipment include a multiplication of conservative assumptions. This built-in conservatism creates a margin in the design of the plant to safely withstand seismic loads higher than the nominal design basis load. A study was therefore initiated by the Maine Yankee Atomic Power Company to assess the margins inherent in the plant seismic design. The purpose of the study was to determine the seismic resistance of critical plant structures and equipment to motion much greater than what would be generated by the design basis earthquake. This report addresses a portion of the study in which Maine Yankee critical equipment is compared to that in the Seismic Qualification Utilities Group (SQUG) experience data base.

The study of the seismic adequacy of critical equipment in the Maine Yankee plant involves an alternative to the usual procedure of analysis or shake table testing. The Maine Yankee Atomic Power Company is a member of SQUG, which has, since 1982, sponsored a research program for the collection and evaluation of data on the performance of power plant equipment in strong earthquakes. Through this program a data base of the seismic experience of equipment similar to that in critical systems in nuclear power plants has been compiled. The use of this seismic experience data base has been recognized as the preferable method of demonstrating the adequacy of critical equipment to withstand the moderate seismic loads predicted for operating nuclear plants in the eastern United States (Reference 11).

Through surveys of power plants and industrial facilities affected by strong earthquakes, examples have been found of nearly all types of equipment critical to the safety of a nuclear plant. In order to maintain a manageable scope, the compilation of experience data focused on eight types of equipment representative of the diversity of electrical and mechanical components in critical nuclear plant systems. These eight types of equipment are as follows:

- Motor Control Centers
- Low Voltage (480 Volt) Switchgear
- Unit Substation Transformers (4160/480 Volt)
- Metal Clad (4160 Volt) Switchgear
- Horizontal Pumps and their Motors
- Vertical Pumps and their Motors
- Air-Operated Valves
- Motor-Operated Valves

The format of this report is set up first to familiarize the reader with the procedure for assessing seismic adequacy through an experience data base, and then to address each of the eight types of representative equipment individually. Chapter 2 presents a brief history of the SQUG program. Chapter 3 describes in some detail the more important sources of seismic experience reviewed in compiling the experience data base. Chapter 4 presents a brief description of the Maine Yankee plant and the locations of its critical systems within the plant structures. Chapter 5 addresses each of the eight types of equipment in individual sections. Each section presents first a general description of the equipment, applicable both to equipment at the Maine Yankee plant and to equipment at various facilities in the experience data base. Criteria are then outlined that define the limits of applicability of the experience data base to the particular type of equipment at the Maine Yankee plant.

2. THE SEISMIC QUALIFICATION UTILITIES GROUP

2.1 The Research Program

In 1981, the Seismic Qualification Utilities Group (SQUG) was formed by an initial group of 16 utilities (now about 30 utilities) for the purpose of developing a practical alternative to the conventional seismic qualification of equipment in nuclear power plants (e.g., shake table testing or analytical procedures). This alternative is based on a thorough review of the performance of certain types of equipment in past earthquakes. The SQUG program also addressed a more basic question: Is seismic qualification for many types of equipment even necessary in view of the successful performance of this equipment in past destructive earthquakes?

Most of the equipment considered significant to nuclear plant safety can also be found in any conventional power plant or large industrial facility. Typical mechanical systems consist of pumps, piping, control valves, heat exchangers, and tanks. These mechanical systems are powered and controlled by transformers, switchgear, motor-control centers, and instrumentation panels. Over the years, most of this equipment has been supplied by a limited number of manufacturers, both in nuclear power plants and in other facilities. Equipment designs generally show little variation among manufacturers and little change since the early 1950's.

A number of earthquakes in the United States have affected power plants and industrial facilities over the past 20 years, primarily in California. Detailed records are typically taken of any damage or problems the facilities encountered as a result of the earthquake. <u>Damage to properly anchored equipment was rare</u>. Such equipment was consistently found to be functional following the earthquakes. Therefore, an extensive data base is available on the experience of typical power plant equipment in major earthquakes.

In January of 1982, EQE Incorporated launched a pilot program to demonstrate the feasibility of using past earthquake experience in lieu of conventional seismic qualification of equipment. The original focus of the program was eight basic types of equipment included in the hot shutdown

systems of nuclear power plants. An extensive and detailed seismic experience data base for equipment was compiled from reviews of power plants, electrical distribution stations, and industrial facilities which were affected by the following California earthquakes:

1. The 1971 San Fernando earthquake (magnitude 6.5)
2. The 1973 Point Mugu earthquake (magnitude 5.7)
3. The 1975 Ferndale earthquake (magnitude 5.5)
4. The 1978 Santa Barbara earthquake (magnitude 5.7)
5. The 1979 Imperial Valley earthquake (magnitude 6.6)
6. The 1980 Humboldt County earthquake (magnitude 7.0)
7. The 1983 Coalinga earthquake (magnitude 6.7)
8. The 1984 Morgan Hill earthquake (magnitude 6.2)

A number of power plants and other power, utility, petrochemical, and industrial facilities were reviewed in the areas most severely shaken by these earthquakes. Most other large earthquakes that have occurred anywhere in the world within the last 20 years were also briefly studied to determine if their data would affect the conclusions of the study. Initially, the collected seismic experience data were intended to correlate seismic damage with characteristics of the equipment. It was thought, for example, that seismic damage might be more common in older equipment, or in equipment from certain manufacturers. It was found, however, that damage to equipment of any kind was rare, even in earthquakes that were much stronger than the design basis earthquakes for most nuclear plants. The few instances of damage were usually related to inadequate or nonexistent equipment anchorage. There is extensive data to indicate that equipment normally continues to function during an earthquake.

The primary conclusions of the research program are that seismic damage to equipment is rare, as long as reasonable precautions for anchorage are taken. Conventional seismic qualification is unnecessary for many types of equipment, with certain limitations.

Data collection activities were closely monitored by senior members of the NRC staff and by their consultants, including the Lawrence Livermore

National Laboratory (LLNL). Through the course of the pilot program, numerous meetings and discussions were held among SQUG, EQE, the NRC, and LLNL regarding the direction of the surveys. Representatives from all involved organizations toured several of the affected power facilities to familiarize themselves with the equipment and interview plant personnel who experienced the events.

The initial phase of the program was completed in the fall of 1982 and a report (Reference 1) was submitted to the NRC for review and comment. Numerous meetings were held between members of the NRC and the SQUG in 1983 to discuss the NRC's comments and questions. Following these discussions, the NRC issued a general endorsement of the use of experience data in lieu of conventional qualification of equipment in operating nuclear power plants. This endorsement was published in the report, "Seismic Qualifications of Equipment in Operating Plants, A Status Report on Unresolved Safety Issue A-46," NUREG-1018, September 1983. In this report, the NRC reaches the following conclusion:

> "...use of experience data for equipment qualification provides the only reasonable alternative to current criteria."

2.2 Senior Seismic Review and Advisory Panel

Although the SQUG pilot program had demonstrated the feasibility of using experience data, it had not defined a criteria explaining how experience data could be applied. An agreement was reached between the NRC and SQUG that a panel of recognized seismic experts would be formed to evaluate the extent to which experience data could be used in lieu of conventional seismic qualification of equipment. As a result, a five member Senior Seismic Review and Advisory Panel (SSRAP) was formed in the spring of 1983.

The NRC and the SQUG agreed that the SSRAP would perform the following tasks:

1. Review the SQUG program.

2. Determine the limits to which experience data could be applied to the seismic qualification of equipment.

3. Recommend additional areas where the program should be expanded.

The SSRAP completed its review of the SQUG program early in 1985. The primary conclusions of the SSRAP are as follows:

1. Equipment in nuclear power plants is generally similar and at least as rugged as equipment installed in conventional power plants.

2. This type of equipment, when properly anchored and with certain reservations, has an inherent seismic ruggedness and has a demonstrated capability to withstand substantial seismic motion without structural damage.

3. Functionality after strong shaking has been demonstrated, although relay chatter during earthquakes may occur.

4. With several important restrictions and exclusions, it is the SSRAP judgment that below certain seismic motion bounds it is unnecessary to perform explicit seismic qualification of the eight types of existing equipment addressed for operating nuclear plants, in order to demonstrate functionality following an earthquake.

5. The existing experience data base reasonably demonstrates the seismic ruggedness of this equipment up to these seismic motion bounds. It is also recommended that a thorough walk-down should be made of each nuclear plant to check the following:

   - Equipment anchorage
   - Falling or impacting hazards from adjacent equipment

- Unusual or nontypical conditions

In addition to these general conclusions, the SSRAP proposed a set of criteria for each of the eight types of equipment, defining restrictions in equipment characteristics for which experience data was applicable in demonstrating seismic adequacy. These specific restrictions basically defined the range of diversity in equipment characteristics covered by the inventory of each equipment type in the data base. They also addressed sources of seismic weakness in equipment that had caused problems in past earthquakes. These restrictions are discussed in later chapters addressing each equipment type specifically.

The SSRAP defined the seismic motion bounds for which the various types of equipment had demonstrated adequacy based on past earthquake experience. These seismic motion bounds were defined as response spectra for horizontal ground motion. These response spectra were developed from the higher motion data base sites that contained significant inventories of equipment. For example, a large portion of the inventory of electrical equipment included in the data base was located in the Sylmar Converter Station, affected by the 1971 San Fernando earthquake. The ground motion spectrum estimated for this particular site was, therefore, considered representative of the demonstrated seismic adequacy of the electrical equipment, motor control centers and switchgear included in the SQUG study.

Three response spectra were developed by the SSRAP to represent the demonstrated seismic adequacy of the various types of equipment addressed in the SQUG study.

> <u>Spectrum A</u>: This spectrum applies to mechanical equipment, horizontal and vertical pumps, air-operated valves, and motor-operated valves mounted on large lines (12 inches diameter or greater).
>
> <u>Spectrum B</u>: This spectrum applies to electrical equipment, motor control centers, low voltage and metal-clad switchgear, and unit substation transformers.

Spectrum C: This spectrum applies to motor-operated valves mounted on small lines (less than 12 inches in diameter). Compared to other types of equipment, the inventory of motor-operated valves (MOVs) supported on small piping was relatively small, and concentrated in the lower motion data base sites. MOVs mounted on smaller lines were, therefore, designated as a separate class from MOVs mounted on large lines. This was prompted by the concern that the torsional loads induced by the motor operator on a small valve and supporting pipe had only been subjected to a moderate seismic load level by the assembled experience data. Spectrum C is, therefore, not as high as Spectra A and B. This spectrum is being re-evaluated in light of experience data collected from the 1985 Chilean earthquake (magnitude 7.8). A large quantity of data from MOVs on small lines which experienced high levels of seismic motion and remained operational were collected. This information is expected to provide the basis for substantially increasing the seismic motion bounds for MOVs.

These three spectra represent the ground motion experienced by the various types of equipment included in the experience data base. Most items of nuclear plant equipment, however, are located within the plant buildings, often several floors above ground level. To account for the potential amplification of the ground motion by the building structure, the SSRAP spectra would have to be compared to the floor response spectra calculated at the particular equipment location. This presents an unnecessarily conservative comparison for the following reasons:

- Much of the equipment studied in compiling the experience data base is located in the upper floors of buildings. Therefore, it experienced a potential amplication of the ground motion similar to or in excess of that predicted for nuclear plant structures.

- It is generally acknowledged that building response analyses of nuclear plant structures predict conservatively high levels

of building amplification, and subsequently high floor response spectra. This overprediction of seismic loads may be justified for the purposes of conservative design, but it can impose severe cost penalties when used to evaluate the adequancy of existing installations.

- There is a large data base of strong motion records taken in various types of buildings during earthquakes. These records normally measure much lower levels of building amplification than those predicted by conventional analytical techniques for building response. The effect of soil-structure interaction, for example, normally reduces the severity of seismic motion between the ground and the base of the building. The severity of motion then gradually increases from its base level with ascending floors. However, building response records demonstrate that ground motion will never be amplified by more than a factor of 1.5 in the lower floors of a building.

If the SSRAP spectra were compared to nuclear plant floor response spectra, the seismic loads experienced by the data base equipment tend to be underpredicted, while the seismic loads postulated for the nuclear plant equipment tend to be overpredicted. In order to allow a more favorable comparison, the SSRAP proposed the following criteria:

- The observation was made that the stiff concrete structures of a nuclear plant were not expected to amplify ground motion by more than a factor of 1.5 in the lower floors of the buildings. More specifically, for floors located within elevations of approximately 40 feet above ground level, a factor of 1.5 should be taken as an upper limit to the amplification of ground motion due to building response.

- The nuclear plant design basis ground motion spectrum, muiltiplied by a factor of 1.5, can be taken as a realistic (and conservative) estimate of the amplified building response

motion for elevations within the building 40 feet above ground level or lower.

- The three SSRAP spectra can then be compared to the nuclear plant design basis ground motion spectrum multiplied by a factor of 1.5, when addressing nuclear plant equipment located within 40 feet of ground level.

- Alternately, the SSRAP spectra can be divided by a factor of 1.5 and compared directly to the nuclear plant design basis ground motion spectra.

- Equipment located on the upper floors of the nuclear plant (higher than 40 feet above ground level), should be addressed by comparing the floor response spectra calculated for their locations with the SSRAP spectra.

In effect, these criteria discount the seismic motion experienced by equipment in the data base by dividing the estimated ground motion of the data base sites by a factor of 1.5. However, it then allows this data base ground motion to be compared to nuclear plant design basis ground motion, rather than overpredicted floor response motion. These criteria do not apply to critical equipment located at high elevations in a nuclear plant. As with the Maine Yankee plant, however, nearly all critical equipment in a nuclear plant is located on the lower floors.

Spectra Types A, B, and C, including the discount factor of 1.5, are plotted in Figure 2-1.

In mid 1985, the NRC finalized their Regulatory Analysis of USI A-46 Requirements for submittal to Committee for the Review of Generic Requirements (CRGR). The staff endorsed the use of SQUG data for final resolution of A-46. An implementation phase will be required for plants to verify that their equipment is covered by SQUG data and SSRAP criteria. The staff also requested (and SQUG is developing) a generic approach for resolution for all plants. The staff concluded that USI A-46 will apply only to

plants that received an operating license before 1977. Specifically, the actions to date are expected to have the following implications:

- All the operating nuclear plants in the United States, with design basis seismic ground accelerations of 0.30g or less, should be allowed to make extensive use of the experience data base. Plants located in areas with design basis ground accelerations exceeding 0.30g should also be allowed to make use of the findings of the SQUG program.

- It is expected that a plant walk-down will be required for application of experience data. The walk-down would check primarily for adequate equipment anchorage and would verify that the equipment fits within the range of generic characteristics developed by SQUG.

- By using experience, effort and expense will be concentrated on the few critical equipment items which have been shown by past experience to be sensitive to seismic motion.

Based on NRC remaining concerns, SQUG has developed a generic list of the types of equipment that are required to remain operational during or after a seismic event to reach safe shutdown. A parallel effort has been initiated to collect seismic test data for various equipment and to incorporate SQUG experience data into a method for assuring adequacy of anchorages.

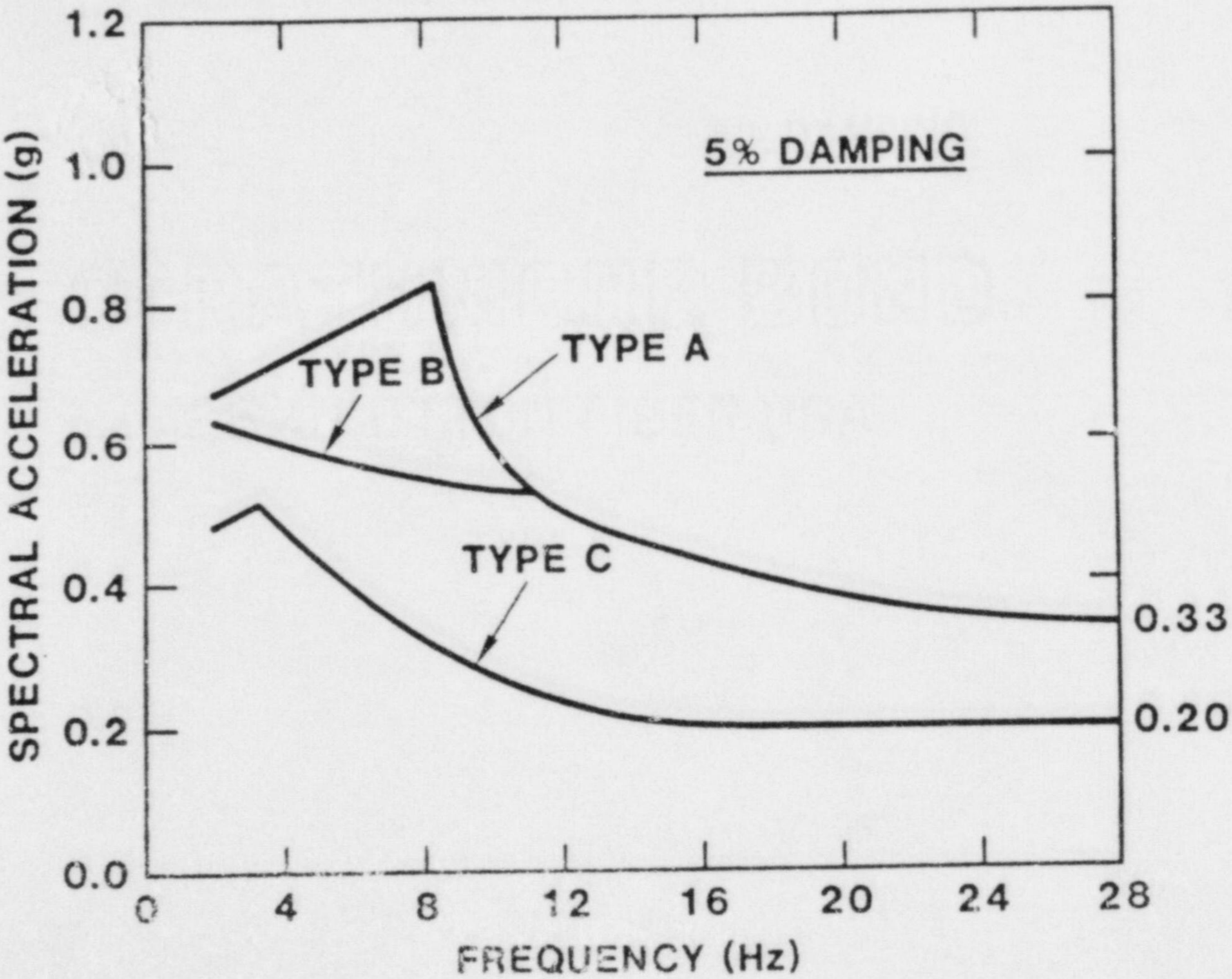


Figure 2-1: Response spectra defining seismic motion bounds for the applicability of experience data to nuclear plant equipment.

3. THE SEISMIC EXPERIENCE DATA BASE

3.1 SQUG Data Base Summary

The current seismic experience data base is based on a review of over 40 sites within the higher ground motion areas of eight earthquakes which occurred in California over the last 15 years (Figure 3-1). These sites include power generating stations, substations, and a variety of industrial facilities, such as oil refineries and chemical plants. A wide variety of equipment exists at these facilities that is representative of critical nuclear plant systems.

Table 3-1 includes the peak ground acceleration (PGA) either estimated or measured at each site reviewed in compiling the experience data base. The estimated PGAs are based on the ground motion record nearest to the site. Site measured PGAs are denoted by an asterisk. In this report, PGA is an average of the peak accelerations in the two orthogonal horizontal directions.

The larger proportion of the facilities included in the data base are as follows:

1. Fossil-fueled power plants
2. Substations
3. Petrochemical facilities

Within each type of facility, the equipment tends to be very similar. Fossil-fueled power plants, for example, have very much the same systems and components from site to site. In the sections that follow, a generic description is presented for each of the three facility types. These generic descriptions provide an indication of the diversity of equipment in the data base.

3.1.1 Power Plants - Power plants that have been affected by earthquakes in California are typically fired by natural gas with an oil fuel backup. Generating units range in size from 10 to 750 megawatts (MW); however, most

of the units in the data base are in the range of 40 to 80 MW. Most of the equipment is not seismically designed although it is anchored. The structures were usually built to the Uniform Building Code (UBC) current at the time of construction.

A generating unit typically includes the following types of equipment: a large boiler and condenser, two or three large boiler feed pumps, several additional vertical or horizontal pumps ranging in size from 10 to 200 horsepower, feedwater heaters, large horizontal and vertical tanks for oil and condensate storage, and one or more cooling towers. Additional systems are included for component cooling water, lubrication, compressed air, and DC power for vital instrumentation. The following electrical equipment is also found: at least one set of 480 Volt switchgear and one set of 2400 or 4160 Volt switchgear with associated transformers, and several motor control centers. Each unit of the plant has several control panels located in a main control room. In addition, each plant contains extensive piping and cable tray runs. A multi-story steel boiler support structure typically houses the boiler and forced draft system. The turbine and condenser system are located in a two-story steel-framed concrete turbine building.

3.1.2 Substations - The data base also includes a number of substations. These normally consist of a control house, which is a one-story concrete block building. The control house contains several control and instrument panels containing a variety of electric relays, recorders, annuciators, switches and indicators. Also in the control house are distribution panels and battery racks with associated battery chargers. The switchyards include a variety of high voltage equipment including oil-filled transformers, oil-filled, air, or gas-filled circuit breakers, and transmission towers.

3.1.3 Petrochemical Facilities - A greater diversity of equipment exists in petrochemical facilities than at power plants and substations. This diversity is due both to variations in facility size, and variations in the function of the facility. Most of the petrochemical facilities reviewed are located in the area of the 1983 Coalinga earthquake, which is the heart of the largest on-shore oil producing region in California.

Petrochemical facilities typically contain large, unanchored, ground-mounted oil or water storage tanks, as well as a variety of smaller tanks and pressure vessels. Scrubbers, absorber columns and cryogenic chillers may be present to remove impurities or extract byproducts from natural gas. Most facilities include heat exchangers or furnaces for warming oil. A large amount of interconnecting piping is included with associated pumps, air-operated valves, and air-compressor systems. Most piping is supported for dead load only, typically on overhead steel racks or pedestals. A one-story control house, typically either a prefabricated steel or a concrete block building, is usually present at each site. The control building will normally house a small control panel, switchgear, transformer, and motor control center. An emergency power system in the form of a battery rack and charger is sometimes found.

3.2 Earthquakes of Primary Interest to the Seismic Experience Data Base

Of the eight California earthquakes studied in the SQUG program, the major portion of the data base was collected from the three largest, the 1971 San Fernando, the 1979 Imperial Valley, and the 1983 Coalinga. A brief description of each earthquake is provided in the sections that follow. Also included is a description of the primary facilities from which most of the equipment seismic experience data were taken.

3.3 The San Fernando Earthquake

The San Fernando earthquake occurred at 6:01 a.m., local time, February 9, 1971. The Richter magnitude 6.6 shock was centered on the northern edge of the Los Angeles metropolitan area, which had a population of more than 8 million at the time. Over 400,000 people were subjected to very strong ground shaking (0.25g or greater) and 2 million more felt moderate shaking (0.15 to 0.25g). Most of the metropolitan area was not strongly affected by the earthquake and its resources were available to counteract the damaging effects of the shock.

The strong motion of the main shock lasted about 12 seconds. The earthquake occurred near the center of the largest concentration of strong-motion

recording instruments in the world; 340 instruments provided strong-motion records. The epicentral location, ground surface faulting and the sites visited for the SQUG program are shown in Figure 3-2.

Several power facilities are located in or near the San Fernando Valley. Little information concerning damage to power facilities was published after the earthquake, primarily because very little damage occurred. However, costly damage did occur at the Sylmar Converter Station.

The following four facilities experienced high levels of ground motion during the San Fernando earthquake (PGAs shown represent the average of the two horizontal directions):

- Sylmar Converter Station (PGA = 0.50g)
- Valley Steam Plant (PGA = 0.30g)
- Burbank Power Plant (PGA = 0.32g)
- Glendale Power Plant (PGA = 0.27g)

3.3.1 Sylmar Converter Station - The Sylmar Converter Station is located near the intersection of the Foothill and Golden State freeways (Figure 3-2). It is owned jointly by Los Angeles Department of Water and Power (LADWP) and Southern California Edison (SCE). The station was new and in operation at the time of the earthquake. The station converts 800 kV direct current (DC) electric power to alternating current (AC) after it is transmitted 846 miles from the hydraulic plants in the State of Washington.

The station consists of a three-story control building containing offices, control equipment, 42 large mercury-arc converter (DC to AC) valves, and a switchyard. The switchyard contains large items of equipment such as converter transformers, AC and DC filters, and capacitors which are located on either side of the building within metal-screened enclosures. The station is located on two basic types of soil: natural soil consisting of mixtures of silt, sand, and clay, and compacted fill with a depth of 5 to 10 feet.

Motion. The facility is located less than two miles from the earthquake's main fault ground rupture, in an area of extensive ground failures that included flow slides and liquefaction. Some of the most spectacular damage to structures from the earthquake occurred in the vicinity of the facility.

No records of ground motion from the San Fernando earthquake were obtained at the Sylmar station site; however, several estimates have been made by various investigators at this and other nearby sites. Typically, the estimates vary between 0.50 and 0.75g. A ground motion estimate based on the Pacoima Dam record (which had a peak horizontal acceleration of 1.25g) scaled to 40% was used in the SQUG study for the Sylmar site. The resulting PGAs for the station are 0.50g in both horizontal directions and 0.30g in the vertical direction. Figure 3-3 presents a comparison of the Sylmar response spectrum for horizontal ground motion (average of two directions) with the NRC Regulatory Guide 1.60 spectrum for a peak ground acceleration of 0.20g. Note that the spectrum for the actual earthquake envelops the Regulatory Guide 1.60 spectrum.

Performance. The station was shut down for many months following the earthquake due to extensive switchyard and valve hall equipment damage. Damage to equipment at the station included the following:

- Anchored rail-mounted transformers fell off support pads and overturned. (Switchyard)
- AC Harmonic filter reactors pulled or snapped anchor bolts and overturned. (Switchyard)
- Oil-filled transformers slid due to sheared anchor bolts. (Switchyard)
- Valve damping capacitor columns snapped anchor bolts on concrete pedestals and overturned. (Switchyard)
- Unanchored auxiliary power transformers slid on supporting concrete pads. Some connecting conduit tore. (Switchyard)

- Unanchored spare control cabinets overturned and suffered severe damage. Control cabinets that were in use were held upright by rigidly attached conduit. (Control Building)

- One unanchored motor control center slid several inches. (Control Building)

- The acoustical tile suspended ceiling collapsed in the control room. (Control Building)

- AC mercury-arc rectifiers were destroyed due to falling current dividers suspended from the ceiling. (Control Building)

- Porcelain columns supporting air-blast circuit breakers snapped. (Switchyard)

- An AC and DC harmonic filter capacitor rack collapsed due to failure of porcelain insulators and aluminium welds. (Switchyard)

- One lightning arrestor snapped. (Switchyard)

- DC voltage dividers failed at junction of porcelain column and steel pedestal. (Switchyard)

- Power factor capacitor racks failed. (Switchyard)

- Unanchored desk mounted control consoles slid several inches. (Control Building)

- Air cooler units jumped off spring isolation mounts. (Control Building)

3.3.2 Valley Steam Plant - The Valley Steam Plant, owned by LADWP, is located on a 150-acre site in the central San Fernando Valley (Figure 3-2). The plant has four generating units with a total capacity of 513 MW. Units

1 through 4 were constructed in 1954, 1954, 1955, and 1956, respectively; their capacities are 100, 100, 157, and 157 MW, respectively. Because of the Valley's mild climate, much of the plant equipment is located outdoors. The plant is located in a flat, alluvial area, on sand, gravel, and boulders that extend to a depth of more than 500 feet.

Motion. The Valley plant is located about ten miles from the epicenter of the San Fernando earthquake and about three miles from the fault. There was no ground breakage at this site. No ground motion record was obtained at this site. For the purpose of estimating the site motion, the response spectra were used from the nearest record (within a building at 8224 Orion Boulevard, Los Angeles). This record measured peak horizontal accelerations of 0.27g (north-south) and 0.14g (east-west). The response spectrum of the averaged horizontal components was scaled upward to account for the closer fault proximity of the plant. The resulting response spectrum for Valley Steam Plant compared to the Regulatory Guide 1.60 spectrum for 0.20g are shown in Figure 3-4. This comparison indicates that the spectrum for the actual earthquake envelops the design response spectrum.

Performance. The effects of the earthquake on the Valley Steam Plant are summarized in the plant's trouble report, which was prepared by the operating utility after a detailed post-earthquake investigation. (Reference 1)

At the time of the earthquake, Units 1, 3, and 4 were on line. Unit 2 was down for scheduled maintenance. The earthquake tripped Units 1 and 4 off line. The trip was attributed to the electric, sudden pressure relays, located on the floor below the control room, that are associated with the high voltage switchyard equipment tying the plant into the Los Angeles power grid. Both Units 1 and 4 lost station power, and all equipment came to a stop. Unit 3 stayed on line throughout the earthquake; however, the flow of gas fuel was interrupted by the closing of a control valve, activated by the vibration of a Mercoid switch. Because Unit 3 was still on line, the operators energized the tie buses between the three units so that Unit 3 could supply power to the rest of the plant. The gas burners in the Unit 3 furnace were relit at 6:20 a.m., 19 minutes after the earthquake. With the plant's lighting system functioning, the operators were

able to make a cursory inspection of Units 1 and 4 to determine whether any obvious damage had occurred. Nothing was seen that would prevent the units from restarting. The plant's log shows Unit 4 coming back on line at 6:50 a.m., 49 minutes after the earthquake, and Unit 1 at 7:12 a.m.

The local gas utility requested that the plant switch from gas to fuel oil after the earthquake. Ruptures of underground gas lines in the San Fernando Valley created problems in the normal supply of gas fuel. Subsequently, the plant's log notes that Unit 2 switched to fuel oil at 7:25 a.m., Unit 3 at 7:45 a.m., and Unit 4 at 8:20 a.m. At 10:55 a.m., the log notes that load was reduced in Unit 4 for inspection of the condenser, which was later found to contain some ruptured tubes.

The damage to the plant included the following:

- Several Unit 4 condenser circulation water tubes ruptured, causing feedwater contamination.
- Insulation was crushed on the main steam line.
- A lightning arrestor broke in the switchyard.
- Automatic control components jolted out of calibration. Some meter linkages disconnected.

3.3.3 Burbank Power Plant - The City of Burbank Power Plant is located on the eastern edge of the central San Fernando Valley (Figure 3-2). The facility is made up of two different power plants: the two-unit Olive Street plant and the five-unit Magnolia Street plant. The plant has total generating capacity of about 180 MW. Olive Units 1 and 2 were constructed in 1958 and 1961. Their capacities are 44 MW each. Magnolia Units 1 through 4 were constructed in the 1940s and early 1950s. Their capacities are 10, 10, 20, and 30 MW, respectively. Magnolia Unit 5 is a gas peaking unit, constructed in the late 1960s, with a capacity of 20 MW. The plant is located on a flat, alluvial site.

Motion. The plant is located about 14 miles from the epicenter of the San Fernando earthquake and about 6 miles from the causative fault. There was no ground breakage at this site. The estimated peak horizontal ground accelerations at the plant site are 0.35g in the east-west direction and 0.29g in the north-south direction. The ground motion record used to estimate the free-field motion at the site was made at the Municipal Services Building, at 533 East Broadway, Glendale. The resulting response spectrum, averaged for the two horizontal directions, and compared to the Regulatory Guide 1.60 spectrum for 0.20g is shown in Figure 3-5. The comparison indicates that the spectrum for the actual earthquake is similar to the Regulatory Guide 1.60 spectrum.

Performance. No major damage was experienced at the Burbank plant. The effects on the Olive and Magnolia plants are summarized separately.

Olive Plant, Units 1 and 2. Several relays tripped during the earthquake, taking both of the Olive units off line. According to the plant's trouble report, the two units were tripped by the action of one or more differential relays located on the main control panel on the second floor of the control building. Station power was not lost during the earthquake. Relay actuation caused the main steam stop valve to close in Unit 1. The watch engineer left the control room and reset the valve, returning the flow of steam to the turbine. At about this time, however, the two units lost their normal supply of station power from the outside grid. An attempt was made to supply station power to the Olive units by starting the Magnolia gas peaking unit; however, tripped relays on the control panel prevented immediate start-up. Station power was lost for about half an hour until substation relays were reset in the Los Angeles power grid and station power returned from the outside. The furnaces of the two Olive units were purged, and the boilers were relit about an hour after the earthquake.

Olive Unit 1 reconnected with the power grid at 8:09 a.m., about two hours after the earthquake. Olive Unit 2 reconnected at 8:24 a.m. Damage at the Olive plant was limited to the following:

- A broken valve and pipe at the demineralizer tank

- A broken front centerline guide on the Unit 2 boiler casing located at the top of the boiler structure

Magnolia Plant, Units 1 through 5. Magnolia Units 2 and 3 were on line at the time of the earthquake and remained on line throughout the earthquake. A fuel-oil gage line ruptured in Unit 3, spraying oil on the front face of the furnace and on the surrounding floor. This caused a drop in the fuel-oil pressure to the burners.

After the earthquake, the system load from the outside grid began to increase the demand on the power generating stations remaining on line. This increased load on the small Magnolia units forced them to exceed their generating capacity. The increasing demand, combined with the reduced fuel-oil pressure and subsequent loss in steam pressure, convinced the watch engineer that he had to manually trip both units of the Magnolia plant off line. All power to the station was consequently lost. The main turbines on Magnolia Units 2 and 3 were kept rolling since they were equipped with steam-driven lubrication oil pumps supplied from the residual steam in the boilers. About half an hour after the earthquake, station power was restored from the outside grid. A few minutes later, plant engineers discovered the tripped relays on the Magnolia Unit 5 controls, reset them, and started the gas peaking plant. Magnolia Units 2 and 3 were brought back on line about three hours after the earthquake.

Damage was noted at the Magnolia Plant as follows:

- An unanchored demineralized water tank in the plant yard shifted, breaking attached piping connections.

- Six bolts at the base of the gantry crane were broken.

- The boiler brickwork on one of the furnaces cracked.

- A fuel-oil gage line in Unit 3 broke.

- A 2-inch-diameter pipe connecting to the Unit 3 main cooling water line cracked. (The plant operators thought this was probably a minor leak since it did not impair restarting the plant.)

- The plant's demineralizer cation tank shifted on its supports.

3.3.4 Glendale Power Plant - The City of Glendale Power Plant is located on the southern edge of the San Fernando Valley (Figure 3-2). In 1971, the plant had five generating units with a total capacity of 148 MW. The individual capacities for Units 1 through 5 are 20, 20, 20, 44, and 44 MW; the units were constructed in 1941, 1947, 1953, 1959, and 1964, respectively. The plant is situated in a flat area of recent alluvia on the north bank of the Los Angeles River.

Motion. The Glendale plant is located about 16 miles from the epicenter of the San Fernando earthquake and about 8 miles from the causative fault. There was no ground breakage at the plant. The peak horizontal ground accelerations are estimated to be 0.30g in the east-west direction and 0.25g in the north-south direction, based on the record from 633 Broadway, Glendale. The averaged response spectrum compared to the Regulatory Guide 1.60 spectrum for 0.20g is presented in Figure 3-6. The comparison indicates that the spectrum for the actual earthquake envelops the design response spectrum for frequencies above 22 Hz. For frequencies below 22 Hz, the two curves follow each other relatively closely.

Performance. Units 3, 4, and 5 were in operation at the time of the earthquake and they continued to generate power during and after the earthquake. One and one-half hours after the earthquake, all three units were tripped because of system disturbances in the entire Los Angeles area grid. Units 3 and 4 were brought back on line 2 minutes later; Unit 5, 9 minutes later. The reported damage in the entire facility was limited to breaks in two small water lines.

3.4 The Imperial Valley Earthquake

On October 15, 1979, a destructive earthquake shook the Imperial Valley of California. The quake, which occurred at 4:16 p.m., had a Richter magnitude of 6.6. Its epicenter was on the Imperial fault 10 miles east of Calexico. There was no loss of life, but there was damage to the towns and of El Centro, Imperial, Brawley, and Calexico, and their surrounding areas.

The affected area (Figure 3-7) experienced a similar destructive earthquake nearly 40 years earlier on May 18, 1940. The October 15, 1979, earthquake was instrumented by a network of strong-motion accelerographs. About 50 records were made, at distances from 4 to 122 miles from the epicenter. One instrument, located 0.6 miles from the fault and 4 miles from the epicenter, recorded a vertical acceleration of 1.74g.

In general, the earthquake did not cause extensive building damage in or around El Centro. The exception was the six-story Imperial County Services Building, which was severely damage.

3.4.1 El Centro Steam Plant - The El Centro Steam Plant is the principal electric power generating facility of the Imperial Irrigation District. The plant has four oil or natural gas fired boilers. Units 1, 2, and 3 were designed by Gibbs and Hill and were built in 1949, 1952, and 1957 respectively. Unit 4 was designed by Fluor and was built in 1968. Units 1 through 4 have capacities of 20, 33, 44, and 80 MW, respectively. The plant is located in a flat area on very deep alluvial deposits composed primarily of stiff to hard clay.

Motion. The plant is about 3 miles from the causative fault and about 15 miles from the epicenter. There was no ground breakage at the site. The nearest strong-motion record was made 4 miles west of the fault trace, about 0.6 miles from the plant. The recorded peak accelerations are 0.51g in the north-south direction, 0.37g in the east-west direction, and 0.93g in the vertical direction. The average horizontal spectrum compared to the Regulatory Guide 1.60 spectrum for 0.20g is shown in Figure 3-8. The

comparison indicates that the spectrum for the actual earthquake envelops the design response spectrum.

Performance. Units 1 and 2 were down for maintenance at the time of the earthquake. Because of disturbances in the transmission system, Units 3 and 4 tripped off line. Unit 3 continued operating to supply the in-house load, but Unit 4 shut down. When the transmission system settled down, it was not possible to restore Unit 4 to service immediately because of a malfunction (not necessarily seismically-induced) at the unit substation which powers the cooling tower fans and circulating water pump valves. This malfunction was cleared manually.

Both Units 3 and 4 developed leaks in the cooling water piping for the hydrogen cooler and the exciter cooler. These are welded steel pipes, 3 and 4 inches in diameter; leaks occurred at heavily corroded spots and at a Victraulic couplings which pulled apart. Also, an insulating Vallett coupling on a 2 inch line in the Unit 4 exciter cooler sprang a leak. By expedient plugging of leaks, Unit 3 was kept in service. Because the load was abnormally low for several hours, Unit 4 was kept out of service long enough to make repairs. Unit 3 was restored to service 15 minutes after the main shock. Unit 4 was back in service 5 hours later.

Other damage at the plant included the following:

- Several anchor bolts stretched on the stacks for Units 1, 2, and 3.

- Several anchor bolts stretched on the transformers. One transformer slid 2 inches.

- An unanchored turbine oil cooler slid on its pedestal.

- Two grounding insulators failed.

- A lightning arrestor in the switchyard broke.

- The guide bracing on a mud drum broke.

- The air-operated saturated steam-to-evaporator valve was damaged when the cast iron yoke sheared due to impact of the operator diaphragm on an adjacent structural steel frame girder.

3.5 The Coalinga Earthquake

The Coalinga earthquake occurred on May 2, 1983, at 4:42 p.m. and had a Richter magnitude of 6.7. The epicenter was located about 9 miles northeast of the town of Coalinga (population 7,000), on the west side of California's San Joaquin Valley. The main shock was followed 3 minutes and 27 seconds later by an aftershock of magnitude 5.6, which added to the damage. There were 61 aftershocks of magnitude exceeding 3.0 within the first 24 hours following the main shock. By August 1, 1983, the sequence of aftershocks included 147 earthquakes of magnitude exceeding 3.0, and 28 earthquakes of magnitude exceeding 4.0. The aftershock of July 22 had a magnitude of 6.0.

The strong motion record nearest to the main event epicenter was made by an array of U.S. Geologic Survey/U.S. Bureau of Reclamation accelerometers at the Pleasant Valley Pumping Plant, located about 6 miles northeast of the epicenter and about 15 miles northeast of the town. Ground acceleration records were taken in the plant switchyard and in the plant basement. Corrected peak ground accelerations of 0.59g and 0.51g were recorded in the horizontal directions in the switchyard, and 0.37g in the vertical direction. In the plant basement, corrected peak horizontal accelerations of 0.31g and 0.27g were recorded, with 0.22g in the vertical direction; the reductions in acceleration indicate a filtering of free-field motion into the building.

The town of Coalinga was severely affected by the earthquake. Old unreinforced masonry buildings and old wood-frame houses suffered the most damage. The central area of the town consisted primarily of old unreinforced brick and concrete block one- and two-story buildings. Most of the

masonry structures partially or completely collapsed or were irreparable and have since been demolished. It was extremely fortunate that no one was killed; however, several injuries occurred. Older wood-frame houses suffered heavy damage, and one-third of these structures were severely damaged. The newer houses performed well; damage was usually limited to the collapse of masonry chimneys and veneers. The performance of steel-frame industrial buildings in and around town was generally good.

The Coalinga earthquake occurred within the largest on-shore oil production region in the state of California. A number of oil wells and oil production facilities are located in the immediate vicinity of the epicenter. EQE engineers surveyed the Coalinga area over a period of several days immediately following the May 2 earthquake. Later, several more detailed investigations of the facilities near the epicenter were conducted.

Figure 3-9 is a map of the Coalinga area showing the various industrial sites investigated in the first days following the earthquake; the epicenter of the May 2 event is shown near the junction of highways 198 and 33.

The following facilities, located in the epicentral area (near-field) of the Coalinga earthquake are of primary interest to this study:

- Pleasant Valley Pumping Plant
- Shell Water Treatment Plant
- Union Oil Butane Plant
- Main Oil Pumping Plant
- Coalinga Water Filtration Plant
- San Luis Canal Pumping Stations

Motion. A number of strong motion records were taken during the main event at varying distances from the epicenter. The measured peak ground accelerations can, therefore, be compared with the mean values estimated from various empirical formulas for a resulting magnitude 6.7 event. The highest acceleration recorded in the Coalinga area is 0.59g. Pending more detailed studies of ground motion for the Coalinga event, 0.6g is the

highest mean peak ground acceleration assumed for the reviewed facilities in the epicentral area.

3.5.1 Coalinga Epicentral Area:

The Pleasant Valley Pumping Plant is located near the San Luis Canal about 1 mile northeast of the junction of highways 33 and 5. The plant was constructed in 1969 by the U.S. Bureau of Reclamation to supply water to the Coalinga area for agricultural and domestic use. The plant consists of a one-story rigid steel-framed building supported by a massive reinforced-concrete basement and raft foundation. The pumping plant draws water from the San Luis Canal through a branch canal, lifts the water about 200 feet, and discharges it into the Coalinga Canal about 1 mile west of the plant. The plant is situated on an alluvial plane that slopes gently eastward into the San Joaquin Valley.

Motion. Strong motion monitors, located in the station switchyard and in the basement of the station, provided the closest ground motion records of the May 2 event. There was no ground breakage at the site. A peak corrected ground acceleration of 0.59g was recorded in the switchyard and 0.31g was recorded in the basement. The averaged horizontal response spectrum taken at the plant switchyard is compared to the Regulatory Guide 1.60 spectrum for 0.20g in Figure 3-10. The comparison indicates that the spectrum from the actual earthquake envelops the Regulatory Guide 1.60 spectrum.

Performance. The pumping plant was in operation at the time of the May 2 earthquake. Power was lost to the plant for about half an hour. Lighting and other vital functions were supplied to the plant by the emergency battery system. The pumps shut down when power to the plant was cut off. The plant operator who had been on duty at the time was interviewed. His main concern at the time of the earthquake was the light fixtures that had fallen from the ceiling of the main operating bay. The fixtures struck the pump control panels and buswork. A brief inspection of the control panels by the operator indicated that there was no serious damage. The plant was restarted about 40 minutes after the earthquake.

Other damage to the plant included the following:

- About 20 stud bolts on a rail supporting a 20-ton crane broke at the expansion joint and the near crane. The crane remained on its rails.
- Large transformers located adjacent to the building broke from their anchor bolts and slid. The transformers remained operational.
- Stretched anchor bolts were found on a vertical backwash tank.
- One monitor in the main control panel has malfunctioned intermittently since the earthquake.
- A discharge gate into the Coalinga canal near the plant failed to operate after the earthquake due to ground slumping on the canal embankment which severed the power conduit to the gate.

The Shell Water Treatment Plant is located in the foothills north of Coalinga, about 4 miles west of the epicenter of the earthquake. The plant was built in 1981. Its primary purpose is to demineralize and filter water before it is injected as steam into oil wells in the area. Typical equipment includes ground-mounted, unanchored oil storage tanks, pressure vessels, demineralizers, filters, vertical tanks, horizontal water and oil pumps, large heat exchangers, air compressors, extensive piping and air-operated valves. The main control house, a one-story steel building, contains two large motor control centers adjacent to the control room and office. The plant was seriously damaged by the May 2 earthquake, primarily due to sliding (as much as 10 inches) of unanchored tanks, pressure vessels and demineralizers.

Motion. The water treatment plant is about 9 miles southwest of the nearest ground motion record made at the Pleasant Valley Pumping Plant. The effects and damage from the earthquake at and near the Shell plant

indicate that the motion there was stronger than at Pleasant Valley. A peak ground acceleration of 0.60g is probably a low estimate for the site.

Performance. Power was lost to the plant during the earthquake and all operating equipment was shut down. Most of the damage centered around the sliding equipment and associated piping. Damage to the plant included the following:

- Oil heaters failed their anchors and slid as much as 2 inches.
- Tall vertical fiberglass brine tanks cracked at their bases and at piping attachments. Rocking of these tanks caused stretching and failure of anchor bolts.
- Many tanks and other pieces of large equipment, such as MCCs, showed signs of rocking in loosened anchor bolts and spalled grout around equipment supports.
- Numerous heavy equipment items (unanchored), including tanks, slid as much as 10 inches on concrete foundation pads, tearing short sections of attached line.
- One ground-mounted oil storage tank suffered an "elephant foot" buckle near its base.

The Union Oil Butane Plant is located on Calaveras Road, northeast of Coalinga, about 2 miles southeast of the epicenter. The plant extracts gas from the nearby oil wells, separates ethane, butane and propane by a cryogenic liquefaction process, and reinjects the gas into the wells. The original portion of the plant was constructed in 1946. It underwent substantial expansion in 1981 and most of the equipment is new. The facility includes a cryogenic gas liquification plant and a compressor plant for reinjection of gas into oil wells.

Motion. The plant is located about 2 miles from the epicenter; the Pleasant Valley Pumping Plant record is about 6 miles from the epicenter.

The effects of the earthquake on the plant site, structures, and equipment indicate that the motion was much stronger than at Pleasant Valley. The operators on duty at the time reported having difficulty standing. For the purposes of this study, the averaged horizontal PGA for the site is estimated to be 0.60g and the average response spectrum is scaled from the Pleasant Valley Pumping Plant spectrum.

Performance. The plant shut down during the May 2 earthquake due to the actuation of vibration sensors on the steam-turbine generators, which provide a power source for large equipment. Shutdown of all equipment was normal as far as the operators could observe. The plant remained down for 10 days for detailed inspection and repair. Damage to the plant included the following:

- A heat exchanger, mounted on a steel and masonry support structure stretched its anchor bolts, but did not fall.
- One main gas line, mounted on a steel column, jumped from its spring pedestal support.
- Three vertical storage tanks rocked sufficiently to break their anchor clips.
- The one-inch vent lines on the propane/butane tanks broke in two places due to sliding and rocking of tanks.
- Piping supported on overhead racks or high steel columns displaced up to 6 inches on supports.
- One-inch-diameter piping broke at three locations in the pneumatic control system of the gas compressor plant.

The Main Oil Pumping Plant is located on a flat site on Shell Road about 4 miles southwest of the epicenter. The pumping plant is the main collection point for oil that is produced in the Coalinga area and pumped into the main pipeline toward the refineries in the San Francisco Bay Area. The

pumping plant includes two one-story concrete block buildings that contain the control house and shop. The plant has seven large ground-mounted oil and water storage tanks. Oil is discharged into the main line by two large turbine-powered pumps. The facility contains a large amount of peripheral equipment, including exposed and buried piping, oil and water pumps, heat exchangers, motor- and air-operated valves, motor control centers, and switchgear. The plant was constructed in 1967 and expanded in 1980.

Motion. The closest record to the plant was made at the Pleasant Valley Pumping Plant, where corrected peak horizontal accelerations of 0.59g and 0.51g were recorded. The effects and damage from the earthquake, and the fact that the plant is closer to the epicenter than Pleasant Valley, indicate that the motion at the Main Oil facility was stronger than at Pleasant Valley. The site suffered extensive ground cracking and settlement. The operator on duty during the earthquake reported that he was knocked off his feet as he tried to run from the control building. An averaged horizontal peak ground acceleration of 0.60g is estimated for the Main Oil Pumping Plant.

Performance. The plant was one of the most seriously damaged facilities investigated after the May 2 earthquake. Power to the plant was lost for 50 hours. Other plant damage included the following:

- The switchyard transformer supplying power to the plant pulled its anchor bolts and slid far enough to break electrical connections.

- Three oil heaters slipped their anchorage and slid several inches.

- One MCC pulled its anchor bolts and slid several inches.

- A 4 kV switchgear assembly sheared its anchor bolts and slid into a conduit flange embedded in the floor. The bottom channel and cabinet walls were dented but the switchgear remained operational.

- An instrument rack in the switchgear room failed its anchor bolts, causing the instruments to slide from their mountings.

- Unanchored portions of the control board moved.

- Two unanchored computer cabinets overturned.

- One unanchored MCC slid several inches.

- A battery rack lacking lateral restraint, lost its batteries.

The Coalinga Water Filtration Plant is located on the Coalinga canal 3 miles east of the earthquake epicenter. The plant filters and chlorinates the domestic water supply for the town of Coalinga and the surrounding oil fields. A one-story, reinforced, concrete-block building houses the control room, offices, a testing laboratory, and various storage rooms. Several large vertical pumps are housed in a seperate building. The plant also includes concrete basins, a small substation, a vertical backwash tank, and miscellaneous small pumps and valves.

Motion. The filtration plant is located 7 miles south of the Pleasant Valley Pumping Plant, where the nearest ground motion record was made. As at other sites in the data base, the Pleasant Valley switchyard averaged horizontal ground motion spectrum, scaled to a peak ground acceleration of 0.60g, is considered representative of the seismic motion experienced at the filtration plant.

Performance. The filtration plant suffered only minor damage during the May 2 event. The plant lost power and all equipment shut down. Power was restored after about 30 minutes, and the plant was restarted. All electrical systems operated normally in spite of sliding up to three inches. Other damage included the following:

- The vertical backwash tank rocked on its base and stretched its anchor bolts. This motion loosened the flanged pipe connections and cracked some of the bottom-to-side welds.

- The substation transformer and switchgear slipped from its anchor clips and slid about 2 inches, cracking the plastic conduit emerging from the ground but not damaging the wires in the conduit.

- Unanchored chlorine cylinders in the chlorine storage room slid several inches, but attached piping was not broked.

- Several recorders on the main control board slid out of their mounting drawers, but did not fall. They were operable when pushed back into place.

3.5.2 San Luis Canal Pumping Stations - The San Luis Canal is the local branch of the California Aqueduct in the Coalinga area. Pumping stations are located at one mile intervals along the canal. These stations draw water from the canal to feed buried irrigation piping to the surrounding farms. Each pumping station includes four or five large vertical turbine pumps with associated discharge piping and motor-operated valves. The larger pump motors range in size from 300 to 900 horsepower. Each station includes a tall vertical surge tank. Power is supplied to the equipment through a transformer and switchgear mounted in outdoor steel enclosures. The stations are unmanned, and are monitored and controlled from a central headquarters by programmable controllers at each station.

Motion. Approximately 20 pumping stations were close enough to the earthquake epicenter to experience ground motion in excess of 0.20g. Peak ground accelerations for the stations investigated range from 0.30 to 0.40g. These estimates are based upon the Pleasant Valley Plant ground motion record and correspond to each Station's distance from the epicenter (Figure 3-11).

Performance. The pumping stations are remotely controlled through a central location about 19 miles north of Coalinga. The pumps operate intermittently according to the irrigation demand in the immediate area. At the time of the earthquake, some pumps were in operation. Power to the pumping stations was temporarily lost during the earthquake and all

operating equipment shut down. According to reports by the operators, all pumps and motor-operated valves were functional following the earthquake. Damage to the pumping stations included the following:

- Stretched anchor bolts on the vertical surge tanks at most stations.

- Buried piping failed due to local ground displacement or settlement at one station.

- An unanchored switchyard transformer slid about 5 inches on a concrete pad, breaking its overhead connection.

- Rocking caused spalling at the concrete base of pumps.

- Over a period of weeks following the initial earthquake, and during the severe aftershocks, three pumps developed problems with worn bearings or leaking packings.

TABLE 3-1

SUMMARY OF SITES REVIEWED IN COMPILING THE SEISMIC EXPERIENCE DATA BASE

Earthquake	Facility	Type of Facility	Estimated Peak Ground Acceleration (g) **
San Fernando Earthquake, 1971	Sylmar Converter Station	Large electrical substation for converting high voltage DC power transmitted over the Pacific Intertie to AC power for use in the Los Angeles area	0.50-0.75
	Rinaldi Receiving Station	Large electrical substation	0.50-0.75
	Valley Steam Plant	Four-unit gas-fired power plant	0.30
	Burbank Power Plant	Six-unit gas-fired power plant	0.32
	Glendale Power Plant	Five-unit gas-fired power plant	0.27
	Pasadena Power Plant	Four-unit gas-fired power plant	0.18
	Saugus Substation	Electrical substation	0.35
	Vincent Substation	Electrical substation	0.15
Point Mugu Earthquake, 1973	Ormond Beach Power Plant	Large two-unit oil-fired power plant	0.20
	Santa Clara Substation	Electrical substation	0.10
Ferndale Earthquake, 1975	Humboldt Bay Power Plant	Two gas-fired units, one nuclear unit	0.30 *
Santa Barbara Earthquake, 1978	Goleta Substation	Electrical substation	0.26 *
	Ellwood Peaker Plant	Small gas turbine plant	0.35
Imperial Valley Earthquake, 1979	El Centro Steam Plant	Four-unit gas-fired power plant	0.42 *
	Drop IV	Two-unit hydroelectric plant	0.40
	Magmamax Geothermal Plant	Small geothermal power plant	0.30
Humboldt Earthquake, 1980	Humboldt Bay Power Plant	Two gas-fired units, one nuclear unit	0.25

* Ground acceleration measured by an instrument at the site
** Average of two horizontal components

TABLE 3-1 (Continued)

Earthquake	Facility	Type of Facility	Estimated Peak Ground Acceleration (g) **
Coalinga Earthquake, 1983	Main Oil Pumping Plant	Pumping station feeding oil pipeline from Coalinga area	0.60
	Union Oil Butane Plant	Petrochemical facility to extract butane and propane from well waste gas	0.60
	Shell Water Treatment Plant	Petrochemical facility to demineralize water prior to steam injection into oil wells	0.60
	Coalinga Feed Lot	Feed mill for cattle yard	0.60
	Coalinga Water Treatment Plant	Potable water purification facility	0.60
	Amador Gas Metering Station	Instrumentation station on a natural gas pipeline	0.60
	Coalinga Nose Dehydration Station	Small plant for extracting moisture from natural gas	0.60
	Coalinga Substation No. 2	Electrical substation	0.60
	Shell Tank Farm No. 29	Oil Storage tank farm	0.60
	Pleasant Valley Pumping Plant	Pumping station to supply water from the San Luis to the Coalinga Canal	0.56 *
	Shell Dehydration Plant	Petrochemical facility for extracting water from oil	0.40
	Chevron Oil Cleaning Plant	Petrochemical facility for treating crude oil	0.40
	Coalinga Substation No. 1	Electrical substation	0.40
	San Luis Canal Pumping Stations (20)	Agricultural pumping stations taking water from the San Luis Canal	0.35
	Gates Substation	Large electrical substation	0.25
	Kettleman Compressor Station	Natural gas pipeline booster station	0.20

* Ground acceleration measured by an instrument at the site
** Average of two horizontal components

TABLE 3-1 (Continued)

Earthquake	Facility	Type of Facility	Estimated Peak Ground Acceleration (g) **
Morgan Hill Earthquake, 1984	United Technologies Chemical Plant	Large research facility for missile systems development	0.45
	IBM/Santa Teresa Facility	Large computer facility for software development	0.37 *
	San Martin Winery	Winery	0.35
	Wiltron Electronics Plant	Electronics manufacturing facility	0.35
	Metcalf Substation	Large electrical substation	0.40
	Evergreen Community College	Large college complex with self-contained HVAC and electrical power plants	0.20
	Mirassou Winery	Winery	0.20
	Gavilan College	Community College	0.12

* Ground acceleration measured by an instrument at the site
** Average of two horizontal components

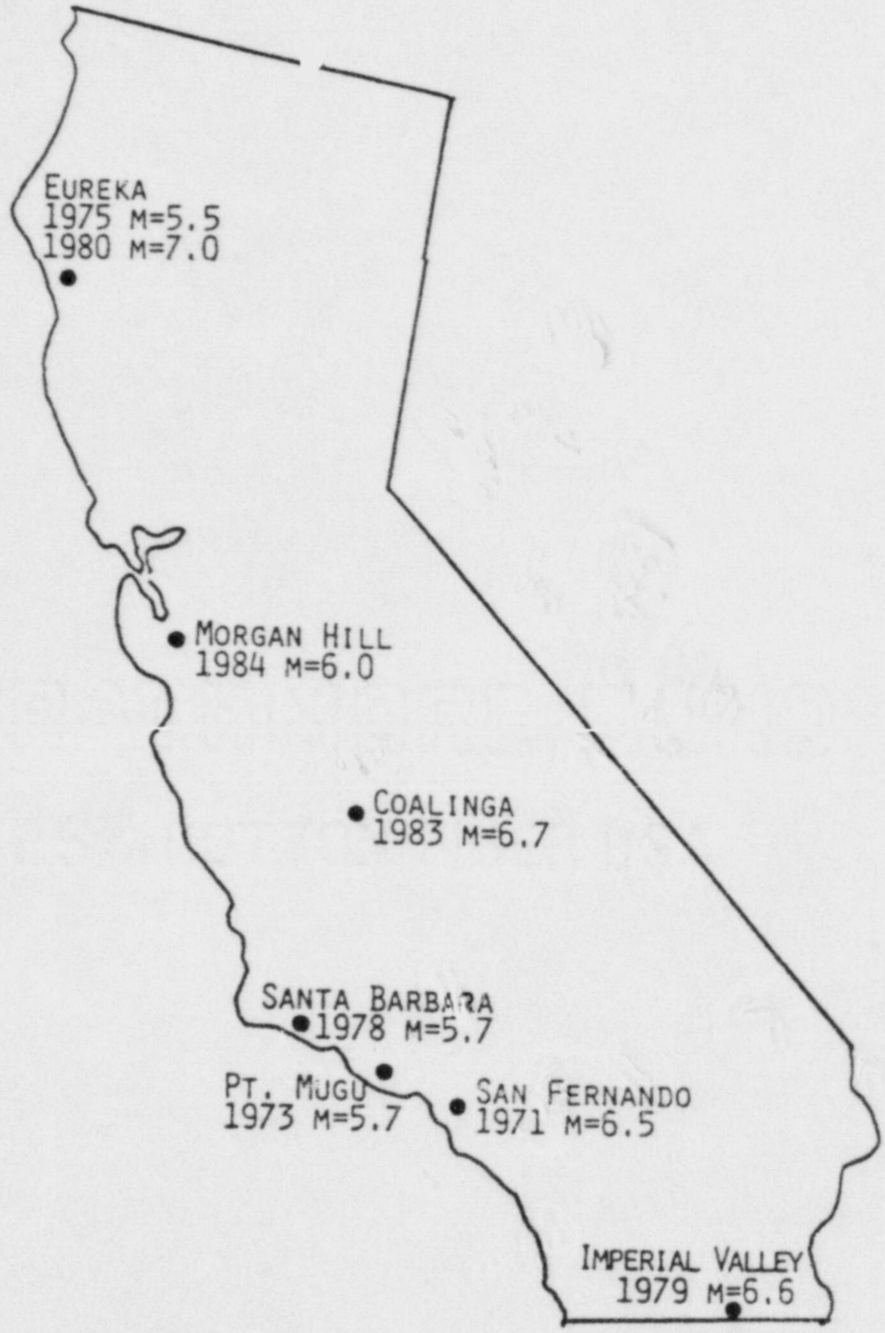


Figure 3-1: Earthquake location and magnitude for data base facilities.

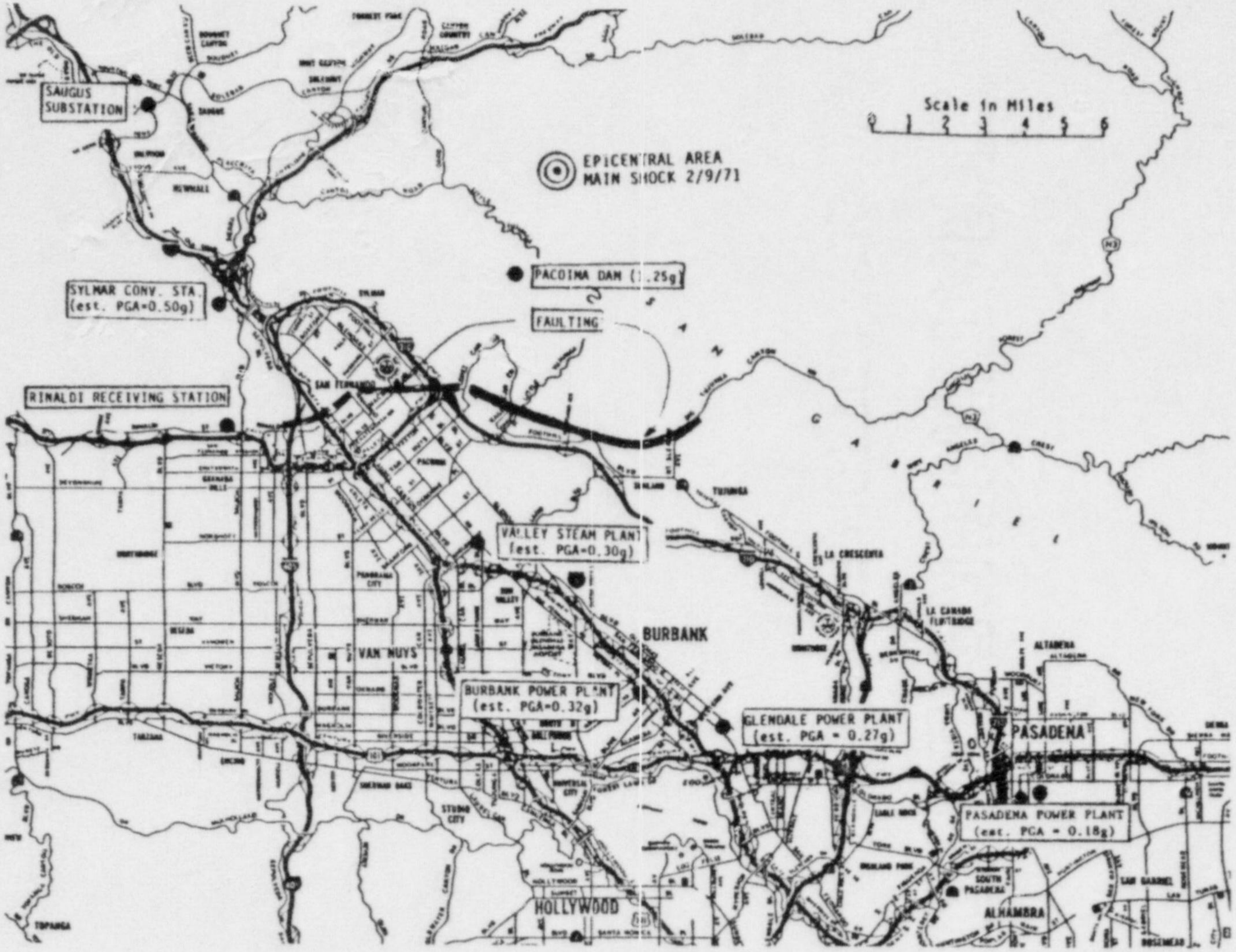


Figure 3-2: Map of the area affected by the San Fernando Earthquake.

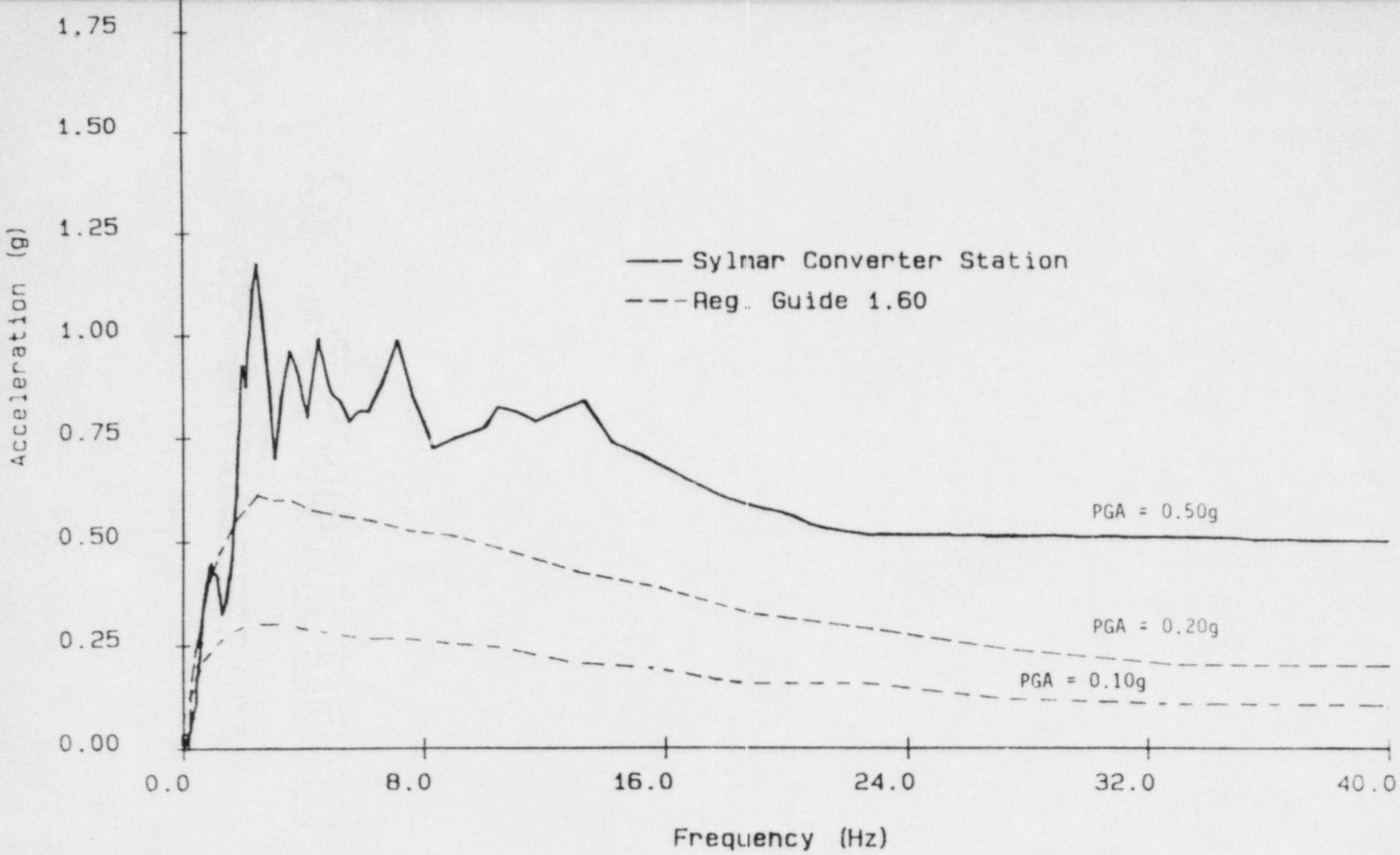


Figure 3-3: A comparison of the free-field response spectrum (average of two horizontal components) for the Sylmar Converter Station with the Regulatory Guide 1.60 Spectrum at 0.20g.

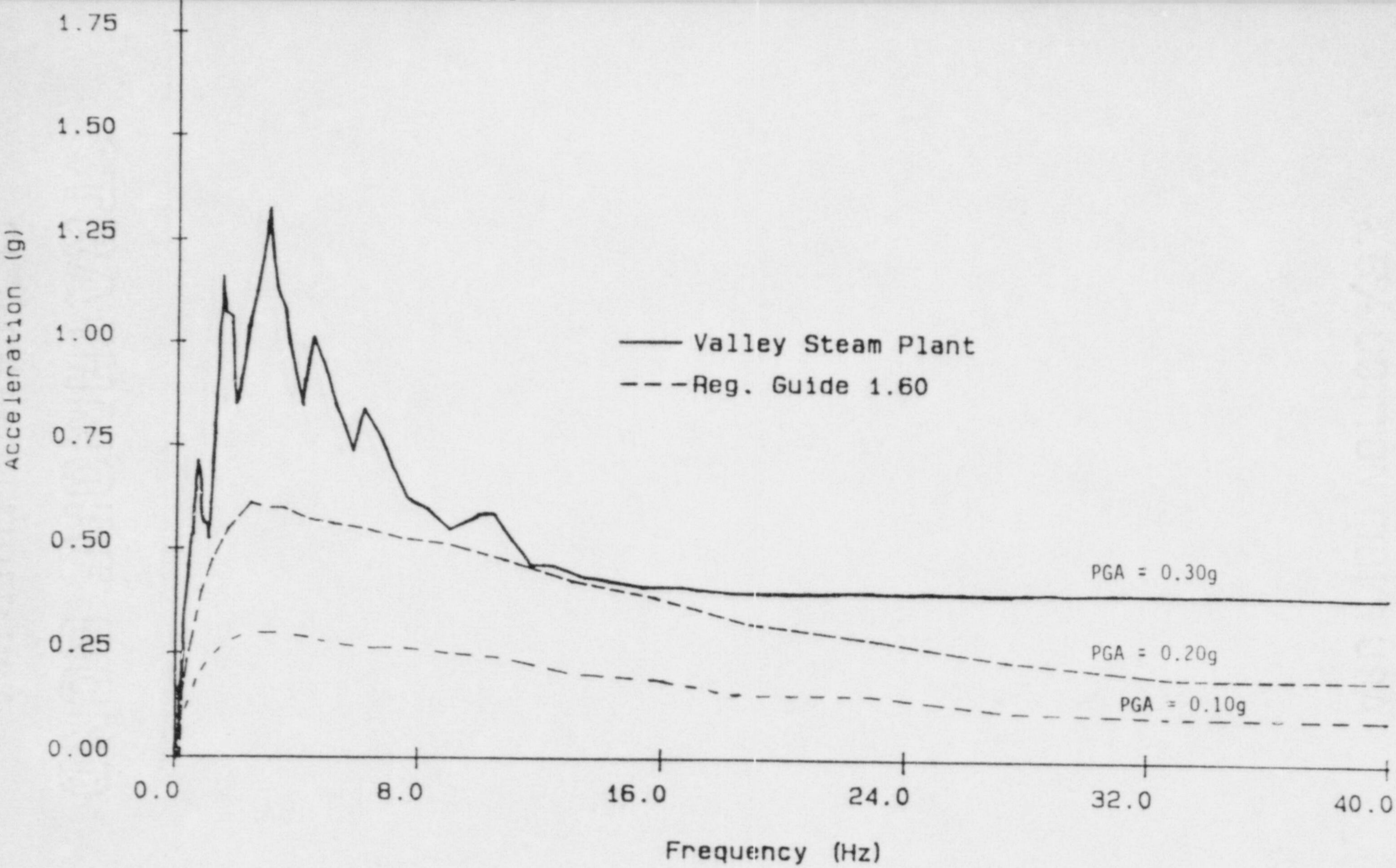


Figure 3-4: A comparison of the free-field response spectrum (average of two horizontal components) for the Valley Steam Plant with the Regulatory Guide 1.60 Spectrum at 0.20g.

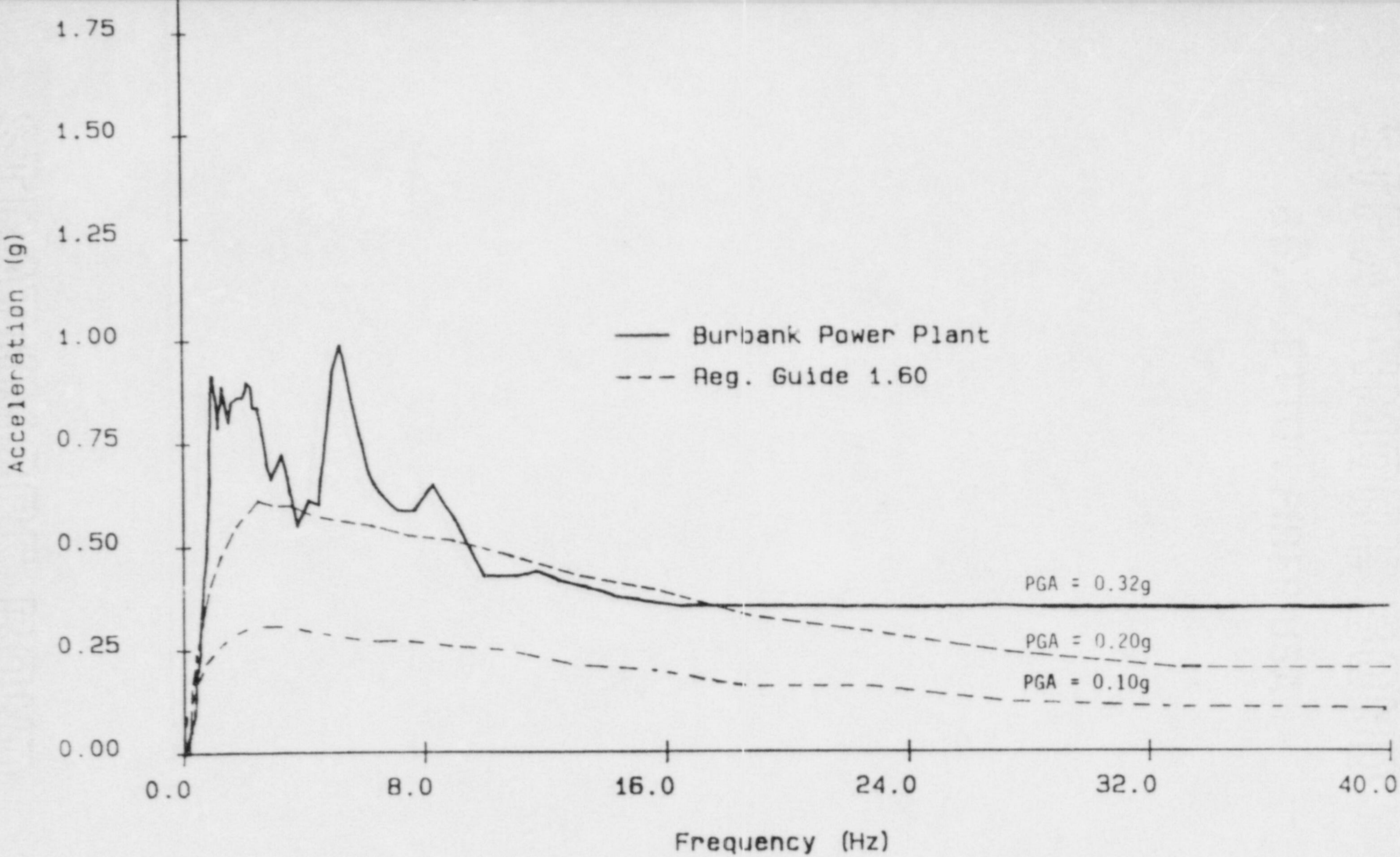


Figure 3-5: A comparison of the free-field response spectrum (average of two horizontal components) for the Burbank Power Plant with the Regulatory Guide 1.60 Spectrum at 0.20g.

EQE

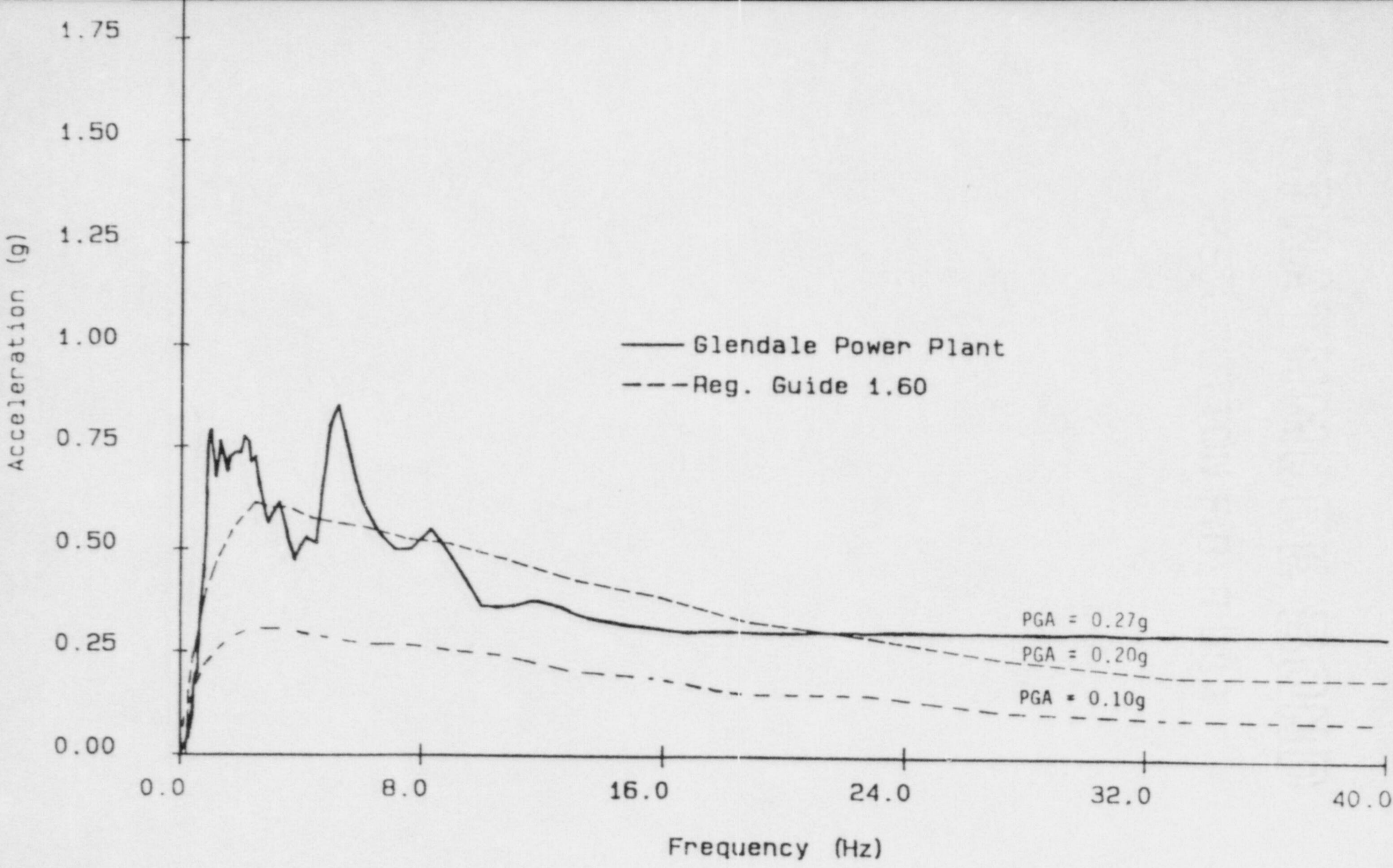


Figure 3-6: A comparison of the free-field response spectrum (average of two horizontal components) for the Glendale Power Plant with the Regulatory Guide 1.60 Spectrum at 0.20g.

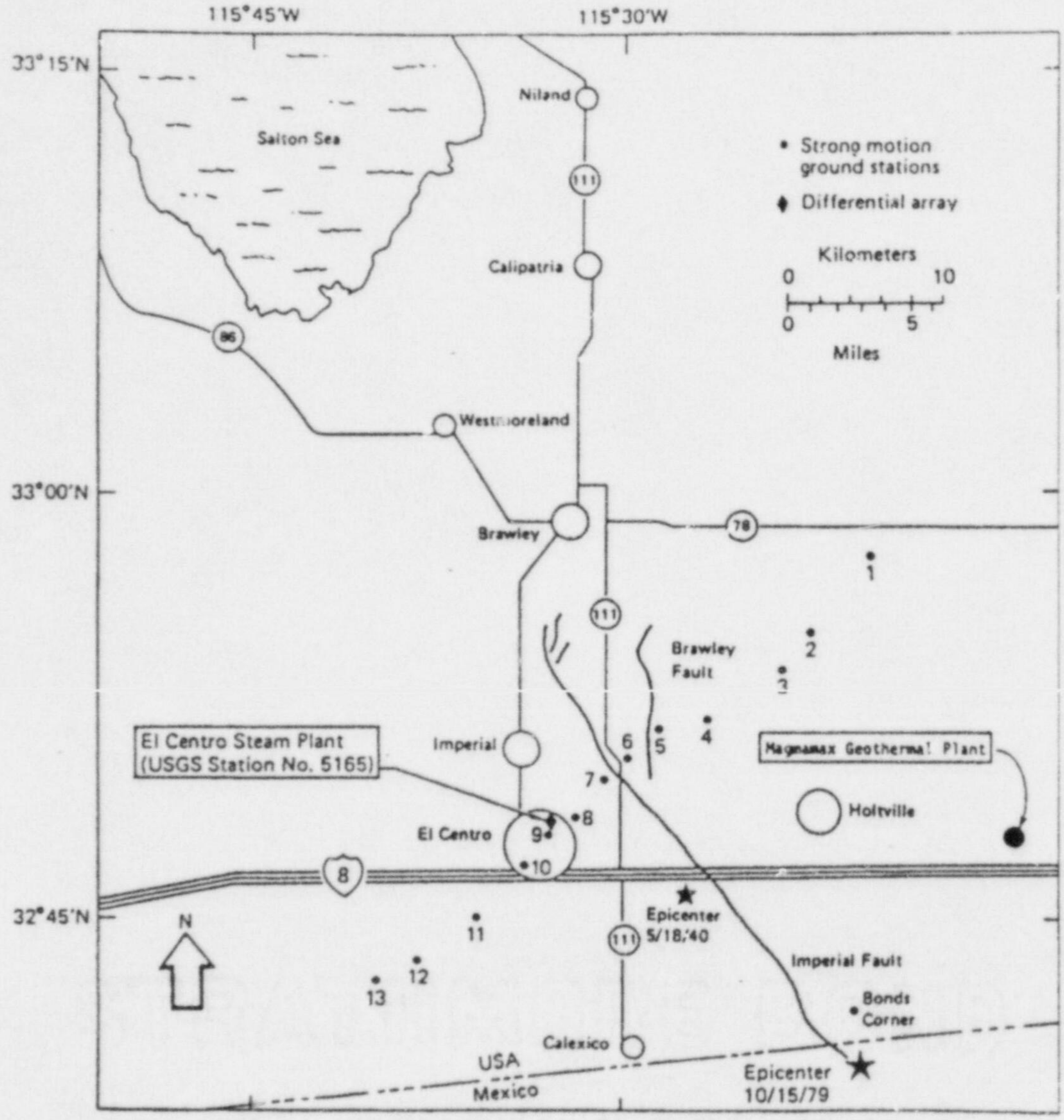


Figure 3-7: Map of the Imperial Valley, California, showing the ruptured segments of the Imperial fault, and the location of the El Centro Steam Plant. Also shown is the array of strong motion monitors that straddles the fault.

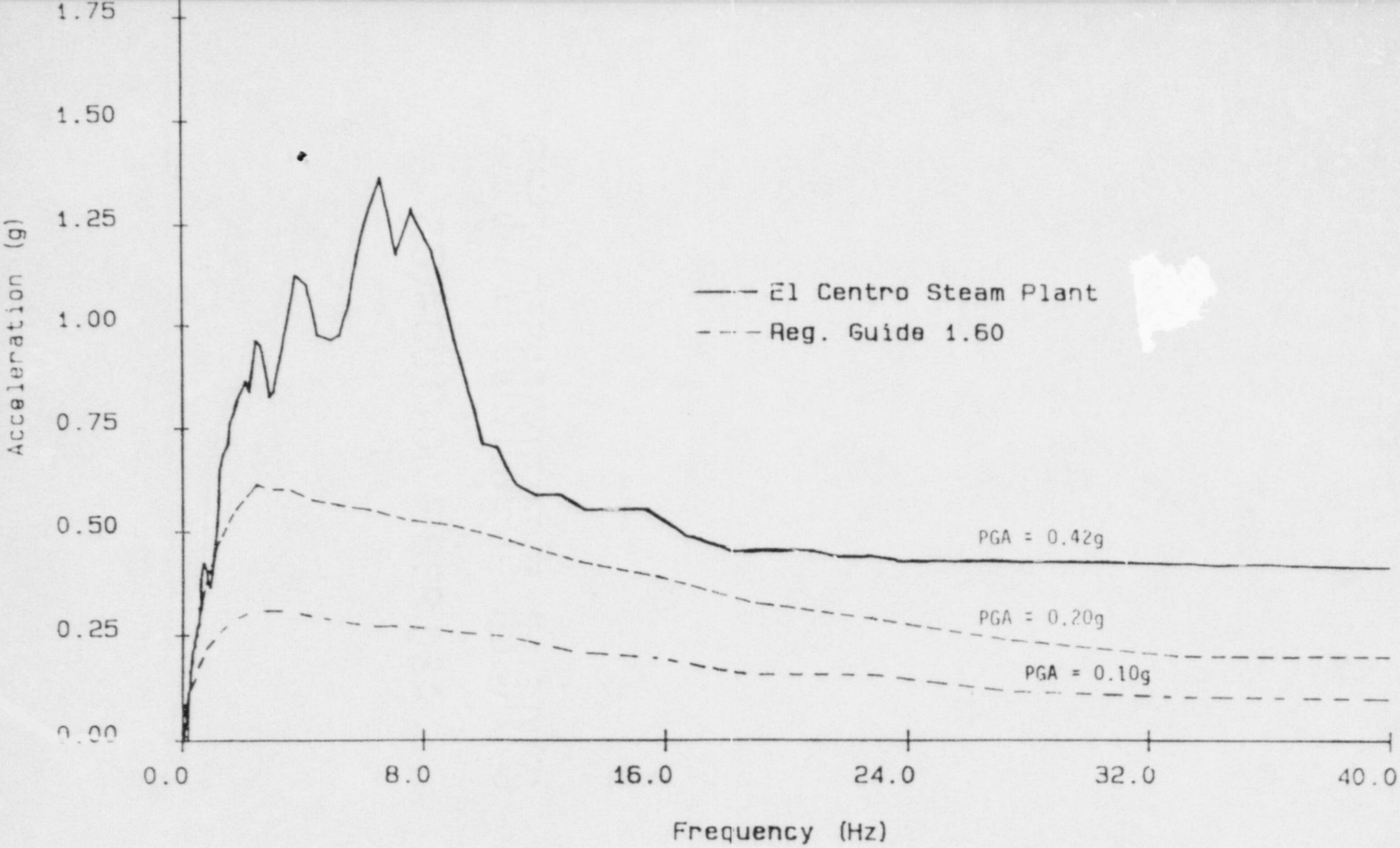


Figure 3-8: A comparison of the free-field response spectrum (av·rage of two horizontal components) for the El Centro Steam Plant with the Regulatory Guide 1.60 Spectrum at 0.20g.

EQE

Figure 3-9: Location of the epicenter of the Coalinga earthquake, the town of Coalinga, and the reviewed facilities.

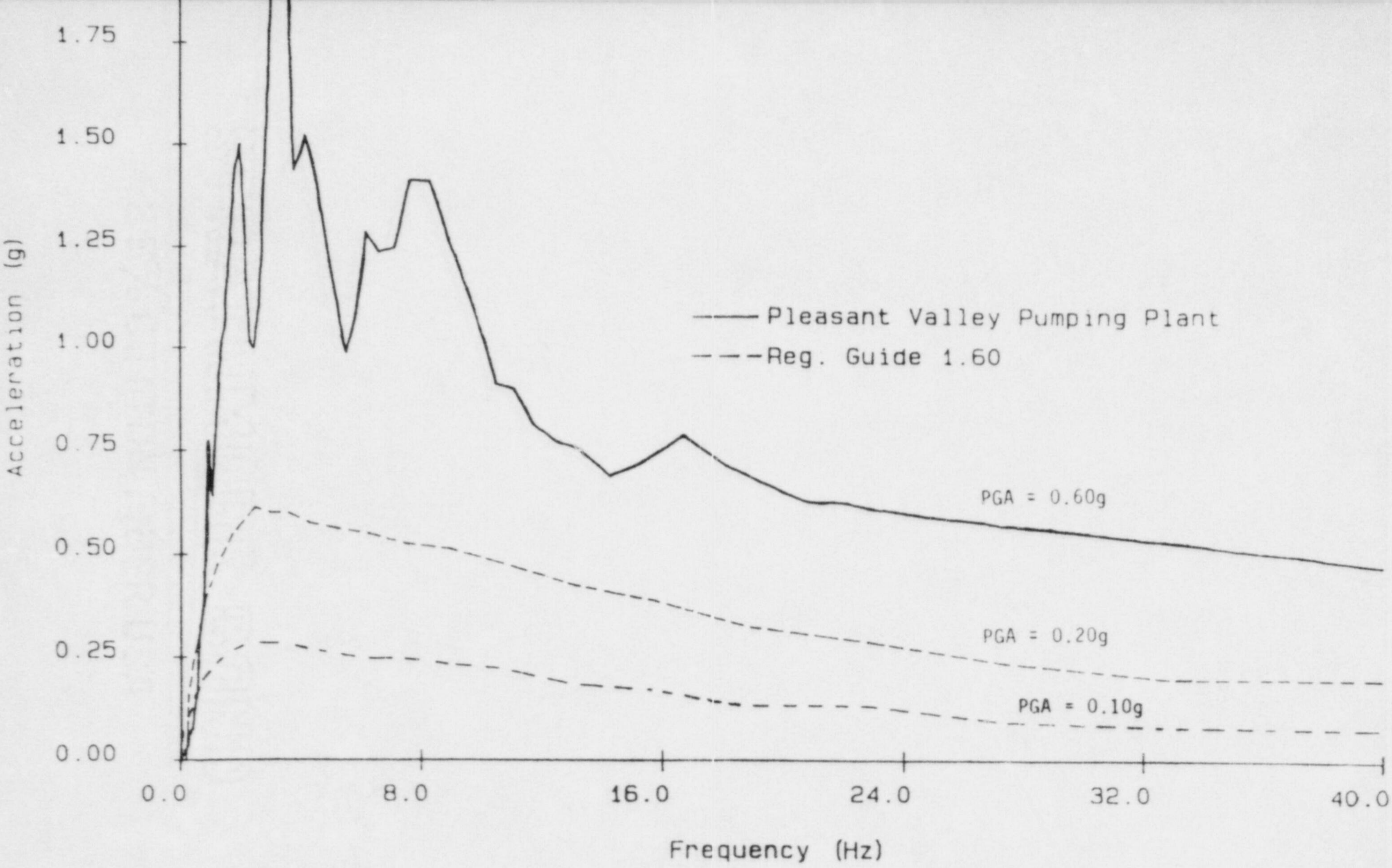


Figure 3-10: A comparison of the free-field response spectrum (average of two horizontal components) for the Pleasant Valley Pumping Plant with the Regulatory Guide 1.60 Spectrum at 0.20g.

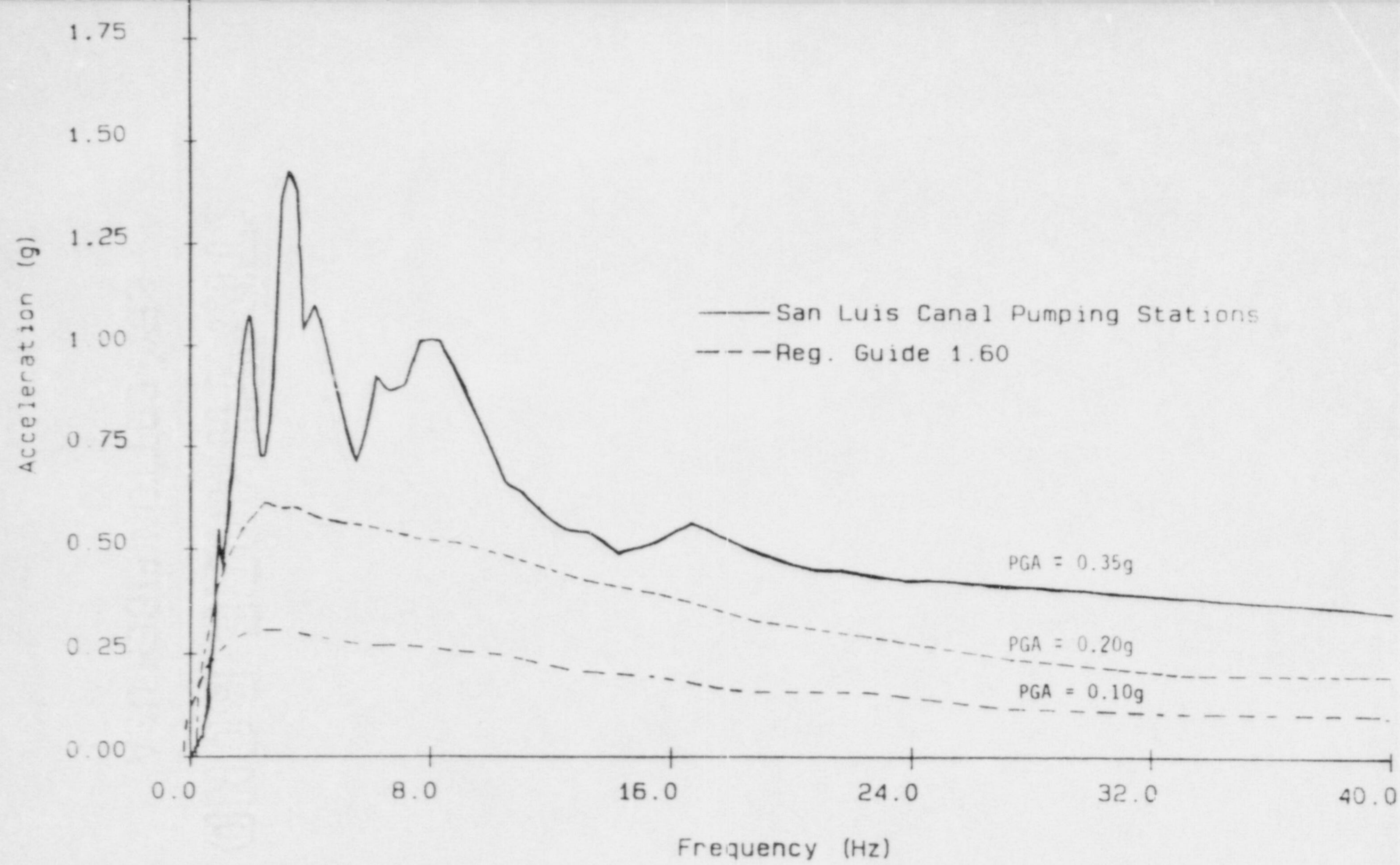


Figure 3-11: A comparison of the free-field response spectrum (average of two horizontal components) for the San Luis Canal Pumping Stations with the Regulatory Guide 1.60 Spectrum at 0.20g.

EQE

4. THE MAINE YANKEE NUCLEAR PLANT

Maine Yankee is a 825 MW pressurized water reactor, electric generating plant located near the mouth of the Back River in southeastern Maine. Figure 4-1 is a site plan view of the plant indicating structures containing critical equipment. Figures 4-2 through 4-11 include more detailed plan and elevation views of these structures, showing locations of critical equipment.

The seismic design of the plant was originally based on a plant-specific Housner-type ground motion response spectrum with a PGA of 0.10g. The NRC staff has questioned the adequacy of this design basis. For purposes of evaluation, the standard ground motion spectrum, specified in USNRC Regulatory Guide 1.60, will be used. The PGA to be used for the plant is a subject of controversy beyond the scope of this study. It is generally agreed, however, that the Regulatory Guide 1.60 spectrum, normalized to a PGA of 0.20g, would envelop any postulated seismic ground motion to be used as a basis for evaluating the adequacy of the Maine Yankee Plant.

Figure 4-12 plots the SSRAP Spectra Types A, B and C superimposed on the Regulatory Guide 1.60 Spectrum normalized to PGAs of 0.10g and 0.20g. As discussed in the subsequent chapters, the SSRAP Spectra represent the seismic motion bounds demonstrated by the past earthquake experience of typical mechanical and electrical equipment.

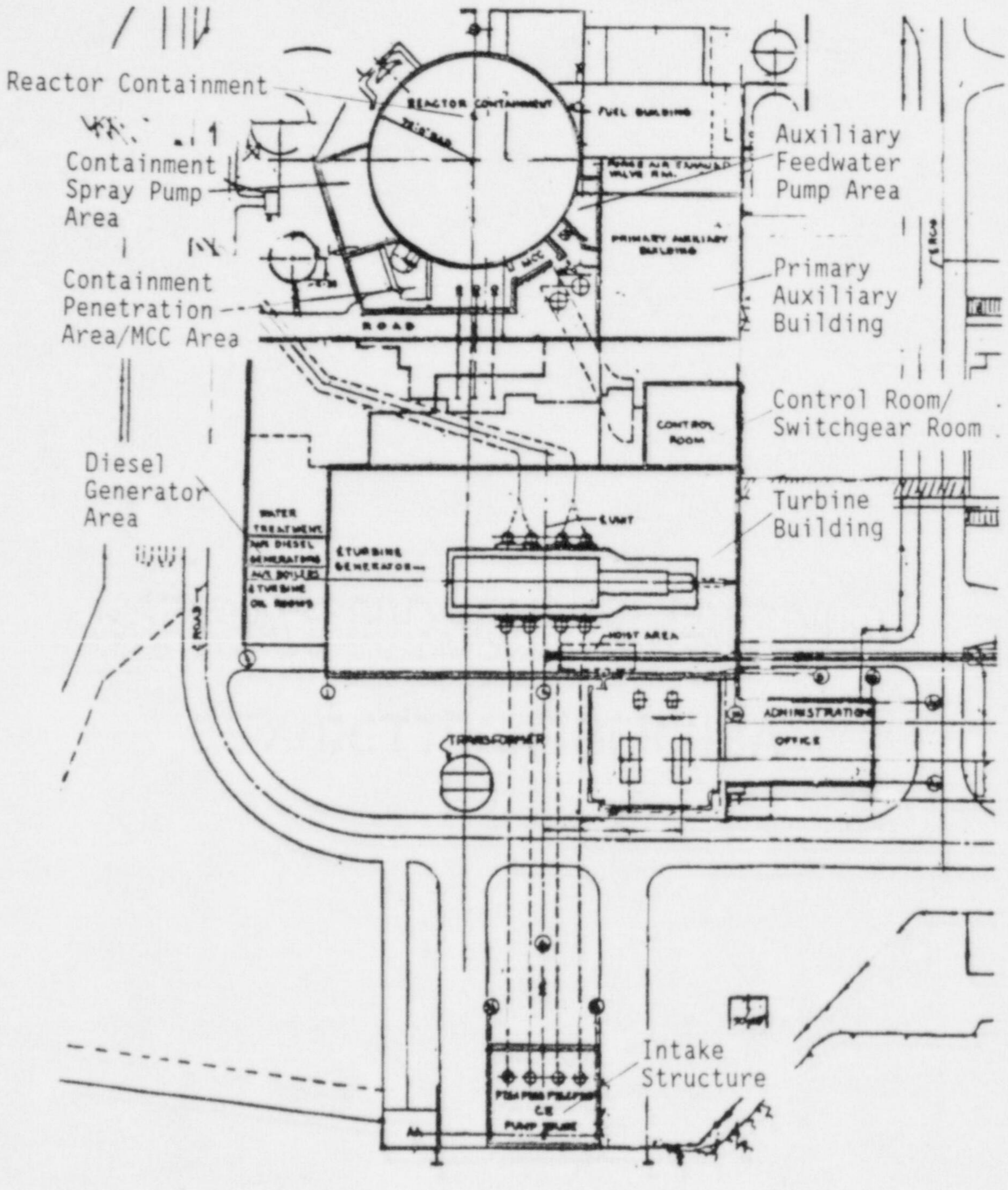
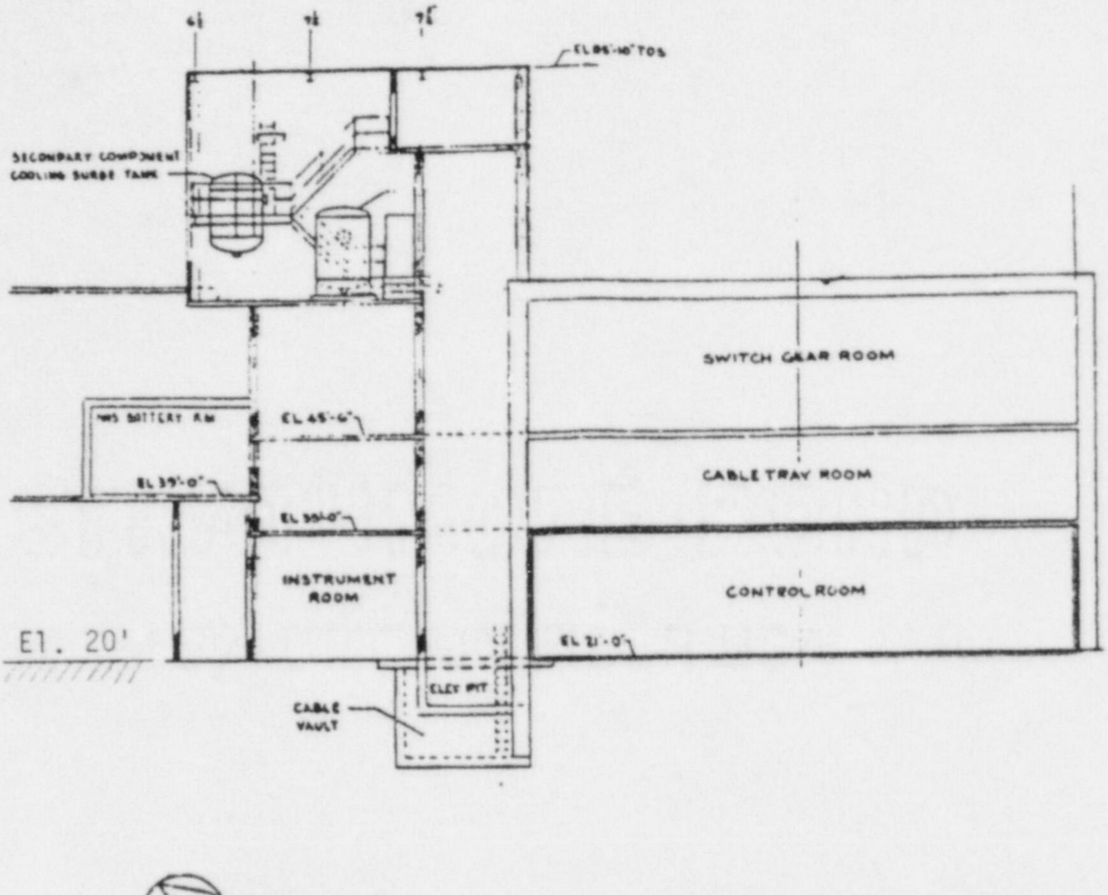


Figure 4-1: Plan of Maine Yankee Nuclear Power Plant



PLAN
MAIN CONTROL BUILDING
EL. 21'-0"

Figure 4-2: Elevation and Plan of the Main Control Building, including Switchgear and Cable Tray Rooms.

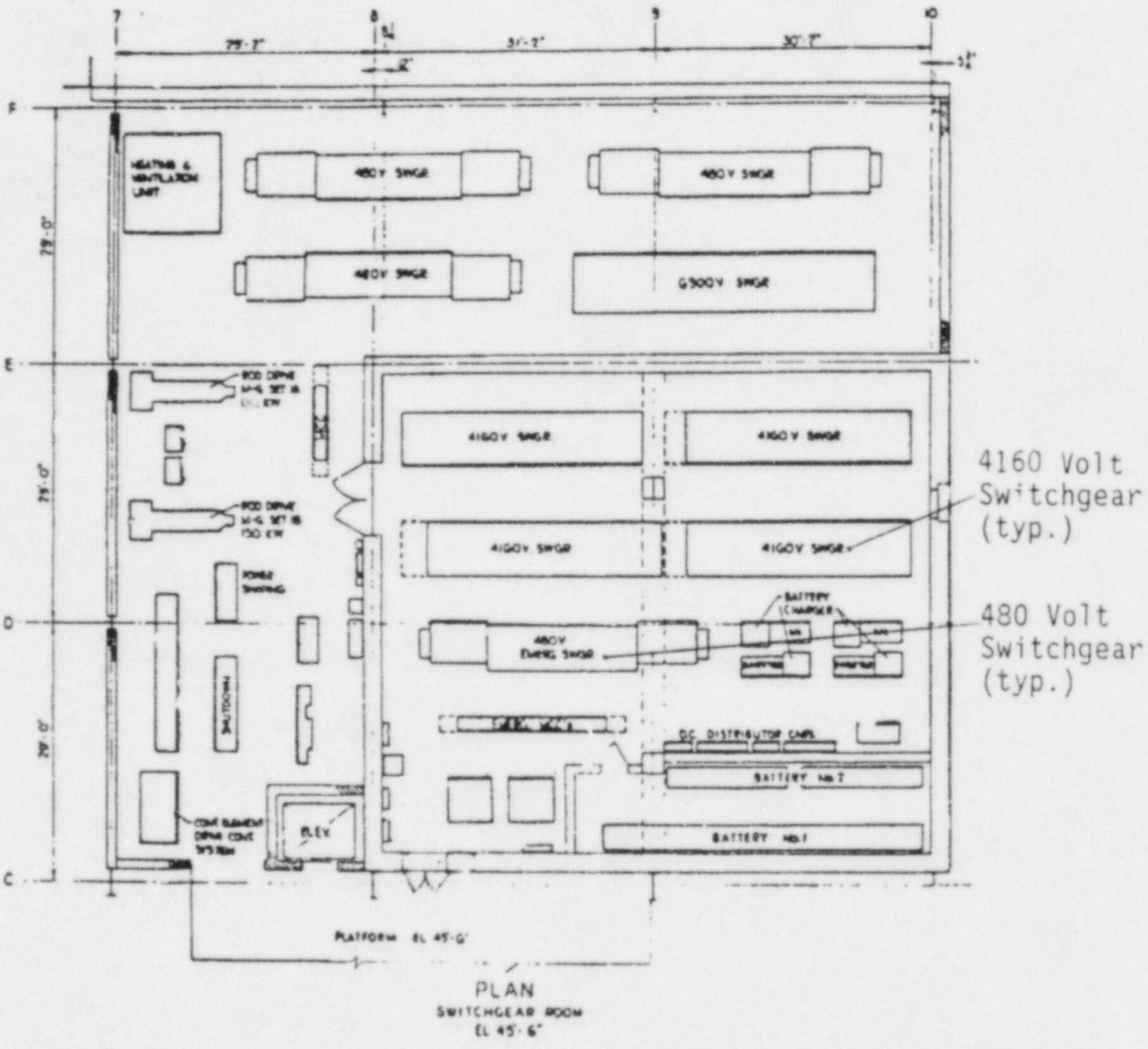
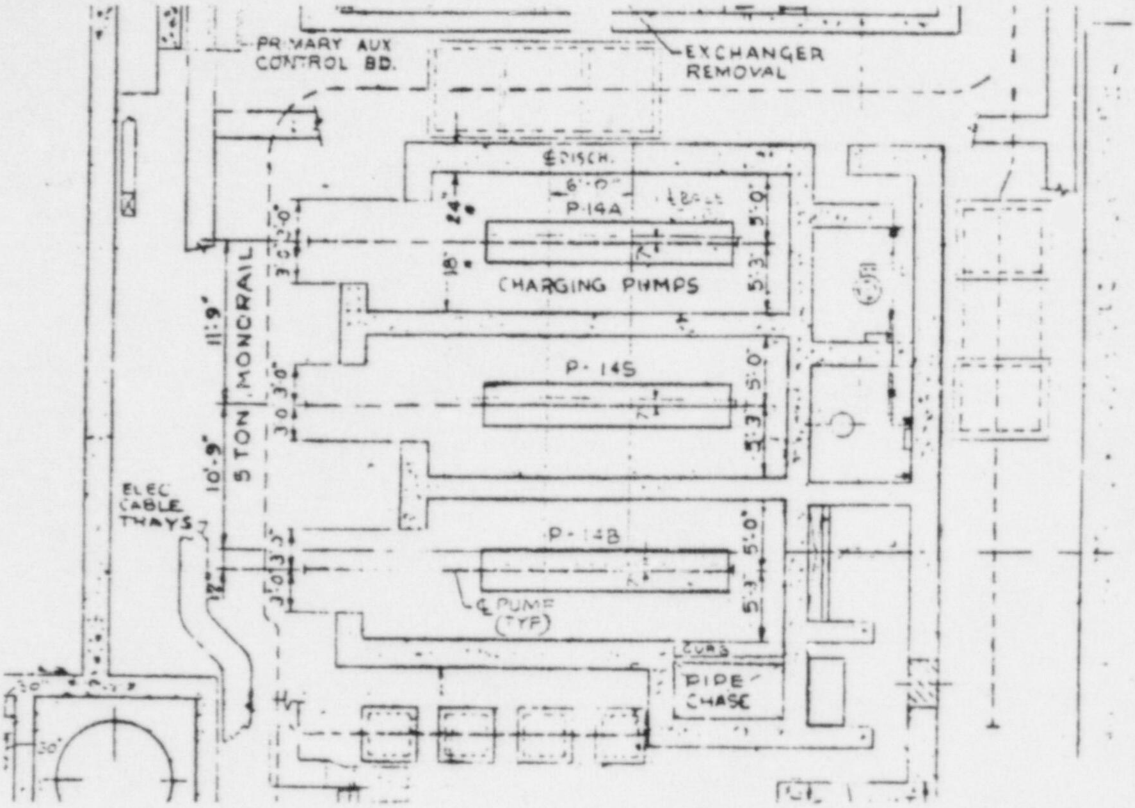


Figure 4-3: Plan of Switchgear Room Showing Critical Equipment Locations.



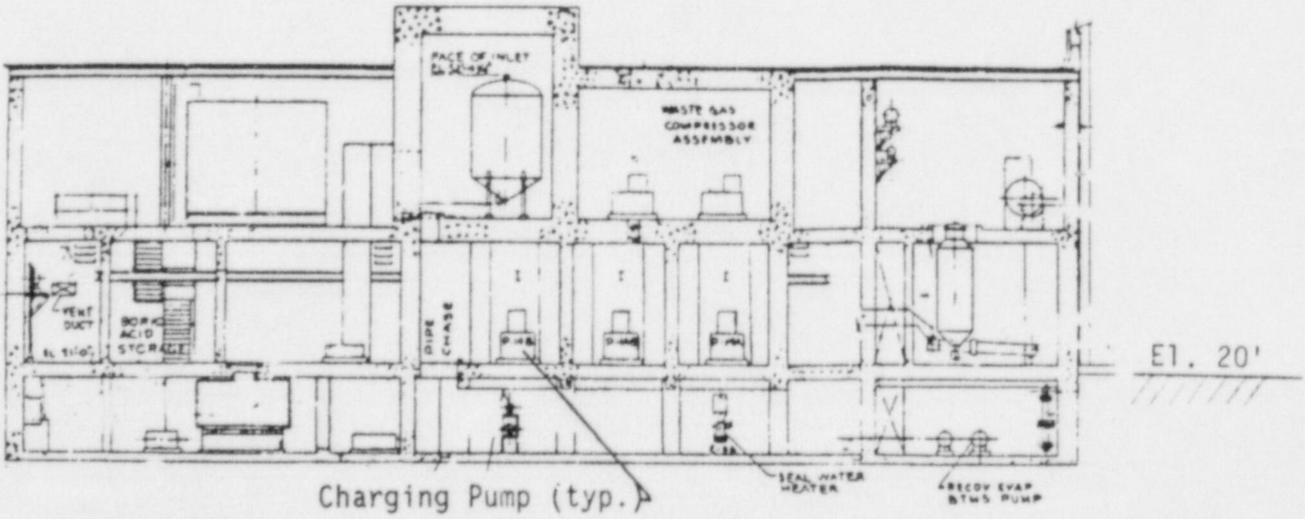


Figure 4-4: Plan and Elevation of Primary Auxiliary Building Showing Critical Equipment Locations.

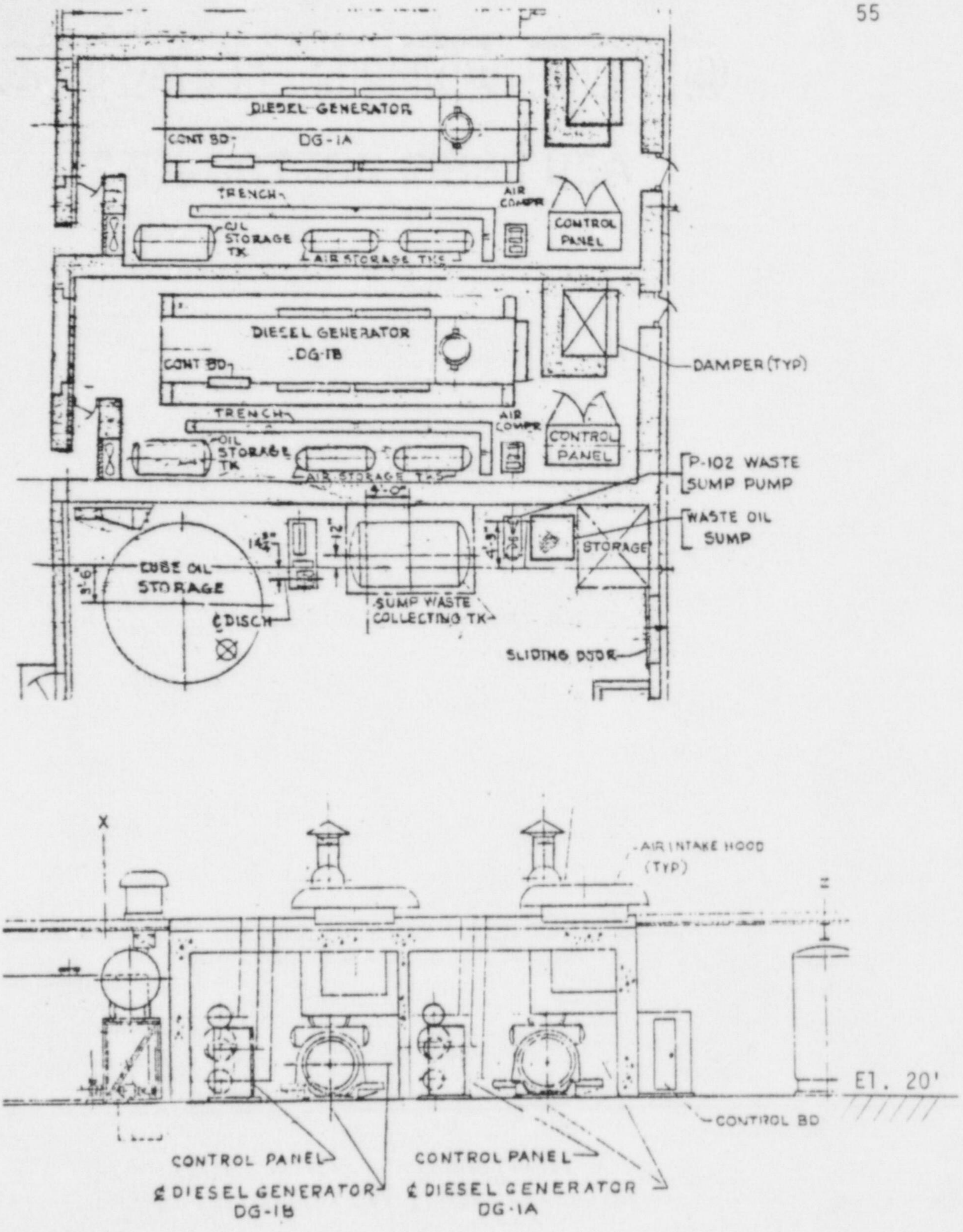


Figure 4-5: Plan and Elevation of Diesel Generator Room Showing Critical Equipment Locations.

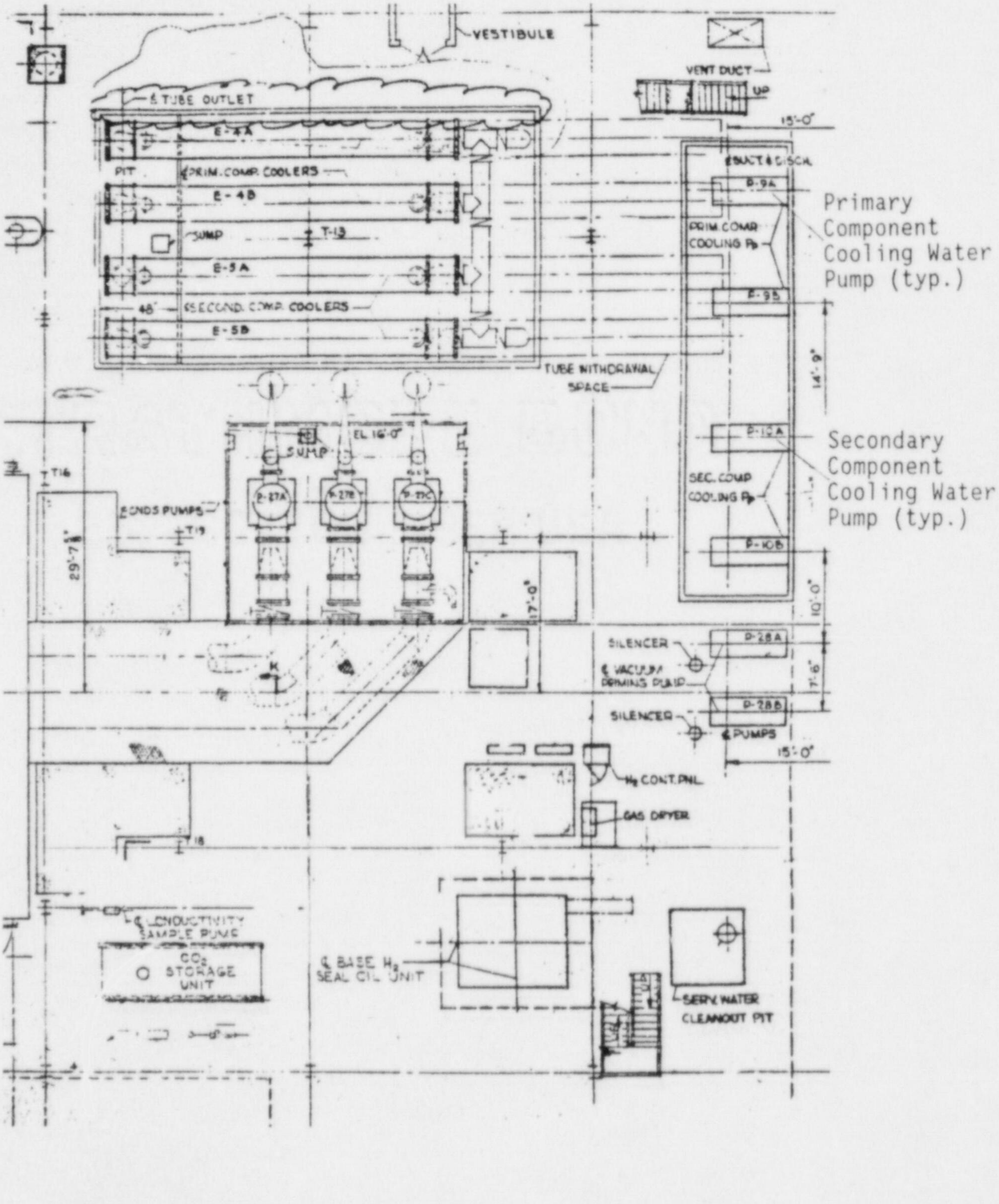


Figure 4-6: Plan of the Turbine Building Showing Critical Equipment Locations.

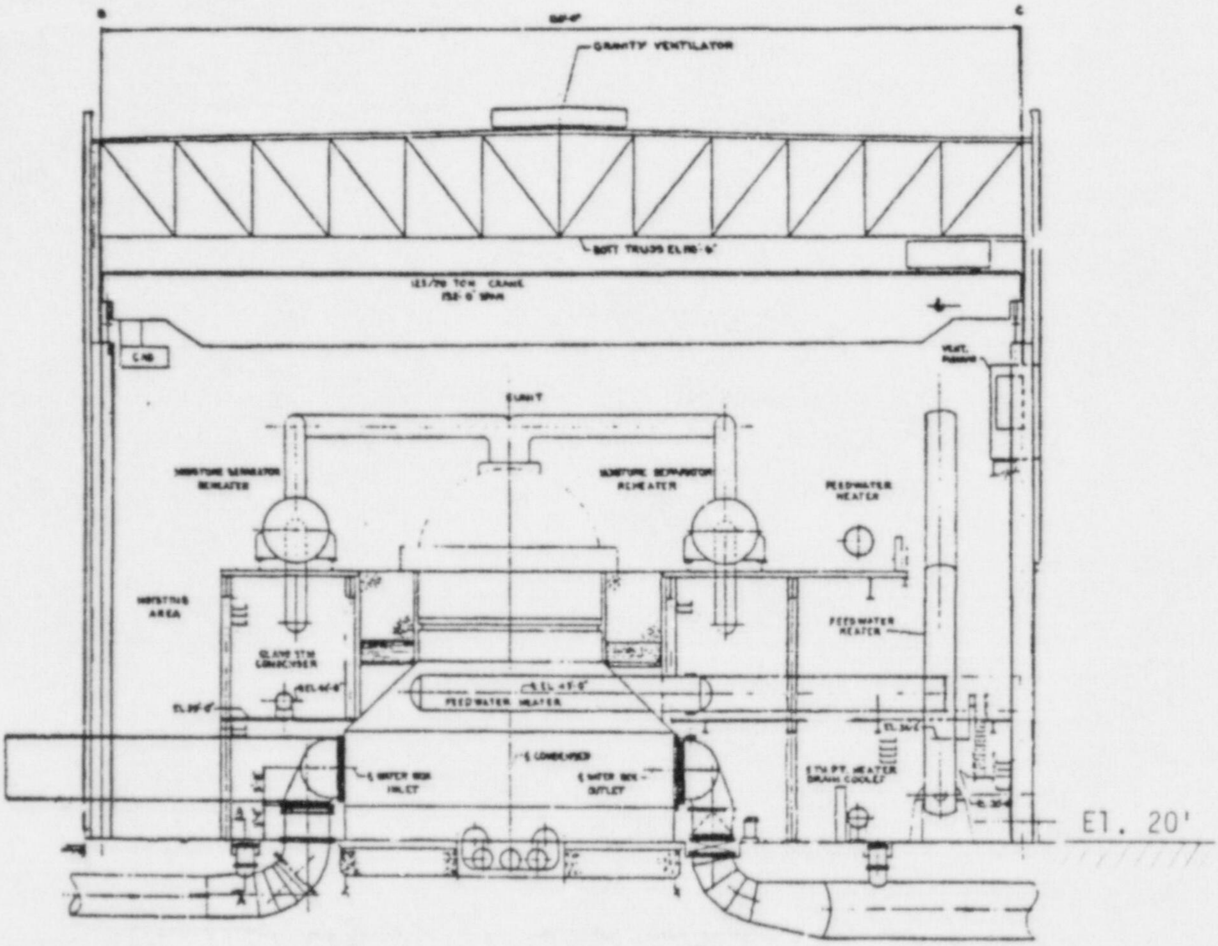


Figure 4-7: Elevation of the Turbine Building.

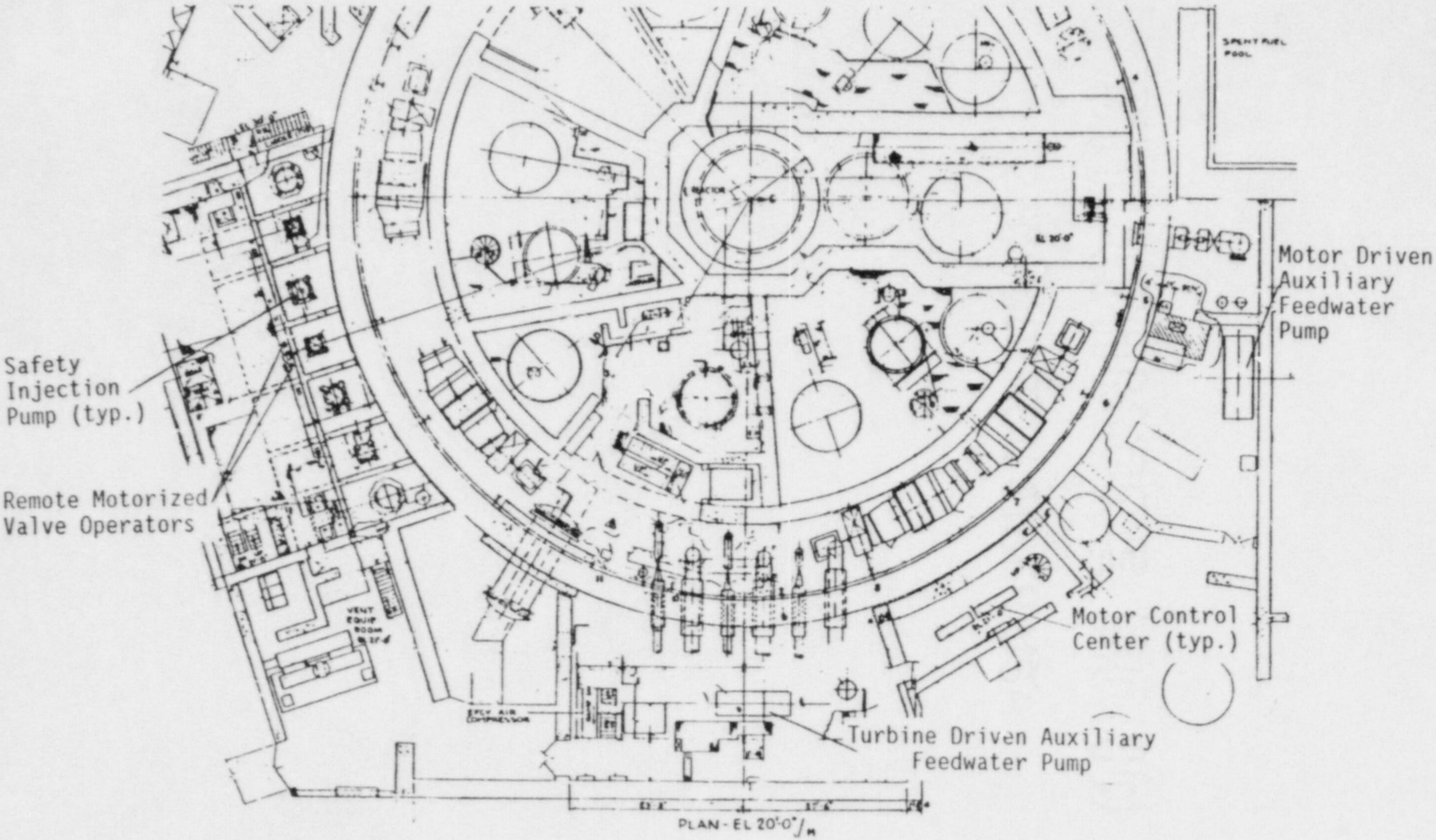


Figure 4-8: Plan of the Containment Building Showing Critical Equipment Locations.

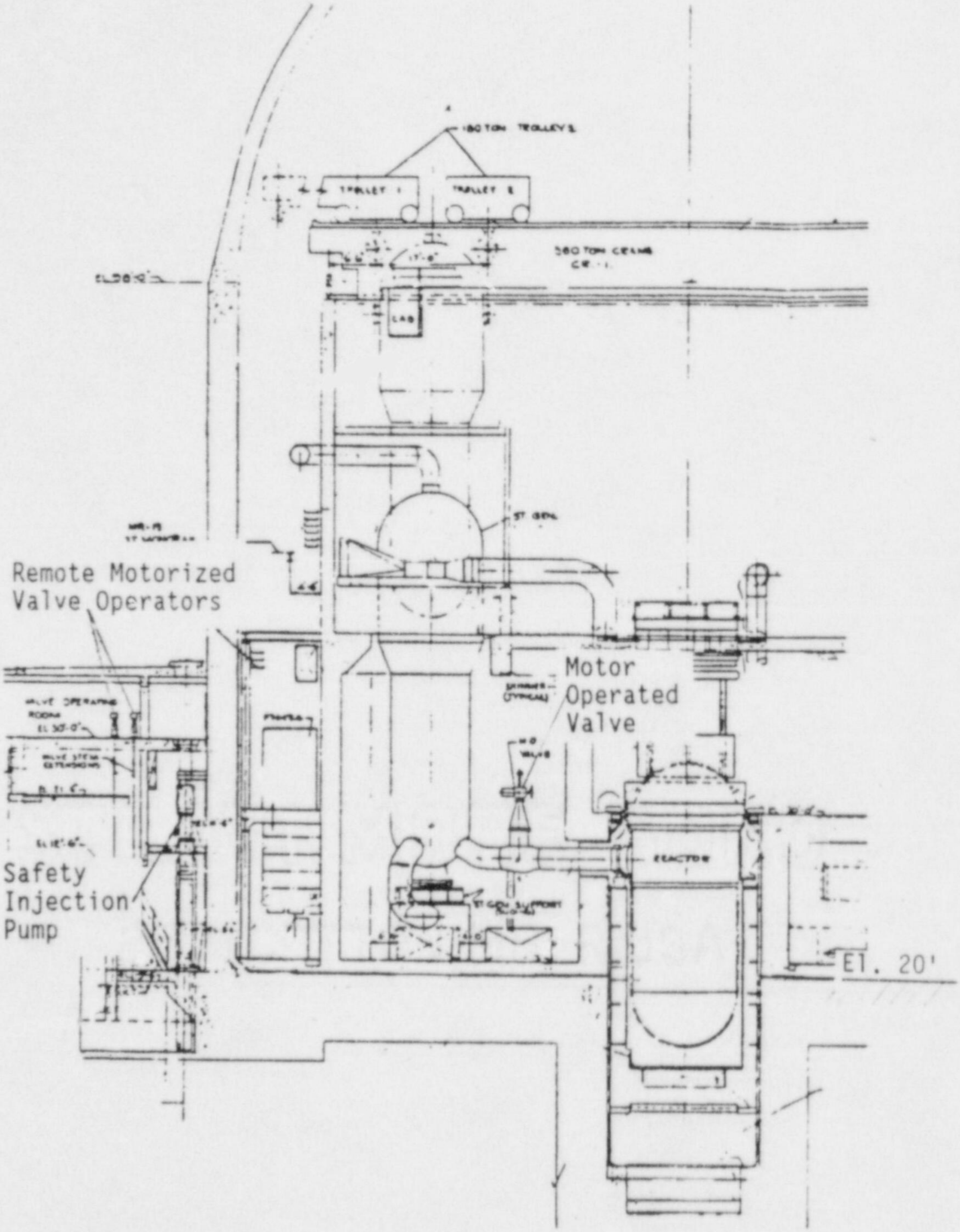


Figure 4-9: Elevation of the Reactor Containment Showing Critical Equipment Locations.

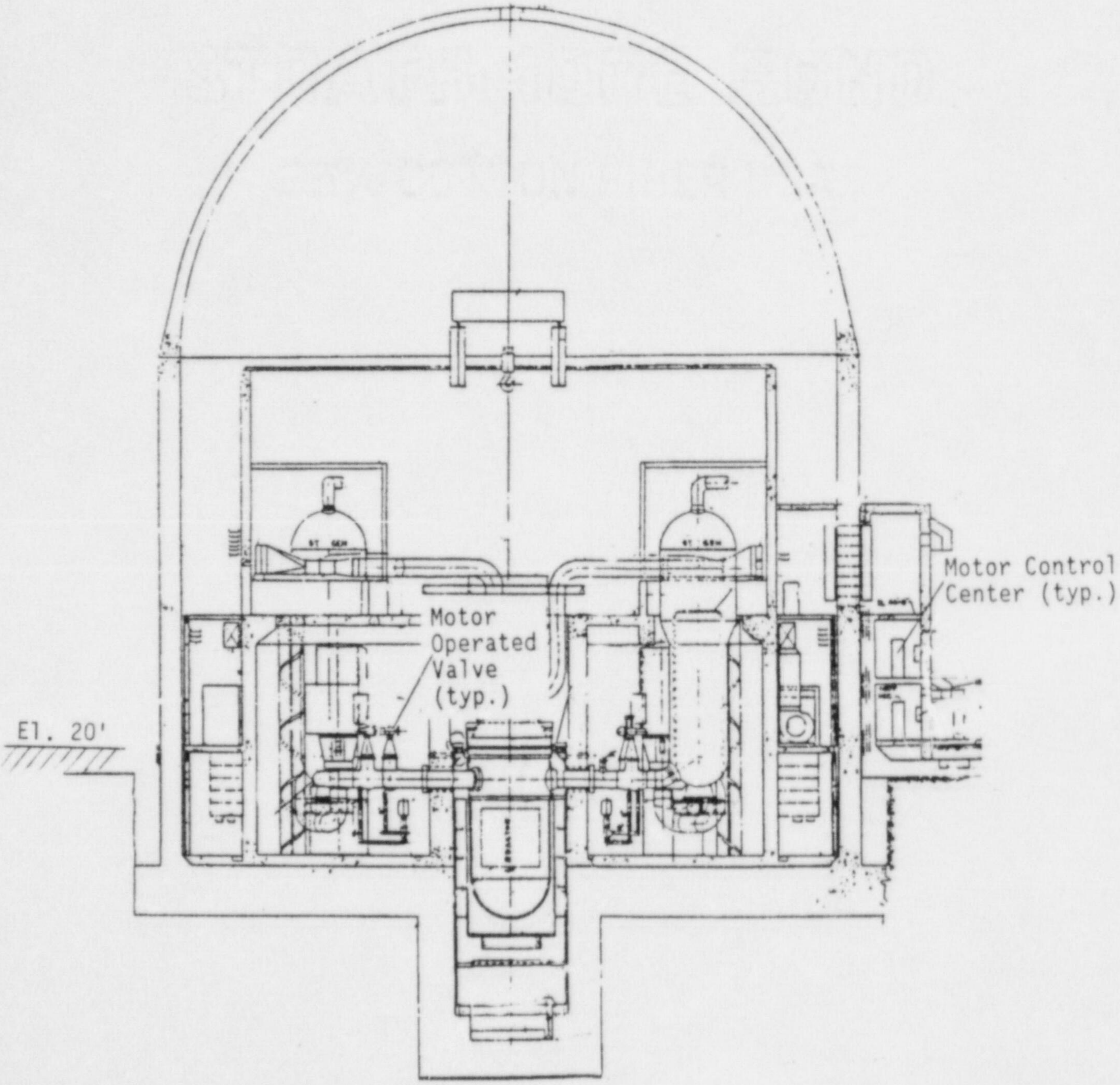


Figure 4-10: Elevation of the Reactor Containment Showing Critical Equipment Locations.

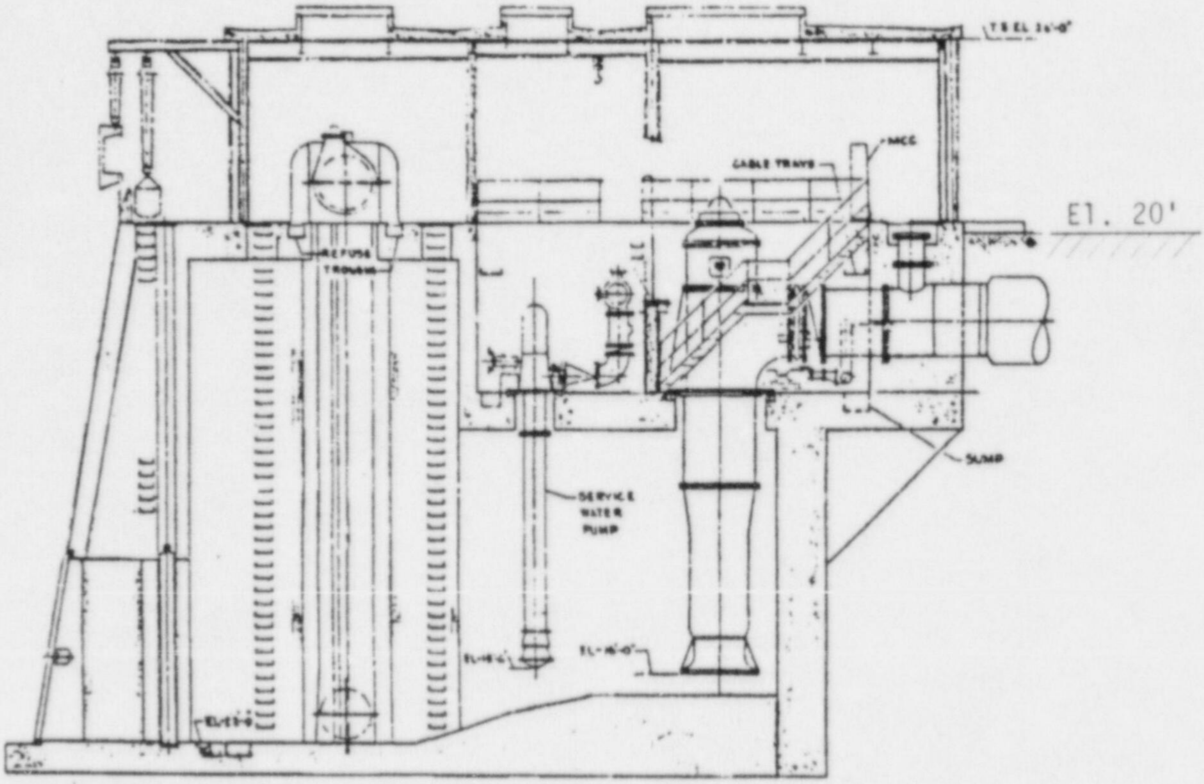


Figure 4-11: Elevation of the Intake Structure Showing Critical Equipment Locations.

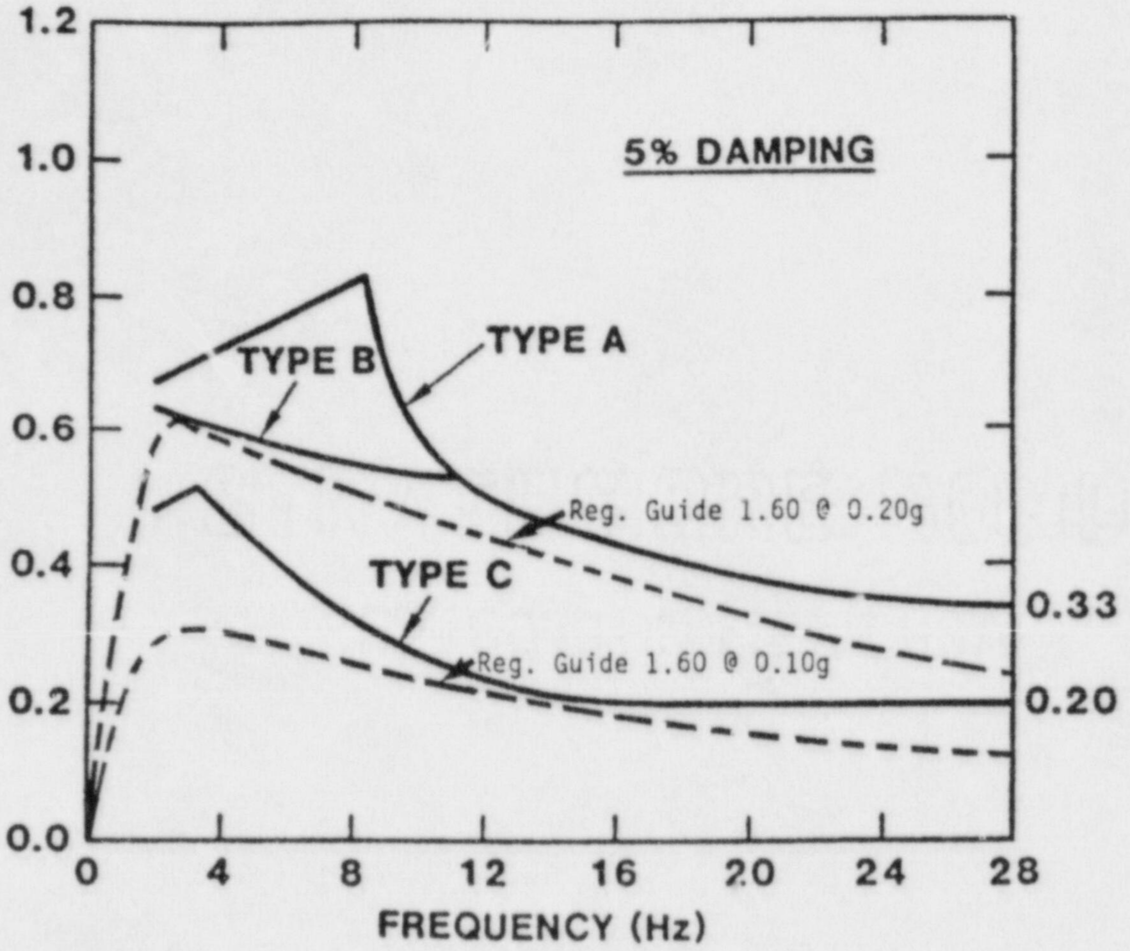


Figure 4-12: Response spectra defining seismic motion bounds for the applicability of experience data to nuclear plant equipment superimposed on the Regulatory Guide 1.60 spectrum normalized to PGAs of 0.10g and 0.20g

5. EXAMPLES OF CRITICAL EQUIPMENT

This chapter presents specific information about eight classes of critical equipment as they pertain to the Maine Yankee plant and the SQUG data base. The eight classes of equipment are addressed in this chapter as follows:

5.1 Motor Control Centers
5.2 Low Voltage Switchgear
5.3 Unit Substation Transformers
5.4 Metal-Clad Switchgear
5.5 Horizontal Pumps and their Motors
5.6 Vertical Pumps and their Motors
5.7 Air-Operated Valves
5.8 Motor-Operated Valves

Each section begins with a general description of the equipment class, applicable to equipment both at the Maine Yankee plant and at various facilities in the experience data base. Criteria are then outlined defining the limits of applicability of the experience data base to the particular type of equipment. These criteria are then applied to selected critical equipment at the Maine Yankee plant.

5.1 Motor Control Centers (MCCs)

The Maine Yankee plant contains several MCCs that control critical equipment. These MCCs are located in the plant switchgear room of the control building and in two of the peripheral cells surrounding the containment structures (MCC Room and Containment Spray Pump House). These are Westinghouse MCCs, Type "W", from the standard product line of the late 1960s and early 1970s. This particular MCC is very common in conventional power plants and industrial facilities constructed within that time period. These MCCs are free-standing cabinets (as opposed to wall- or rack-mounted units). Section 5.1.1 presents a general description of MCCs found in both the Maine Yankee plant and the seismic experience data base.

5.1.1 Description of Motor Control Centers - MCCs serve electric motors powered at 600 Volts or less and are a common fixture in industrial facilities with large installations of mechanical equipment. Typical operating voltages are 440 to 480 Volts, with currents ranging up to 1200 Amperes, depending on the size of the motor served. MCCs consist of assemblies of motor controllers, each of which serves an individual electric motor. A motor controller protects the electric motor against excessive current during start-up or faulted conditions.

Motor control centers consist of a sheet metal assembly containing individual motor controllers stacked in vertical sections. These vertical sections are the basic building blocks of an MCC. Vertical sections are normally 20 inches wide by 90 inches high. The depth of the section will vary from 12 to 24 inches. MCCs can contain motor controllers on either one or two faces of the assembly. Double-faced units are normally 20 or 24 inches deep, to allow room for two stacks of motor controllers back-to-back.

Individual motor controllers consist of a sheet metal box which is mounted into its cubicle in the MCC and secured by one or more anchor screws. Electrical connection to the main power source is through three clips in the rear of the unit, which clamp to bus bars routed vertically through each section. The height of individual motor controller cubicles ranges from 6 inches to the full cabinet height, depending on the size of motor it serves. The National Electrical Manufacturers Association (NEMA) sets standards for the size of motor controller cubicles, ranging from NEMA size 1 to 6, depending on the motor size. Standards such as NEMA Publication ICS 6-1978 address minimum thickness of sheet metal in the MCC and minimum requirements for structural framing. Floor anchorage of MCCs is typically by bolts through holes provided in the base channels, or by welding the base channel to steel baseplates embedded in the floor.

All MCCs fit the basic characteristics described above. MCCs have little variation in construction from manufacturer to manufacturer. The basic design and construction of MCCs has changed very little since the 1950's. MCCs are sufficiently standardized in construction and operation to be addressed on a generic basis with respect to their seismic ruggedness. The

experience data base contains a large number of MCCs that have survived a variety of earthquakes. This sample covers the range of characteristics of MCCs (manufacturer, vintage, size) commonly found in industry. So far, in the compilation of the data base, no examples have been found of MCCs failing in earthquakes, indicating an inherent seismic ruggedness. This seismic ruggedness does not appear to be sensitive to details in construction or operation.

5.1.2 The Seismic Experience Data Base for MCCs - The basis for determining the seismic adequacy of MCCs that comply with normal industry construction standards is presented in Table 5-1. This table summarizes the experience data collected for MCCs reviewed at data base sites affected by the San Fernando, Imperial Valley and Coalinga earthquakes. This information formed the basis of the conclusions reached by the SSRAP regarding MCCs and the applicability of seismic experience data.

The format of Table 5-1 is explained below. The first four columns define the data base site by earthquake, facility visited, estimated PGA, and location of MCCs within the facility. The fifth and sixth columns quantify the MCC assemblies and the motor controllers at each site. Columns seven and eight summarize nameplate information. The performance of the data base facility during and after the earthquake is summarized in the last column, which includes any damage or observed effects to MCCs.

Figures 5-1 and 5-2 compare MCCs at the Maine Yankee plant with other MCCs in the experience data base.

5.1.3 SQUG Criteria for the Review of Motor Control Centers - Upon reviewing the results of the experience data survey for MCCs, it was concluded that motor control centers are sufficiently rugged to survive a seismic event and remain operational thereafter provided certain conditions are met for the nuclear plant equipment.

- The nuclear plant design basis ground motion spectrum must be enveloped by the Type B spectrum (Figure 2-1) for equipment located within 40 feet of the plant exterior grade elevation.

- The cabinet must have stiffly engineered anchorage. Under significant shaking, stiffly anchored cabinets will have a fundamental frequency greater than 8 Hz.

- Cutouts in the cabinet sheet metal, including the side sheathing between multi-bay cabinets, must be less than 6 inches wide by 12 inches high.

- All internal subassemblies must be securely attached to the cabinet structure.

- Adjacent sections of multi-bay cabinets must be bolted together.

- External attachments to the cabinet must have a total weight of less than 100 pounds.

5.1.4 Conformance of Maine Yankee Motor Control Centers with SQUG Criteria - A survey of the critical MCCs at the Maine Yankee plant was made to check their compliance with the SQUG criteria. It was noted that all critical MCCs are located within 40 feet of ground level. The Type B ground motion spectrum applicable to MCCs envelops a Regulatory Guide 1.60 ground motion spectrum normalized to 0.20g PGA (Figure 4-12). It appears, therefore, that the seismic motion bounds demonstrated by MCCs in past earthquakes envelop the Maine Yanke plant.

The anchorage of motor control centers in the Maine Yankee plant is much stronger than what is common for MCCs in data base sites. MCCs in the plant switchgear room are bolted to angles which abut the front and rear base channels of the MCC. MCCs adjacent to the containment penetration area are anchored to the floor and also braced at the top of the cabinet to the nearest wall.

The various other requirements are also met by MCCs at the Maine Yankee plant. All cutouts in the sheet metal of the cabinets are small and accommodate common fixtures in MCC construction, such as interlock switches

that penetrate the front face of each cubicle. All components inside the cabinets are bolted to the cabinet structure. Adjacent MCCs sections are bolted together through adjoining walls according to normal industry construction. The MCCs do not support any large attachments.

5.2 Low Voltage Switchgear

Low voltage (480 Volt) switchgear serving critical equipment in the Maine Yankee plant are located in the switchgear room of the control building. The switchgear are General Electric "Type AK-5" assemblies. These are probably the most common models of low voltage switchgear found in industrial facilities and power plants constructed in the 1960s and 1970s. The switchgear assemblies include a dry transformer attached to one end which steps down the incoming power from 4160 Volts to 480 Volts prior to routing it to the switchgear. The combination of switchgear and transformer form a single structure, a unit substation, common in modern industrial facilities. Section 5.2.1 presents a general description of low voltage switchgear that applies to the units in the Maine Yankee plant, and to common switchgear included in the seismic experience data base.

5.2.1 Description of Low Voltage Switchgear - Low voltage switchgear are assemblies of circuit breakers that protect mechanical systems powered at 600 Volts or less. Most low voltage switchgear operate at 440 to 480 Volts. Operating currents range up to 6000 Amperes, depending on the size of equipment served. The purpose of low voltage switchgear is similar to that of motor control centers -- to protect electrical equipment against excessive current during faulted conditions. The primary difference between switchgear and MCCs is the size of electrical load carried. A single low voltage circuit breaker will often supply power to an entire MCC.

An assembly of low voltage switchgear consists of a sheet metal enclosure containing individual circuit breakers stacked vertically. As with an MCC, the vertical section is the basic building block of the switchgear assembly. Vertical sections contain a stack of from one to four circuit breaker cubicles, depending on the size of the breakers. Vertical sections are typically 20 inches wide, 90 inches tall and 60 inches deep. As with

MCCs, multiple sect ons are bolted together through adjacent walls to form assemblies of any width. Switchgear assemblies often include a separate compartment for housing control relays, switches and instrumentation. The transformer that supplies power to the switchgear is often attached to one end of the assembly, so that it becomes a structural part of the same unit. These transformers step down the power from an intermediate level, typically 4160 Volts, to the low voltage level of 600 Volts or less.

The individual circuit breakers in the switchgear assembly are mounted on rollers, allowing the breaker to slide into a rack within its cubicle. A mechanical latch holds the breaker firmly in place when it is energized. Electrical connection is made through clamps at the rear of the breaker which attach to bus bars in the rear of the cabinet.

Standards for the construction and operating parameters of low voltage switchgear are maintained by the National Electrical Manufacturers Association (NEMA No. ICS 6-1978) and the Americal National Standards Institute (ANSI Standard C37.20-1965). These standards determine the minimum structural framing and sheet metal thickness for switchgear cabinetry. Switchgear is typically anchored to the floor by bolts through the holes provided in the base channels, or by welds to embedded baseplates in the concrete floor.

All switchgear included in the experience data base fits the basic characteristics described above. All major manufacturers of switchgear adhere to the NEMA or ANSI standards. As a result the construction and operation of switchgear is very much the same, regardless of manufacturer. The design of switchgear has changed very little since the 1950s. Low voltage switchgear are sufficiently standardized in construction and operation to be addressed on a generic basis with respect to seismic ruggedness. The experience data base includes a number of switchgear assemblies that have survived a variety of earthquakes. So far, no examples of low voltage switchgear failing in earthquakes have been found, indicating an inherent seismic ruggedness.

<u>5.2.2 The Seismic Experience Data Base for Low Voltage Switchgear</u> - The basis for determining the seismic adequacy of low voltage switchgear that comply with normal industry construction standards is presented in Table 5-2. The table summarizes the experience data available for low voltage switchgear located in facilities affected by the San Fernando and Imperial Valley earthquakes.

Figure 5-3 presents a comparison of switchgear at the Maine Yankee plant with other switchgear in the experience data base. Typical circuit breakers at Maine Yankee and in the data base are shown in Figure 5-4.

<u>5.2.3 SQUG Criteria for the Review of Low-Voltage Switchgear</u> - The criteria established by SQUG for low-voltage switchgear are identical to those applicable to motor control centers.

- The nuclear plant design basis ground motion spectrum must be enveloped by the Type B spectrum (Figure 2-1) for equipment located within 40 feet of the plant exterior grade elevation.

- The cabinet must have stiffly engineered anchorage. Under significant shaking, stiffly anchored cabinets will have a fundamental frequency greater than 8 Hz.

- Cutouts in the cabinet sheet metal, including the side sheathing between multi-bay cabinets, must be less than 6 inches wide by 12 inches high.

- All internal subassemblies must be securely attached to the cabinet structure.

- Adjacent sections of multi-bay cabinets must be bolted together.

- External attachments to the cabinet must have a total weight of less than 100 pounds.

5.2.4 Conformance of Maine Yankee Low Voltage Switchgear with SQUG Criteria - Switchgear at the Maine Yankee plant were checked for compliance with the criteria outlined above. It was noted that the switchgear room is located at an elevation within 40 feet of ground level. The Type B ground motion spectrum, applicable to switchgear, envelops the Regulatory Guide 1.60 spectrum normalized to 0.20g (Figure 4-12). It is apparent that the seismic motion bounds demonstrated by the experience of switchgear in past earthquakes envelops the Maine Yankee plant.

The anchorage of switchgear in the Maine Yankee plant is much stronger than commonly found in experience data base facilities. The switchgear assemblies have braces that wrap around the cabinet and are bolted into the concrete floor. The dry transformer is anchored by welds of the base channels to steel embedded in the floor.

The various other requirements listed above are also met by the low voltage switchgear at the Maine Yankee plant. All cutouts in the sheet metal are small, and are common in switchgear to accomodate circuit breaker handles and similar fixtures through the front face of their cubicles. All components inside the cabinets are either attached to the cabinet or the circuit breaker structures. Adjacent sections of switchgear are bolted together through adjoining walls according to normal industry construction. The switchgear cabinets do not support any large attachments.

5.3 Unit Substation Transformers

Transformers in the Maine Yankee plant that step down power from 4160 Volts to 480 Volts are attached directly to the low voltage switchgear they serve, forming a single structure or unit substation. These particular transformers are the dry or air-cooled type, as opposed to the oil-cooled type also common in unit substations. Section 5.3.1 presents a general description of transformers that applies to those in the Maine Yankee plant and to transformers included in the seismic experience data base.

5.3.1 Description of Unit Substation Transformers - A unit substation transformer supplies power to low voltage switchgear. It is often attached

to one end of the switchgear assembly so that it becomes a structural part of the same unit. These transformers step down power from an intermediate level, typically 4160 to 2400 Volts, to the low voltage level of 600 Volts or less. The transformer structure consists of copper or aluminum coils embedded in insulating fabric and housed in a sheet metal enclosure. Oil-cooled transformers submerge the coils in an oil bath. The transformer enclosure forms a rectangular oil tank with oil cooling coils attached to the sides.

Standards for the construction of unit substation transformers are maintained by the National Electrical Manufacturers Association (NEMA No. 6-1978) and the American National Standards Institute (ANSI Standard C37.20-1965). These standards determine the minimum structural framing and sheet metal thickness for transformer cabinetry.

<u>5.3.2 Seismic Experience Data Base for Transformers</u> - The basis for determining the seismic adequacy of unit substation transformers is presented in Table 5-3. The table summarizes the experience data for unit substation transformers at facilities affected by the San Fernando, Imperial, and Coalinga earthquakes.

Figure 5-5 compares the unit substation transformers at the Maine Yankee plant with transformers in the experience data base.

<u>5.3.3 SQUG Criteria for the Review of Unit Substation Transformers</u> - Upon reviewing the experience data base for unit substation transformers, it was concluded that these transformers are sufficiently rugged to survive a seismic event and remain operational thereafter provided certain conditions are met for the nuclear plant equipment.

- The nuclear plant design basis ground motion spectrum must be enveloped by Type B spectrum (Figure 2-1) for equipment located within 40 feet of the plant exterior grade elevation.

- Both the unit substation transformer and its enclosures must have engineered anchorage.

5.3.4 Conformance of Maine Yankee Unit Substation Transformers with SQUG Criteria - A review of the unit substation transformers in the Maine Yankee plant demonstrates that they comply with these two criteria. It was noted that the Type B ground motion spectrum applicable to transformers envelops the Regulatory Guide 1.60 spectrum normalized to 0.20 PGA (Figure 4-12). It is apparent, therefore, that the seismic motion bounds demonstrated by unit substation transformers in past earthquakes envelop the Maine Yankee plant.

Based on conservative predictions of building amplification of ground motion, the anchorage of the transformers in the switchgear room has been designed to the seismic loads that would be experienced in a design-basis earthquake.

5.4 Metal-Clad Switchgear

Metal-clad switchgear serving critical systems in the Maine Yankee plant are located in the switchgear room of the control building. The switchgear are General Electric assemblies featuring "Magnablast" circuit breakers, commonly found in modern power plants and industrial facilities. Section 5.4.1 presents a general description of metal-clad switchgear that is applicable both to the Maine Yankee equipment and to switchgear in the experience data base.

5.4.1 Description of Metal-Clad Switchgear - Metal-clad switchgear are assemblies of circuit breakers that protect mechanical systems powered at intermediate voltage levels, typically 2400 to 4160 Volts. In both function and construction, metal-clad switchgear are similar to low voltage switchgear.

The switchgear consist of one or more sheet metal enclosures which are mounted side by side and connected to form an assembly. Each unit is made up of a primary and secondary enclosure. The primary enclosure, located at the rear of the assembly, contains the high voltage conduit and connections. The secondary enclosure is located at the front or breaker withdrawal side of the unit. It consists of a compartment with a hinged door

upon which are mounted protective control relays and instrumentation. Terminal blocks, fuse blocks, and additional control devices are mounted inside the enclosure on the side walls. A trough is normally provided at the top to carry wiring between individual cabinets.

The individual circuit breakers are mounted on rollers, allowing the breaker to engage and disengage its electrical connections at the rear of the cubicle. A mechanical latch holds the breaker firmly in place when it is energized. Electrical connection is made through clamps at the back of the breaker which attach to bus bars in the rear of the cabinet.

Standards for the construction and operating parameters of metal-clad switchgear are maintained by the National Electrical Manufacturers Association (NEMA No. ICS 6-1978) and the American National Standards Institute (ANSI Standard C37.20-1965). These standards determine the minimum structural framing and sheet metal thickness for switchgear cabinetry.

Switchgear is typically anchored to the floor by bolts through the holes provided in the base channels, or by welds to embedded baseplates in the concrete floor.

All switchgear included in the experience data base fit the basic characteristics described above. All major manufacturers of switchgear adhere to the NEMA or ANSI standards. As a result, the construction and operation of switchgear is very much the same regardless of manufacturer. The design of switchgear has changed very little since the 1950s. Metal-clad switchgear are sufficiently standardized in construction and operation to be addressed on a generic basis with respect to seismic ruggedness. The experience data base includes a number of switchgear assemblies that have survived a variety of earthquakes. So far, no examples of metal-clad switchgear failing in earthquakes have been found (although minor structural damage was experienced by an assembly during the Coalinga earthquake), indicating an inherent seismic ruggedness.

5.4.2 The Seismic Experience Data Base for Metal-Clad Switchgear - The basis for determining the seismic adequacy of common metal-clad switchgear

is presented in Table 5-4. This table summarizes the experience data available for metal-clad switchgear in facilities affected by the San Fernando, Imperial Valley and Coalinga earthquakes.

Figures 5-6 and 5-7 present a comparison of metal-clad switchgear at the Maine Yankee plant with other switchgear from various facilities in the experience data base.

5.4.3 SQUG Criteria for the Review of Metal-Clad Switchgear - The criteria established by SQUG for metal-clad switchgear are similar to those for low voltage switchgear and motor control centers.

- The nuclear plant design basis ground motion spectrum must be enveloped by the Type B spectrum (Figure 2-1) for equipment located within 40 feet of the plant exterior grade elevation.

- The cabinet must have stiffly engineered anchorage. Under significant shaking, stiffly anchored cabinets will have a fundamental frequency greater than 8 Hz under significant shaking.

- Cutouts in the cabinet sheet metal, including the side sheathing between multi-bay cabinets, must be less than 12 inches wide by 12 inches high. Note that this maximum cutout size is different from that specified for motor control centers and low voltage switchgear.

- All internal subassemblies must be securely attached to the cabinet structure.

- Adjacent sections of multi-bay cabinets must be bolted together.

- External attachments to the cabinet must have a total weight not exceeding 100 pounds.

EQE

5.4.4 Conformance of Maine Yankee Metal-Clad Switchgear with SQUG Criteria - Switchgear in the Maine Yankee plant were checked for compliance with the criteria outlined above. It was noted that the switchgear room is located at an elevation within 40 feet of ground level. The Type B ground motion spectrum, applicable to switchgear, envelops the Regulatory Guide 1.60 spectrum normalized to 0.20g (Figure 4-12). It is apparent that the seismic motion bounds demonstrated by the experience of switchgear in past earthquakes envelops the Maine Yankee plant.

The anchorage of the metal-clad switchgear at the Maine Yankee plant is much stronger than commonly found in the experience data base facilities. The assemblies are anchored to the floor by a combination of puddle welds to embedded steel and bolts to angles abutting the rear base channel of the cabinets. In addition, opposing switchgear assemblies have overhead bracing running across the walkway between them (Figure 5-6). This overhead bracing ties the two assemblies together at the top to resist overturning moment and increase the stiffness of the cabinet structure.

Various other requirements listed above are also met by the metal-clad switchgear in the Maine Yankee Plant. The cabinets do not have any large cutouts in the sheet metal facing, other than the standard penetrations for door-mounted protective relays. All internal components are attached either to the cabinet or the circuit breaker structure. Adjacent cabinets are bolted together through adjoining walls. No large attachments are supported by the sheet metal face of the assemblies.

5.5 Horizontal Pumps

The Maine Yankee plant includes several horizontal pumps of various types. Examples are as follows:

- Component cooling water pumps -- motor-driven, single stage centrifugal pumps
- Emergency feedwater pumps -- motor-driven, multi-stage, centrifugal pumps

- Charging pumps -- motor-driven multi-stage centrifugal pumps,

- Auxiliary charging pump -- a motor-driven positive displacement pump

These horizontal pumps are somewhat diverse in design and size. A general description of the various types of horizontal pumps commonly found in power plants is presented in Section 5.5.1. This description is applicable both to pumps at the Maine Yankee plant, and to pumps included in the seismic experience data base.

<u>5.5.1 Description of Horizontal Pumps</u> - Horizontal pumps are one of the most common equipment items in the various data base facilities reviewed for the compilation of seismic experience data. Hundreds of pumps are included in the data base facilities. There have been no instances of seismic failure or significant seismic effects on the operation of horizontal pumps.

There are two basic categories of horizontal pumps commonly found in power plants: rotating impeller pumps and piston-driven positive displacement pumps.

Rotating impeller pumps can be single-stage or multistage. A single-stage centrifugal pump is one in which the discharge head is developed by the centrifugal force of a single impeller. Single-stage pumps operate at a high flow rate with a relatively low differential pressure. They normally have a direct connection between motor and impeller so that both rotate at the same speed. Typical applications of single stage centrifugal pumps in power plants include cooling water circulation.

Multi-stage pumps utilize two or more impellers operating in series to form a turbine. Multi-stage pumps operate at a relatively low flow rate with a high pressure differential. Larger multi-stage pumps are often driven through a gearbox which reduces the rotating speed between motor and impeller. Typical applications of mutli-stage pumps in power plants include feedwater injection into boilers or steam generators.

Positive displacement pumps use a piston drive rather than rotating impellers. These pumps work on the same principle as a piston engine in reverse. An electric motor drives a gear box which translates rotating motion into reciprocating motion. Piston pumps operate at a relatively low flow rate and high differential pressure.

Horizontal pumps generally include the following basic components:

- Electric drive motor or a steam turbine
- Pump impeller housed in a steel or cast iron casing
- Drive shaft connecting the motor and pump, sometimes by way of a gear box
- Inlet and discharge lines to the pump

Horizontal centrifugal pumps are normally powered by AC induction motors. A number of examples are also included in the experience data base of diesel-engine and steam turbine powered pumps. Pump motors normally are served by 480 or 4160 Volt systems, depending on size. Motor-pump power can range from fractions of a horsepower to several thousand horsepower, depending on the application.

The motor and pump are normally bolted to the same steel skid, which is in turn anchored to the concrete floor. The most common floor anchorage is with bolts or friction clips which attach the skid bottom channel to the floor. Since the motor and pump are anchored rigidly to the same skid, there is no danger of differential displacement during an earthquake causing binding in the drive shaft.

<u>5.5.2 The Seismic Experience Data Base for Horizontal Pumps</u> - The basis for determining the seismic adequacy of horizontal pumps typical to power plants and industrial facilities is presented in Table 5-5. The table summarizes the experience data available for horizontal pumps from

facilities affected by the San Fernando, Imperial Valley and Coalinga earthquakes.

Figures 5-8 and 5-9 present a comparison of pumps at the Maine Yankee plant with other pumps in the experience data base.

5.5.3 SQUG Criteria for the Review of Horizontal Pumps - Upon reviewing the results of the experience data survey for horizontal pumps, SQUG has concluded that, due to their inherent design and operating requirements, all horizontal pumps are relatively stiff and rugged devices. Further, horizontal pumps and motors are sufficiently rugged to survive a seismic event and remain operational thereafter provided certain conditions exist for nuclear plant equipment.

- The nuclear plant design basis ground motion spectrum must be enveloped by the SQUG Type A spectrum (Figure 2-1) for equipment locations within 40 feet of the plant grade elevation.

- The drive motor (or turbine drive) and pump must be rigidly connected through their base to prevent relative displacement.

- Shaft thrust restraint must be assured in both directions.

5.5.4 Conformance of Maine Yankee Horizontal Pumps with SQUG Criteria - A survey of the various horizontal pumps at the Maine Yankee Plant demonstrates their compliance with these criteria. It was noted that all pumps in the plant hot shutdown system are located within 40 feet of ground elevation. The Type A Spectrum, applicable to pumps, envelops the Regulatory Guide 1.60 ground spectrum normalized to 0.20g (Figure 4-12). It is apparent that the seismic motion bounds demonstrated by the experience of horizontal pumps in past earthquakes envelops the Maine Yankee plant.

All pumps and motors at the Maine Yankee plant are mounted on common steel skids, precluding any significant differential displacement under seismic loads. A review of the manufacturers' literature reveals that the

motor-pump drive shafts are supported on bearings that restrain the rotating mass in all directions.

5.6 Vertical Pumps

The Maine Yankee plant includes several types of vertical pumps in a diversity of applications. Examples are as follows:

- Service water pumps -- large deep-well turbine pumps supplying cooling water to the component cooling system

- Low-Head safety injection pump -- large, deep-well, barrel-type, turbine pumps supplying water to the safety injection system

- Diesel-generator fuel pumps -- small deep well turbine pumps supplying diesel oil from an underground fuel storage tank to the diesel day tank

A general description of vertical pumps is presented in Section 5.6.1 which covers the pumps at the Maine Yankee Plant as well as pumps in the seismic experience data base.

5.6.1 Description of Vertical Pumps - Vertical pumps are a common equipment item in power plants and large industrial facilities. They range in size from units of a few horsepower to several thousand horsepower depending on application. Hundreds of vertical pumps are included among the various earthquake sites that have been investigated. Details have been collected on only a portion of these pumps, with the emphasis placed on the larger units. All instances of seismic effects on vertical pumps in the data base, however, have been studied.

Most vertical pumps included in the experience data base are of the deep well turbine impeller type. This type of pump typically consists of an AC motor supported on a steel or cast iron frame that rests on a square base flange anchored to a concrete foundation. The pump discharge line joins

the motor support frame just above the base flange. The pump itself is mounted in a vertical casing projecting below the base flange into a subsurface well or pit. This vertical casing contains the pump shaft that supports the turbine impeller at the casing bottom. Deep well pumps have a casing that is submerged in water (or other liquid). The casing is open at the bottom for suction into the pump impeller. Can or barrel pumps have a cylindrical tank that surrounds the casing. The annulus between the inner casing and the surrounding barrel (or can) serves as the fluid reservoir from which the the pump draws suction.

All vertical pumps have the same basic construction: the motor is supported above the base of the pump and the casing is supported below. Because of high operational loads, the structure of vertical pumps, in particular the anchorage of the pump base, is quite rugged.

The experience data base for vertical pumps includes a wide variety of sizes, applications, manufacturers, and vintages. Data collection on vertical pumps focused primarily on larger units since these were considered the most suceptable to seismic damage.

5.6.2 The Seismic Experience Data Base for Vertical Pumps - The basis for determining the seismic adequacy of vertical pumps typical to power plants and industrial facilities is presented in Table 5-6. The table summarizes the experience data available for vertical pumps from facilities affected by the San Fernando, Imperial Valley and Coalinga earthquakes.

Figure 5-10 presents a comparison of pumps at the Maine Yankee plant with other pumps in the experience data base.

5.6.3 SQUG Criteria for the Review of Vertical Pumps - Upon reviewing the experience data base for vertical pumps, SQUG has concluded that their inherent design and operating requirements make them relatively stiff and rugged devices. Vertical pumps and motors were judged to be sufficiently rugged to survive a seismic event and remain operational provided certain conditions were met for the nuclear plant equipment.

- The nuclear plant design basis ground motion spectrum must be enveloped by the Type A spectrum (Figure 2-1) for equipment locations within 40 feet of the plant grade elevation.

- The length of vertical casing cantilevered below the base flange of the pump must not exceed 20 feet.

- The impeller drive shaft must be supported within the casing, particularly at the casing bottom.

5.6.4 Conformance of Maine Yankee Vertical Pumps with SQUG Criteria - A survey of the critical vertical pumps at the Maine Yankee plant demonstrates their compliance with these criteria. It was noted that the service water pumps, for example have a casing length of approximately 20 feet into the pit of the intake structure. The casing length of the diesel fuel oil transfer pumps is less than 20 feet. The casing lengths of the containment spray and the safety injection pumps are about 30 feet. Rather than being cantilevered, however, these casings are supported as they penetrate several floors of the Containment Spray Pump Building. The flexibility of these supported casings is, therefore, less than the flexibility of a 20 foot cantilever. Manufacturers' literature for these pumps shows that impeller drive shafts are supported at the base of the casing as well as at intermediate points between the impeller and the pump base flange.

5.7 Air-Operated Valves

Air-operated valves (AOVs) are included in several mechanical systems at the Maine Yankee plant. A general description of air-operated valves that would apply to valve operators in the Maine Yankee plant and also in the seismic experience data base is presented in Section 5.7.1.

5.7.1 Description of Air-Operated Valves - AOVs are controlled using a pneumatic drive as the valve actuator. The most common pneumatic actuator found in both nuclear and fossil-fueled plants is a pneumatic diaphragm actuator. This actuator includes a bell housing containing the diaphragm,

supported on a cast iron or steel yoke which is attached to the valve body. The actuator diaphragm forms an air pressure barrier between the top and bottom sections of its bell housing. The differential pressure across the diaphragm controls the position of the actuator rod (the valve stem) attached to the diaphragm, which in turn controls the position of the valve.

The air pressure on the actuator diaphragm is controled by a pneumatic relay which is often mounted directly to the valve yoke. This relay regulates the pressure of service air to the actuator diaphragm, either by instrument air pressure in a pneumatic control system, or by electrical signals to small solenoid valves in an electronic control system.

Pneumatic actuators are usually cantilevered either above or to the side of the valves they serve. The length of the cantilevered actuator from the valve body is typically one to four feet, depending on the size of the valve. Depending on manufacturer, the valve and actuator can form a continuous body, or the actuator can be attached to the valve through a flanged or ring clamp connection.

The design and construction of AOVs has changed very little since the 1950s. AOVs can, therefore, be addressed on a generic basis regarding their seismic ruggedness. The experience data base contains a large number of AOVs that have survived a variety of earthquakes. This sample covers a wide range of the characteristics of AOVs (size, weight, vintage). So far, in the compilation of the data base, only one example of an AOV failing in an earthquake has been found (Table 5-7; Section 3.4.1). AOVs seem to have an inherent seismic ruggedness.

5.7.2 The Seismic Experience Data Base for Air-Operated Valves - The basis for determining the seismic adequacy of typical air-operated valves is presented in Table 5-7. The table summarizes the experience data available for AOVs from facilities affected by the San Fernando, Imperial Valley and Coalinga earthquakes.

Figures 5-11 to 5-13 present a comparison of AOVs at the Maine Yankee plant with AOVs in the experience data base.

5.7.3 SQUG Criteria for the Review of Air-Operated Valves - Upon reviewing the results of the experience data survey for air-operated valves, SQUG concluded that AOVs, within the size limits specified in Figure 5-14, are sufficiently rugged to survive a seismic event and remain operational thereafter, provided certain conditions are met for nuclear plant equipment.

- The nuclear plant design basis ground motion spectrum must be enveloped by the Type A spectrum (Figure 2-1) for equipment located within 40 feet of the plant exterior grade elevation.
- The valve body cannot be of cast iron.
- The valve must be mounted on at least a one-inch line.
- To prevent severe differential displacement between the valve and operator, the operator cannot be braced to a structure adjacent to the line unless the line is also braced to the structure immediately adjacent to the valve.
- The height of the air-operator must fall within certain limits represented in the experience data base (Figure 5-14).
- Auxillary systems attached to the valve, such as the air supply lines, must be evaluated seperately.

5.7.4 Conformance of Maine Yankee Air-Operated Valves with SQUG Criteria - A representative sample of critical air-operated valves at Maine Yankee has been reviewed to insure compliance with these criteria. These AOVs are located within 40 feet of ground elevation. As shown in Figure 4-12, the Type A ground motion spectrum, applicable to AOVs, envelops the Regulatory Guide 1.60 spectrum normalized to 0.20g. It is apparent that

the seismic motion bounds demonstrated by the experience of AOVs in past earthquakes envelop the Maine Yankee plant.

The AOVs at Maine Yankee were also reviewed to the other SQUG criteria with the following results:

- No air operators are mounted on cast iron valve bodies;
- All AOVs are mounted on lines of at least 1 inch in diameter or specific provisions have been made to support the operator with the pipe from a common structure;
- Air operators are not independently supported from adjacent structures which could result in excessive differential movement between valve and operator;
- Attached tubing and conduit had adequate flexibility to accomodate anticipated seismic movement.

Figure 5-14 illustrates the limits placed on the size of valve air-operators as a function of the size of the supporting line. The dimensions of sample valves at the Maine Yankee plant are plotted on the graph to demonstrate where they fall with respect to these limits.

5.8 Motor-Operated Valves

Motor-operated valves are included in several systems at Maine Yankee. A general description of motor-operated valves that is applicable to either valves at the Maine Yankee plant or valves included in the experience data base is presented in Section 5.8.1 below.

5.8.1 Description of Motor-Operated Valves - Motor-operated valves (MOVs) control the opening and closing of a valve using an electric motor as the valve actuator. Valve motor operators usually include an electric drive motor, control mechanism (torque and limit switches), a gearbox, and an

actuator shaft mounted to a steel frame or yoke cantilevered from the valve housing.

Motor operators may be mounted in any position, cantilevered vertically above or below the valve, or horizontally to the side. The operator and yoke sometimes form a double cantilever, with the operator mounted above and to one side of the valve. The yoke, connecting the operator to the valve body, may take the form of a steel pipe enclosing the actuator shaft or a frame of welded beams. The attachments of the motor/gearbox to the yoke and the yoke to the valve are typically through bolted flange connections or occasionally ring clamps.

In some applications, motor operators are mounted at a remote location above the valve. In this configuration, the operator is usually mounted atop a steel pipe that encloses the long valve actuator shaft. The pipe enclosing the shaft is supported at one or more intermediate points prior to its attachment to the valve. This configuration may occur in power plants where the operator is mounted on a floor above a contaminated cell containing the valve, or where valves are submerged in wells, where the operator is mounted at a ground level.

The complexity of the control system included within a motor operator depends on its vintage and application. Modern valve operators may include transmitters to remote instruments, indicating valve position on a control board and a local motor controller built into the operator housing rather than in a remote MCC.

The size of a valve operator depends on the size of the valve and the power required for valve operation. The smallest operators typically weigh about 100 pounds. Larger operators typically weigh 500 pounds, and operators as heavy as 2,000 pounds can be found in certain power plant applications.

The design and construction of MOVs has changed very little since the 1950s. MOVs can, therefore, be addressed on a generic basis regarding their seismic ruggedness. The experience data base contains a large number of MOVs that have survived a variety of earthquakes. This sample covers a

wide range of the characteristics of MOVS (size, weight, vintage). So far, in the compilation of the data base, no examples have been found of MOVs failing in earthquakes, indicating inherent seismic ruggedness.

5.8.2 The Seismic Experience Data Base for Motor-Operated Valves - Table 5-8 summarizes the experience data base for MOVs from the San Fernando, Imperial Valley and Coalinga earthquakes. Figures 5-15 and 5-16 present a comparison of MOVs at the Maine Yankee plant with MOVs in the experience data base (all the MOVs in the figures are on lines less than 12 inches in diameter).

5.8.3 SQUG Criteria for the Review of Motor-Operated Valves - Upon reviewing the results of the experience data survey for motor-operated valves, SQUG concluded that MOVs are sufficiently rugged to survive a seismic event and remain operational thereafter provided certain conditions exist in the nuclear facility. Due to a shortage in data available for very massive MOVs and for MOVs mounted on small diameter lines, the SSRAP has developed two spectra to define the seismic ruggedness of MOVs.

The majority of the MOVs included in the seismic experience data base were mounted on large diameter piping (12 inches or greater). For this reason the seismic experience of MOVs mounted on large diameter lines were considered adequately represented by the Type A spectrum applicable to other types of mechanical equipment.

Examples in the data base of MOVs mounted to smaller lines (less than 12 inches in diameter) were found mostly at lower seismic motion sites. The moment arm of the operator compared to the pipe diameter was considered to be an important parameter with respect to the torsional loads that might be imposed on the pipe by the operator in an earthquake. Therefore, a separate spectrum, Type C (Figure 2-1) was designated for MOVs on smaller lines, based on the estimated ground motion of the sites that contained most of the smaller MOVs. It illustrates seismic motion bounds that are significantly lower than those of Spectra Types A and B.

In addition to specifying two separate seismic motion bounds for MOVs of different size ranges, the SSRAP proposed the following additional criteria for MOVs in nuclear plants:

- The valve body and operator yoke cannot be of cast iron.
- The valve must be mounted on at least a two-inch line.
- The operator cannot be braced to a structure adjacent to the line unless the line is also braced to the structure immediately adjacent to the valve.

The SQUG criteria for motor-operated valves are beind re-evaluated in light of additional experience data collected from, among other sources, the 1985 Chilean earthquake (magnitude 7.8). A large quantity of data from MOVs on small lines which which experienced high levels of seismic motion has recently been collected. This information is expected to substantially increase the seismic motion bounds applicable to MOVs. In addition, the new data is expected to relax the SQUG restrictions on the size of the moment arm of the valve operator.

5.8.4 Conformance of Maine Yankee Motor-Operated Valves with SQUG Criteria - Several MOVs at Maine Yankee were reviewed to check their compliance with the criteria outlined above. It was noted that nearly all of the MOVs are located within 40 feet of ground elevation. The Type A spectrum, applicable to MOVs on large lines, envelops the Regulatory Guide 1.60 ground motion spectrum normalized to a 0.20g PGA (Figure 4-12). The Type C spectrum, applicable to MOVs on smaller lines, falls between the Regulatory Guide 1.60 spectrum normalized to a PGA of 0.10g and a PGA of 0.20g (Figure 4-12). It is apparent, therefore, that the seismic motion bounds demonstrated by the experience of MOVs on large lines envelop requirements for Maine Yankee plant. The current seismic motion bounds illustrated by the Type C Spectrum for smaller MOVs are comparable to, but do not envelop the Regulatory Guide Spectrum at 0.20 g. However, the current seismic motion bounds for smaller MOVs do not include additional

data recently collected. The adequacy of smaller MOVs should be demonstrated by an expanded experience data base.

The size restrictions on valve motor operators applicable to the Type A spectrum are illustrated in Figure 5-17. The MOVs must be mounted on lines of 12 inches diameter or greater. In addition, restrictions are placed on the weight of the motor operators, and the height of the operator measured from the centerline of the supporting pipe. These restrictions reflect the limits of the experience data base for MOVs based on the original experience data base. Specific motor-operated valves in the Maine Yankee plant are plotted in Figure 5-17, illustrating their dimensions with respect to the limits of applicability of experience data.

The size restrictions for valve motor operators applicable to the Type C spectrum are illustrated in Figure 5-18. Again, specific MOVs in the Maine Yankee plant are plotted on the graph, illustrating their dimensions with respect to the limits of applicability. Included within the sampling of MOVs reviewed at Maine Yankee are valves which do not comply with the current SQUG restrictions regarding operator height versus line size. Most of these valves will be adequately verified by the updated data base.

The MOVs at Maine Yankee were also reviewed to the other SQUG criteria with the following results:

- No motor operators are mounted to cast iron valves;
- All MOVs are mounted on lines of at least 2 inches in diameter or specific provisions have been made to support the operator with the pipe from a common structure;
- Motor operators are not independently supported from adjacent structures which could result in excessive differential movement between valve and operator.

TABLE 5-1
SUMMARY OF SEISMIC EXPERIENCE DATA BASE FOR MOTOR CONTROL CENTERS

Earthquake	Facility	Estimated Peak Ground Acceleration (g)	Location Within Facility	Number of MCCs	Number of Motor Controllers	Manufacturer	Vintage	Performance of MCCs During and Following Earthquake
San Fernando Earthquake, 1971	Sylmar Converter Station	0.50	Basement Second Floor Third Floor	11 7 5	180 109 35	General Electric Cutler Hammer	1970	The station contains a total of 24 MCCs. None of the units required repair after the earthquake; all were operable once power was restored. One MCC slid about two inches due to inadequate anchorage.
	Valley Steam Plant	0.40	Ground Floor Second Floor	6 11	83 218	Federal Pacific General Electric	1956 1953	Only one of three operating units retained power during the earthquake. All equipment served by motor controllers continued to function as long as power was maintained. No MCCs were damaged by the earthquake.
	Burbank Power Plant	0.35	Ground Floor	5	126	Westinghouse Cutler Hammer	1962 1958	Four units were operating at the time of the earthquake. All units operated through the earthquake, but lost power shortly after. There were no malfunctions of equipment that could be attributed to motor controllers. No MCCs were damaged by the earthquake.
	Glendale Power Plant	0.30	Basement	16	162	Westinghouse General Electric Square D	1963 1959 1953	Three units were operating at the time of the earthquake. All units remained on line during and after the earthquake. All equipment served by motor controllers functioned normally. No MCCs were damaged by the earthquake.
	Pasadena Power Plant	0.20	Ground Floor Second Floor Third Floor	1 2 1	24 20 30	General Electric Federal Pacific	1965 1957	Two units were operating at the time of the earthquake. Both units continued operating during and after the earthquake. All equipment served by motor controllers functioned normally. No MCCs were damaged by the earthquake.
Imperial Valley Earthquake, 1979	El Centro Steam Plant	0.50	Ground Floor Second Floor	3 2	30 30	Square D Westinghouse	1968 1957	Two units were operating at the time of the earthquake. One unit lost power, the other continued operating. All equipment served by motor controllers functioned normally in the operating unit. No MCCs were damaged in the earthquake.

TABLE 5-1 (Continued)
SUMMARY OF SEISMIC EXPERIENCE DATA BASE FOR MOTOR CONTROL CENTERS

Earthquake	Facility	Estimated Peak Ground Acceleration (g)	Location Within Facility	Number of MCCs	Number of Motor Controllers	Manufacturer	Vintage	Performance of MCCs During and Following Earthquake
Coalinga Earthquake, 1983	Epicentral Area	0.60	Ground Floor	7	212	Westinghouse Furnace Electric ITE/Gould Nelson Electric	1980 1980 1980 1970	The plants lost power during the earthquake. Three of the MCCs slid due to lack of anchorage. One MCC slid one inch in spite of its anchorage. No MCCs were damaged by the earthquake.
	San Luis Canal Pumping Plants	0.35	Ground Floor	4	25	Westinghouse General Electric	1970 1970	The pumping plants lost power during the earthquake. No MCCs were damaged.

SUMMARY OF SEISMIC EXPERIENCE DATA BASE FOR LOW VOLTAGE SWITCHGEAR

Earthquake	Facility	Estimated Peak Ground Acceleration (g)	Location Within Facility	Number of Switchgear Assemblies	Number of Circuit Breakers	Manufacturer	Vintage	Performance of Low Voltage Switchgear During and Following Earthquake
San Fernando Earthquake, 1971	Sylmar Converter Station	0.50	Basement	5	37	General Electric	1970	Low voltage switchgear were not damaged in the earthquake; all assemblies were operable once power was restored to the station. One switchgear assembly slid about three inches due to failure of its very light anchorage.
	Valley Steam Plant	0.40	Second Floor	7	60	ITE/Imperial	1956 1953	Only one of three operating units retained power during the earthquake. Equipment served by the switchgear continued to function as long as power was not lost. Switchgear were not damaged by the earthquake.
	Burbank Power Plant	0.35	Ground Floor	4	60	Westinghouse	1962 1958	Four units were operating at the time of the earthquake. All units operated through the earthquake, but lost power shortly after. There were no malfunctions of equipment served by switchgear. Switchgear were not damaged by the earthquake.
	Glendale Power Plant	0.30	Basement Mezzanine	1	24	General Electric	1953	Three units were operating at the time of the earthquake. All units remained on line during and after the quake. All equipment served by switchgear functioned normally. Switchgear were not damaged by the earthquake.
	Pasadena Power Plant	0.20	Turbine Floor	3	46	Westinghouse General Electric	1955 1957 1965	Two units were operating at the time of the earthquake. Both units remained on line during and after the earthquake. All equipment served by switchgear functioned normally. Switchgear were not damaged in the earthquake.
Imperial Valley Earthquake, 1979	El Centro Steam Plant	0.50	Ground Floor	6	100	General Electric	1949 to 1968	Two units were operating at the time of the earthquake. One unit lost power, the other continued operating. All equipment served by switchgear functioned normally as long as power was not lost. Switchgear were not damaged by the earthquake.

TABLE 5-3
SUMMARY OF SEISMIC EXPERIENCE DATA BASE FOR UNIT SUBSTATION TRANSFORMERS

Earthquake	Facility	Location Within Facility	Number of Transformers	Estimated Peak Ground Acceleration (g)	Manufacturer, Model, Approximate Vintage	Performance of Transformers During and Following Earthquake
San Fernando Earthquake, 1971	Sylmar Converter Station	Basement	5	0.50	General Electric Cutler-Hammer 1970	Facility lost power for several months, no damage to low-voltage transformers.
	Valley Steam Plant	Ground Floor	12	0.30	Molony 1950s	Three units were on line. Two tripped off line and lost power; one remained on line. No damage to low voltage transformers.
	Burbank Olive Plant	Ground Floor	2	0.32	Westinghouse ca. 1960	Four units were on line; two tripped off line, two remained on. All shut down shortly after the earthquake as off-site power was lost. No damage to transformers.
	Glendale Power Plant	Ground Floor	2	0.27	Unspecified	Three units were on line; all remained on line. No damage to transformers.
Imperial Valley Earthquake, 1979	El Centro Steam Plant	Ground Floor	5	0.42	General Electric 1948-1968	Two units were on line. One lost power; one tripped off line but continued to operate. No damage to low voltage transformers.
Coalinga Earthquake, 1983	Main Oil Pumping Plant	Ground Floor	2	0.60	Sierra Transformer 1970	The station lost power during the earthquake and all equipment shut down. Both transformers slid, one failing its anchorage. The sliding broke short sections of conduit, causing an electrical ground in one unit.
	Pleasant Valley Pumping Plant	Ground Floor	1	0.49	Allis Chalmers 1969	The plant lost power during the earthquake and all equipment shut down. The transformer was undamaged.

TABLE 5-4

SUMMARY OF SEISMIC EXPERIENCE DATA BASE FOR METAL-CLAD SWITCHGEAR

Earthquake	Facility	Estimated Peak Ground Acceleration (g)	Location Within Facility	Number of Switchgear Assemblies	Number of Circuit Breakers	Manufacturer	Vintage	Performance of Metal-Clad Switchgear During and Following Earthquake
San Fernando Earthquake, 1971	Sylmar Converter Station	0.50	Basement	1	19	General Electric	1970	Metal-clad switchgear was live during and following the earthquake.
	Valley Steam Plant	0.40	Second Floor	8	96	General Electric Westinghouse	1956 1953	Only one of three operating units retained power during the earthquake. Equipment served by the switchgear continued to function as long as power was maintained. Switchgear were not damaged by the earthquake.
	Burbank Power Plant	0.35	Ground Floor	2	24	Westinghouse	1962 1958	Four units were operating at the time of the earthquake. All units operated through the earthquake, but lost power shortly after. There were no malfunctions of equipment served by switchgear. Switchgear were not damaged by the earthquake.
	Glendale Power Plant	0.30	Basement	4	32	General Electric Westinghouse	1953 1959 1964	Three units were operating at the time of the earthquake. All units remained on line during and after the quake. All equipment served by switchgear functioned normally. Switchgear were not damaged by the earthquake.
	Pasadena Power Plant	0.20	Turbine Floor	3	50	Allis Chalmers Federal Pacific General Electric	1965 1957 1965	Two units were operating at the time the earthquake. Both units remained on line during and after the earthquake. All equipment served by switchgear functioned normally. Switchgear were not damaged in the earthquake.
Imperial Valley Earthquake, 1979	El Centro Steam Plant	0.50	Turbine Deck	7	60	General Electric	1949 to 1968	Two units were operating at the time of the earthquake. One unit lost power, the other continued operating. All equipment served by switchgear functioned normally as long as power was maintained. Switchgear were not damaged by the earthquake.
Coalinga Earthquake, 1983	Epicentral Area	0.60	Ground Floor	4	26	Nelson Electric Allis Chalmers General Electric	1970 1969 1963 to 1980	The plant lost power during the earthquake. One 2400 V switchgear slid but was undamaged. One poorly anchored 4160 V switchgear slid several inches, shearing its anchor bolts and suffering cabinet damage upon impact with a conduit flange embedded in the floor. No switchgear components required replacement.

TABLE 5-5
SUMMARY OF SEISMIC EXPERIENCE DATA BASE FOR HORIZONTAL PUMPS

Earthquake	Facility	Estimated Peak Ground Acceleration (g)	Location Within Facility	Number of Pumps	Manufacturer	Vintage	Performance of Horizontal Pumps During and Following Earthquake
San Fernando Earthquake, 1971	Valley Steam Plant	0.40	Ground Floor	33	Electric Machinery Elliot General Electric Byron-Jackson United	1956 1953	Only one of three operating units retained power during the earthquake. Pumps were undamaged and continued to function in the operating unit.
	Burbank Power Plant	0.35	Ground Floor	26	General Electric US Electric De Laval Worthington Pacific	1941 to 1962	Four units were operating at the time of the earthquake. All units operated through the earthquake, but lost power shortly after. Pumps were undamaged and showed no signs of malfunction during the earthquake.
	Glendale Power Plant	0.30	Basement	28	General Electric Byron-Jackson Ingersol-Rand	1941 to 1964	Three units were operating at the time of the earthquake. All units remained on line during and after the earthquake. Pumps incurred no damage or malfunctions.
	Pasadena Power Plant	0.20	Ground Floor	10	General Electric Byron-Jackson	1965 1957 1955	Two units were operating at the time of the earthquake. Both units operated through the earthquake. Pumps incurred no damage or malfunctions.
Imperial Valley Earthquake, 1979	El Centro Steam Plant	0.50	Ground Floor	13	General Electric Allis-Chalmers Byron-Jackson	1949 to 1968	Two units were operating at the time of the earthquake. One unit lost power, the other continued operating. Pumps were undamaged and continued to operate where power was not lost.
Coalinga Earthquake, 1983	Epicentral Area	0.60	Ground Floor	19	Westinghouse Reliance Bingham Gould Worthingham	1967 to 1980	The plants lost power during the earthquake Pumps were undamaged except for some minor grout cracking and some possible increased bearing wear.

TABLE 5-6
SUMMARY OF SEISMIC EXPERIENCE DATA BASE FOR VERTICAL PUMPS

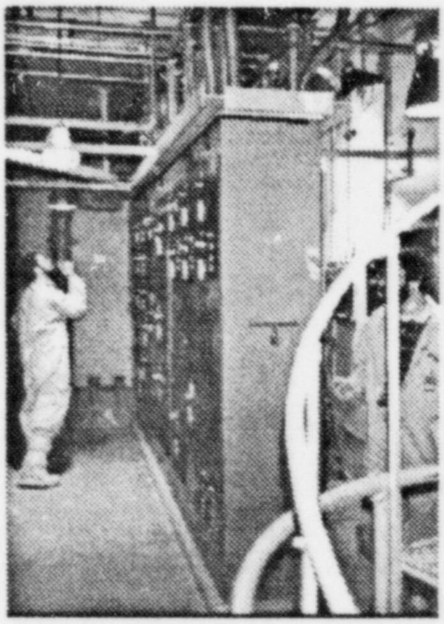
Earthquake	Facility	Estimated Peak Ground Acceleration (g)	Location Within Facility	Number of Pumps	Manufacturer	Vintage	Performance of Vertical Pumps During and Following Earthquake
San Fernando Earthquake, 1971	Valley Steam Plant	0.40	Ground Floor	32	General Electric Westinghouse Johnston Electric Byron-Jackson	1956 1953	Only one of three operating units retained power during the earthquake. Pumps were undamaged and continued to function in the operating unit.
	Burbank Power Plant	0.35	Ground Floor	6	General Electric Allis-Chalmers Byron-Jackson Pacific	1962 1958	Four units were operating at the time of the earthquake. All units operated through the earthquake, but lost power shortly after. Pumps were undamaged and showed no signs of malfunction during the earthquake.
	Glendale Power Plant	0.30	Basement	9	General Electric Allis-Chalmers Byron-Jackson Peerless	1941 to 1964	Three units were operating at the time of the earthquake. All units remained on line during and after the earthquake. Pumps incurred no damage or malfunctions.
	Pasadena Power Plant	0.20	Ground Floor	4	General Electric Foster-Wheeler	1965 1957	Two units were operating at the time of the earthquake. Both units operated through the earthquake. Pumps incurred no damage or malfunctions.
Coalinga Earthquake, 1983	Epicentral Area	0.60	Ground Floor	17	Westinghouse Seimans-Allis US Electric Byron-Jackson	1967 1980	The plants lost power during the earthquake. Pumps were undamaged except for some minor grout cracking of grout in their foundations.
	San Luis Canal Pumping Stations	0.35	Ground Floor	56	General Electric Westinghouse US Electric Peabody Johnston Byron-Jackson	1980 1970	The pumping stations lost power during the earthquake. Pumps were undamaged for increased wear on three units.

TABLE 5-7
SUMMARY OF SEISMIC EXPERIENCE DATA BASE FOR AIR-OPERATED VALVES

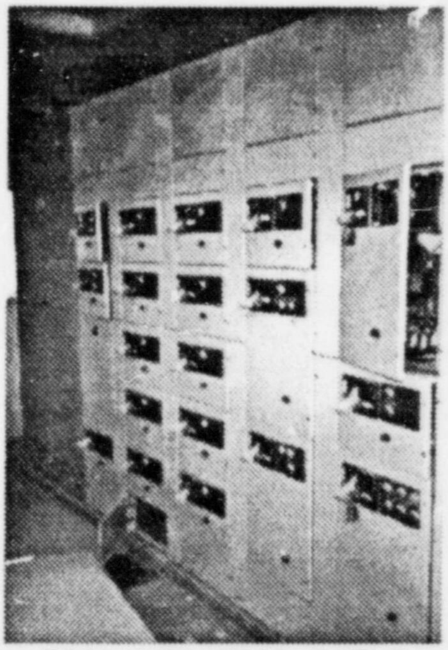
Earthquake	Facility	Estimated Peak Ground Acceleration (g)	Location Within Facility	Number of AOVs	Manufacturer	Vintage	Performance of AOVs During and Following Earthquake
San Fernando Earthquake, 1971	Valley Steam Plant	0.40	Elevation 945 Elevation 964	148	Mason-Neilan Bailey	1956 1953	Only one of three operating units retained power during the earthquake. No valves were damaged.
	Burbank Power Plant	0.35	Fourth Floor Turbine Deck	94	Climax Bailey Fisher	1962 1958	Four units were operating at the time of the earthquake. All units operated through the earthquake, but lost power shortly after. No valves were damaged.
	Glendale Power Plant	0.30	Basement Operating Floor	57	Fisher	1965 1959	Three units were operating at the time of the earthquake. All units remained on line during and after the earthquake. No valves were damaged.
Imperial Valley Earthquake, 1979	El Centro Steam Plant	0.50	Mezzanine Turbine Deck	75	Bailey Keiley-Mueller Fisher	1968 1957	Two units were operating at the time of the earthquake. One unit lost power, the other continued operating. One valve failed due to impact of operator diaphragm on an adjacent steel girder. No other valves were damaged.
Coalinga Earthquake, 1983	Epicentral Area	0.60	Ground Floor	101	Fisher Orbit Dover-Norris Jamesbury	1980 1967	The plants lost power during the earthquake. No valves were damaged.

TABLE 5-8
SUMMARY OF SEISMIC EXPERIENCE DATA BASE FOR MOTOR-OPERATED VALVES

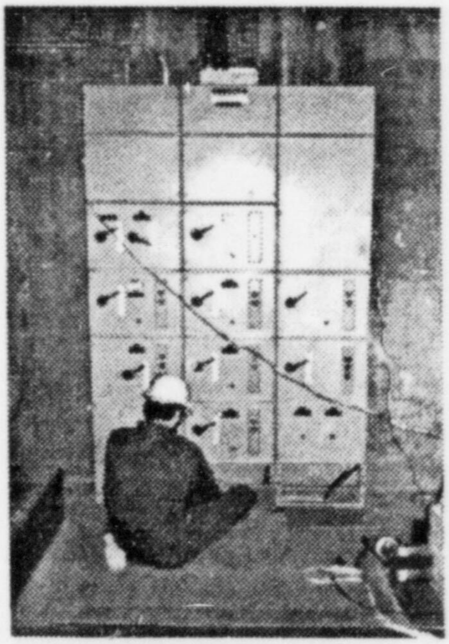
Earthquake	Facility	Estimated Peak Ground Acceleration (g)	Location Within Facility	Number of MOVs	Manufacturer	Vintage	Performance of MOVs During and Following Earthquake
San Fernando Earthquake, 1971	Valley Steam Plant	0.40	Second Floor	31	McBain Limitorque	1956 1953	Only one of three operating units retained power during the earthquake. No valves were damaged. Full load valves operate at 2000 psi and 400oF.
	Burbank Power Plant	0.35	Ground Floor	4	Limitorque	1962 1958	Four units were operating at the time of the earthquake. All units operated through the earthquake, but lost power shortly after. No valves were damaged.
	Glendale Power Plant	0.30	Basement Operating Floor Sixth Floor	7	Limitorque	1964 1959	Three units were operating at the time of the earthquake. All units remained on line during and after the earthquake. No valves were damaged.
Imperial Valley Earthquake, 1979	El Centro Steam Plant	0.50	Ground Floor Elevation 1030 Elevation 1045	6	Limitorque	1968 1957	Two units were operating at the time of the earthquake. One unit lost power, the other continued operating. No valves were damaged.
Coalinga Earthquake, 1983	Epicentral Area	0.60	Ground Floor	55	Limitorque	1980 1967	The plants lost power during the earthquake. No valves were damaged. Connecting plastic conduit casings were damaged.
	San Luis Canal Pumping Plants	0.35	Ground Floor	29	Limitorque Rotork	1970	The pumping plants lost power during the earthquake. No valves were damaged.



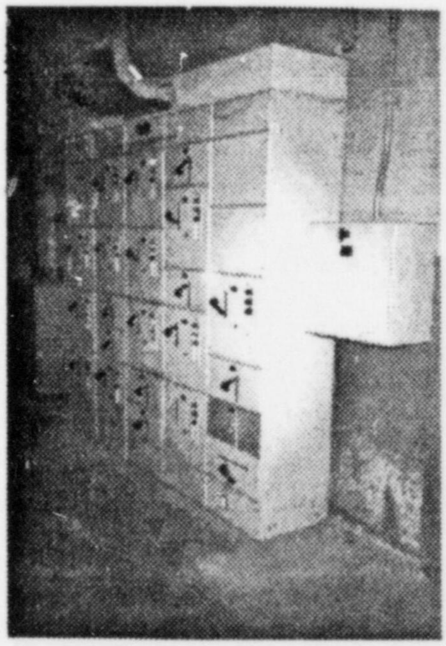
MAINE YANKEE
Westinghouse MCC
Type W, 1972.



COALINGA NEAR-FIELD
Shell Water Treatment Plant
PGA: 0.60g
Westinghouse MCC,
Five Star, 1981.

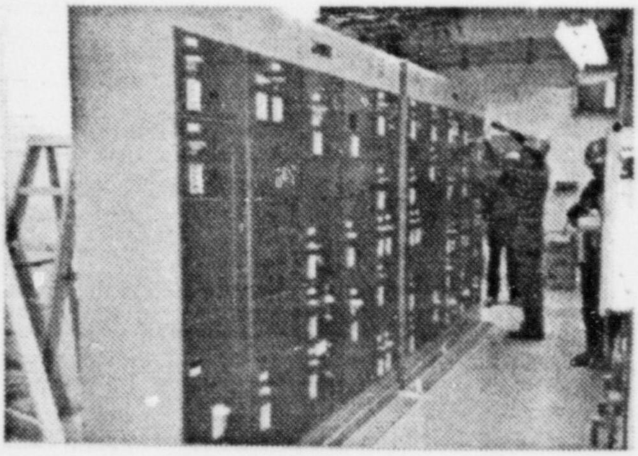


GLENDALE PLANT
PGA: 0.27g
Westinghouse MCC,
11-300 Series, 1963.

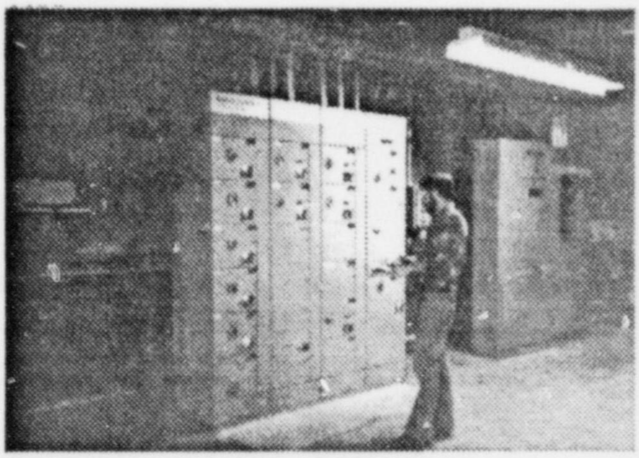


BURBANK PLANT
PGA: 0.32g
Westinghouse MCC,
11-300 Series, 1960.

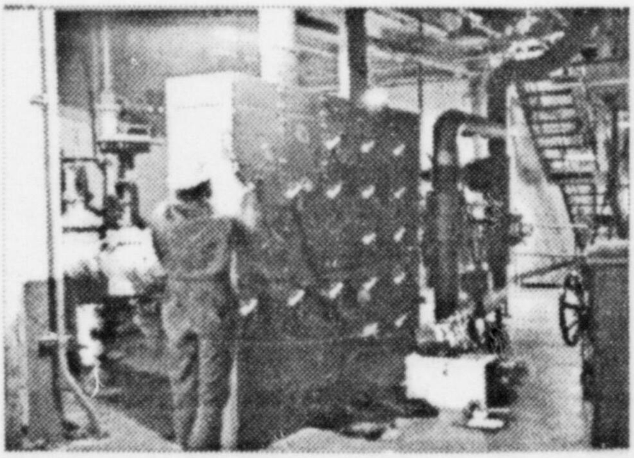
Figure 5-1: Comparison of Motor Control Centers at Maine Yankee with data base plants.



MAINE YANKEE
Westinghouse MCC, Type W,
1972.

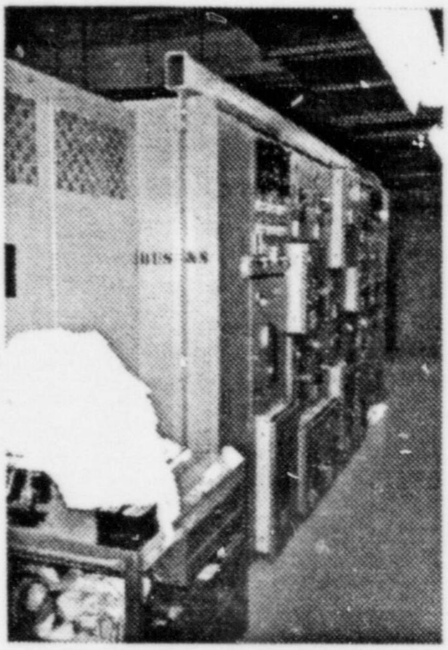


SYLMAR CONVERTER STATION
PGA: 0.50g
General Electric MCC,
7700 Line Series, 1970.

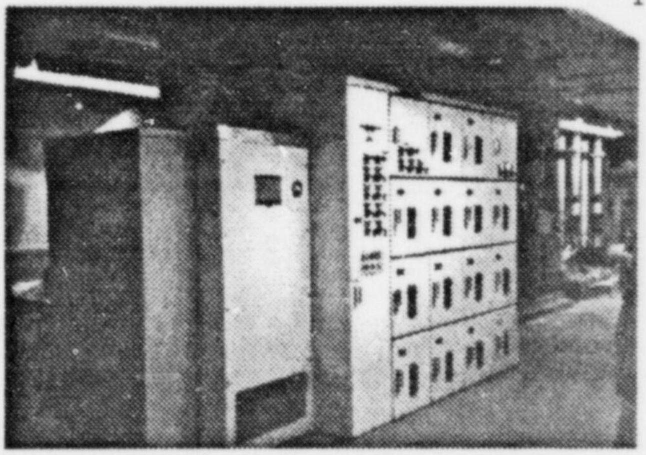


EL CENTRO PLANT
PGA: 0.42g
Westinghouse MCC,
11-300 Series, 1957.

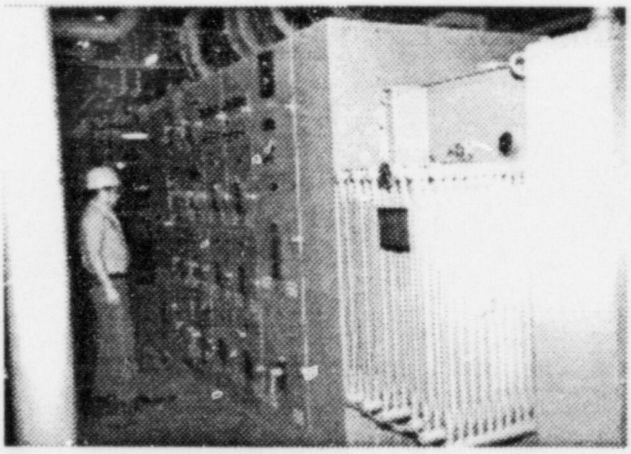
Figure 5-2: Comparison of Motor Control Centers at Maine Yankee with data base plants.



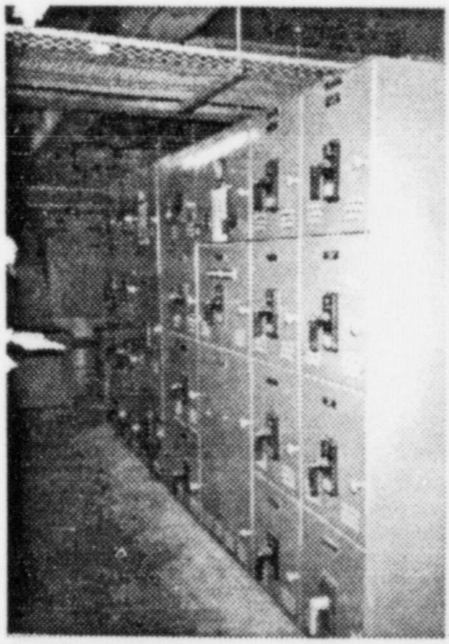
MAINE YANKEE
(Note dry type transformer, 4 kV/480 V, left of switchgear.)
General Electric, Switchgear, Type AKD-5, 1972.



SYLMAR CONVERTER STATION
PGA: 0.50g
(Note dry type transformer, 4 kV/480 V, left of switchgear.)
General Electric Switchgear, Type AKD-5, 1970.

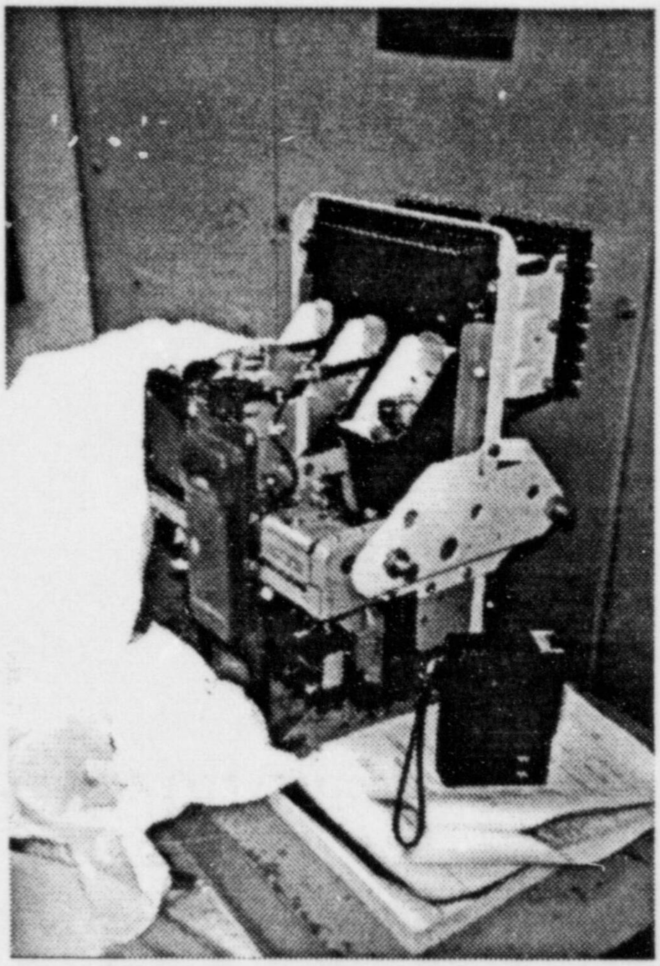


EL CENTRO PLANT
PGA: 0.42g
(Note oil-cooled transformer, right of switchgear.)
General Electric Switchgear, Type AKD-5, 1968.

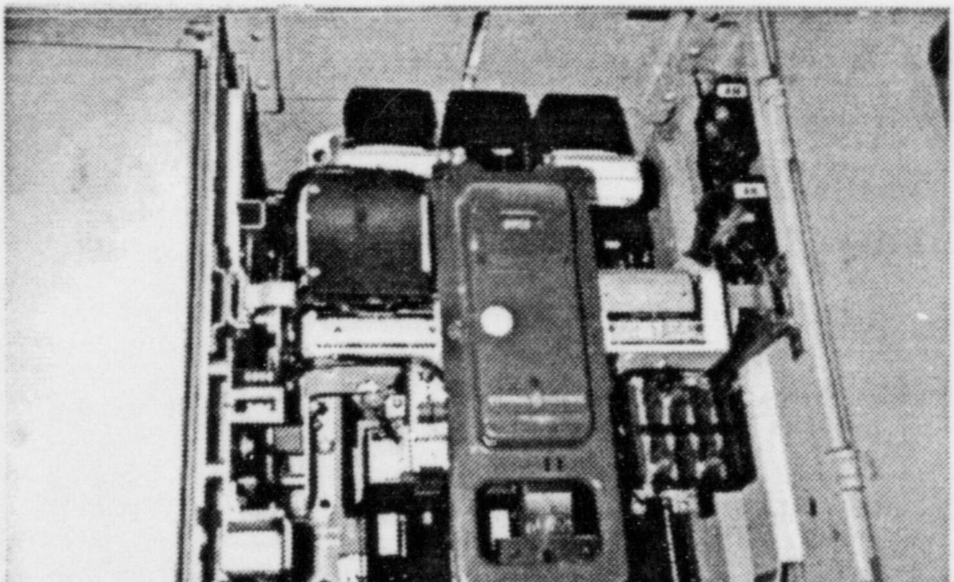


GLENDALE PLANT
PGA: 0.27g
General Electric, Low Voltage Switchgear, 1953.

Figure 5-3: Comparison of Low Voltage Switchgear and Unit Substation Transformers at Maine Yankee with data base plants.

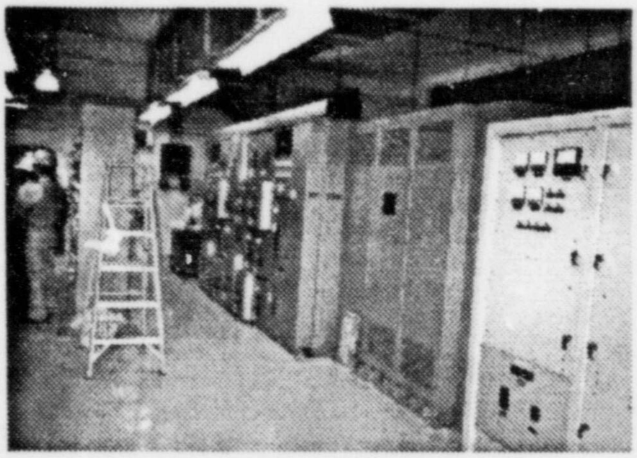


MAINE YANKEE
General Electric, 480 Volt Breaker,
Type AK-25-1.

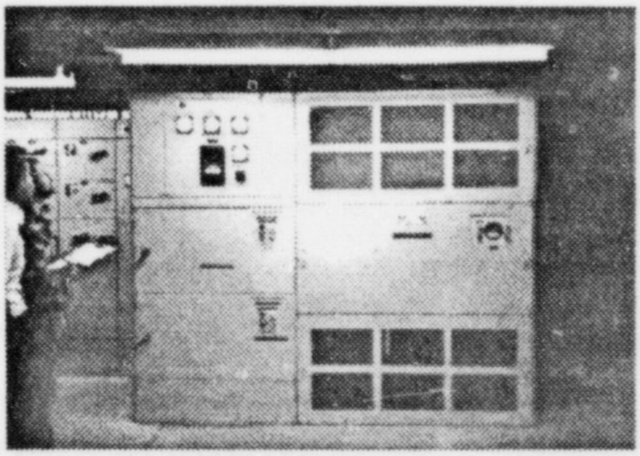


SYLMAR CONVERTER STATION, PGA: 0.50g
General Electric, Type AK-3A-25 Breaker.

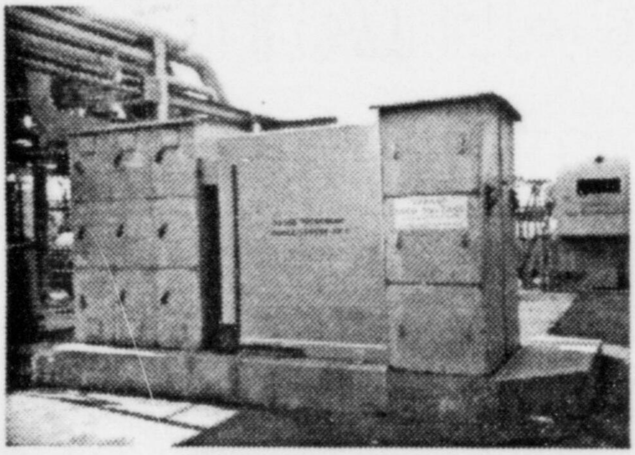
Figure 5-4: Comparison of Circuit Breakers on Low Voltage Switchgear at Maine Yankee with typical data base equipment.



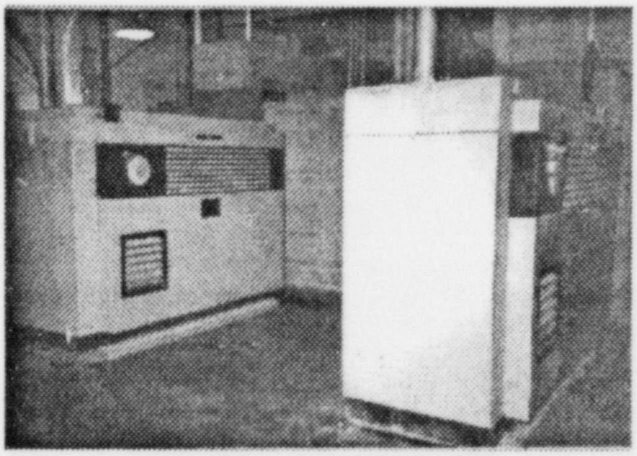
MAINE YANKEE
General Electric Dry Transformer
4160/480 Volts



SYLMAR CONVERTER STATION
PGA: 0.50g
Cutler-Hammer Dry Transformer
4160/480 Volts

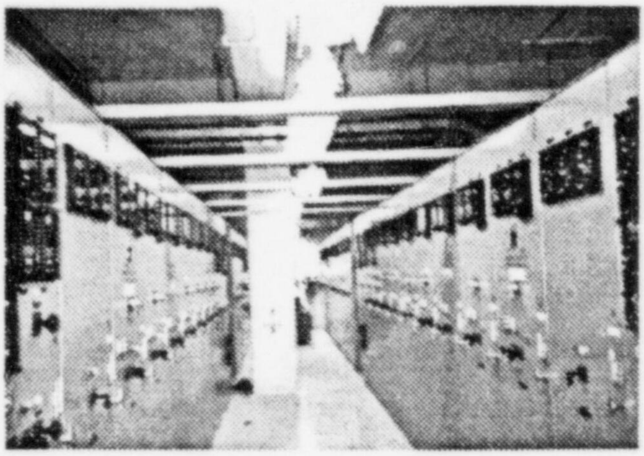


VALLEY STEAM PLANT
PGA: 0.30g
Molony Dry Transformer
4160/480 Volts

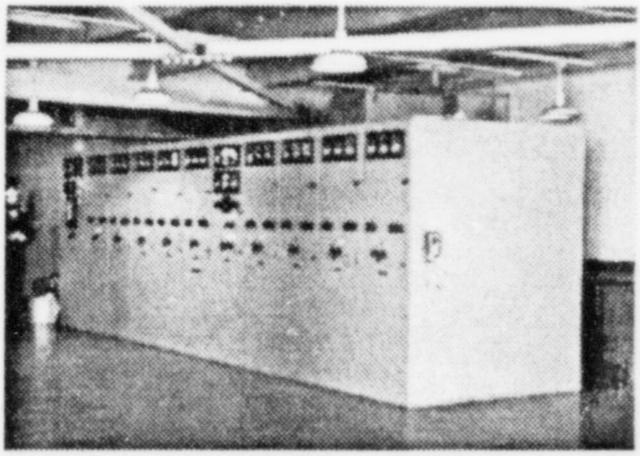


EL CENTRO PLANT
PGA: 0.42g
General Electric Dry Transformer
2400/480 Volts

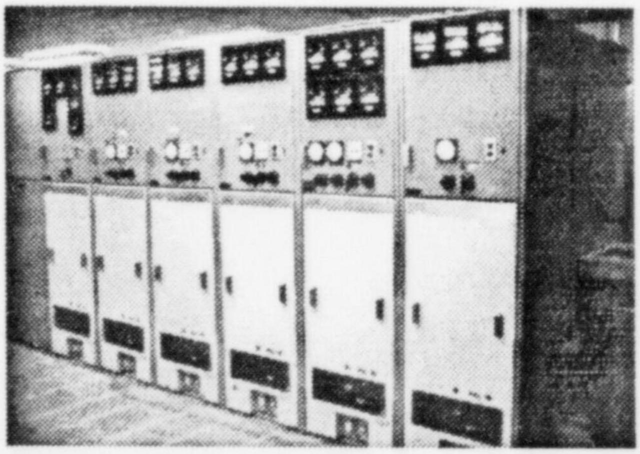
Figure 5-5: Comparison of Unit Substation Transformers at Maine Yankee with data base plants.



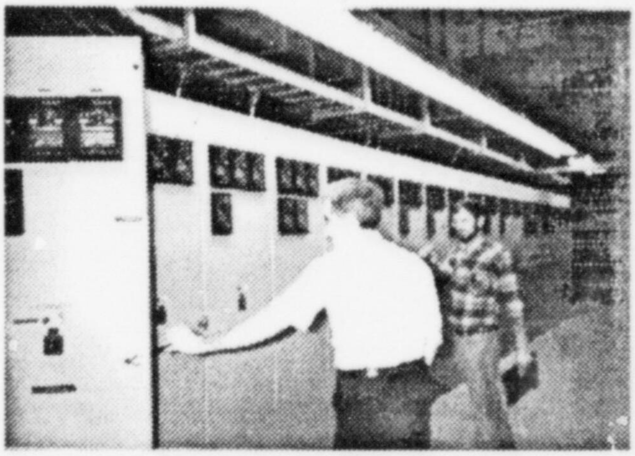
MAINE YANKEE
General Electric, 4.16 kV
Switchgear, 1972.



EL CENTRO PLANT
PGA: 0.42g
General Electric, 2.8 kV
Switchgear, 1968.

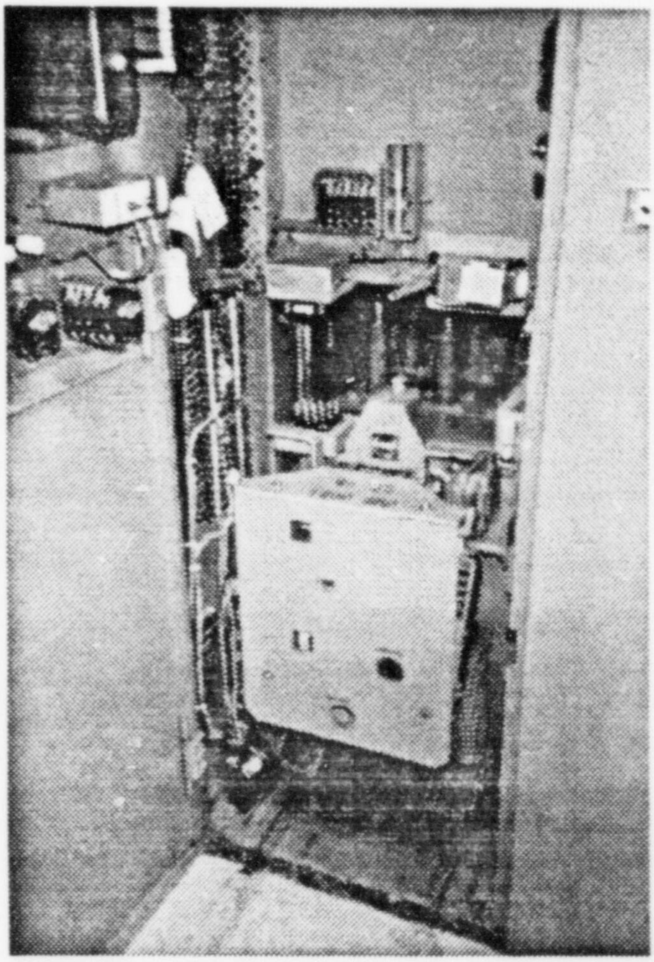


COALINGA NEAR-FIELD
PGA: 0.60g
General Electric, 4.16 kV
Switchgear, 1976.

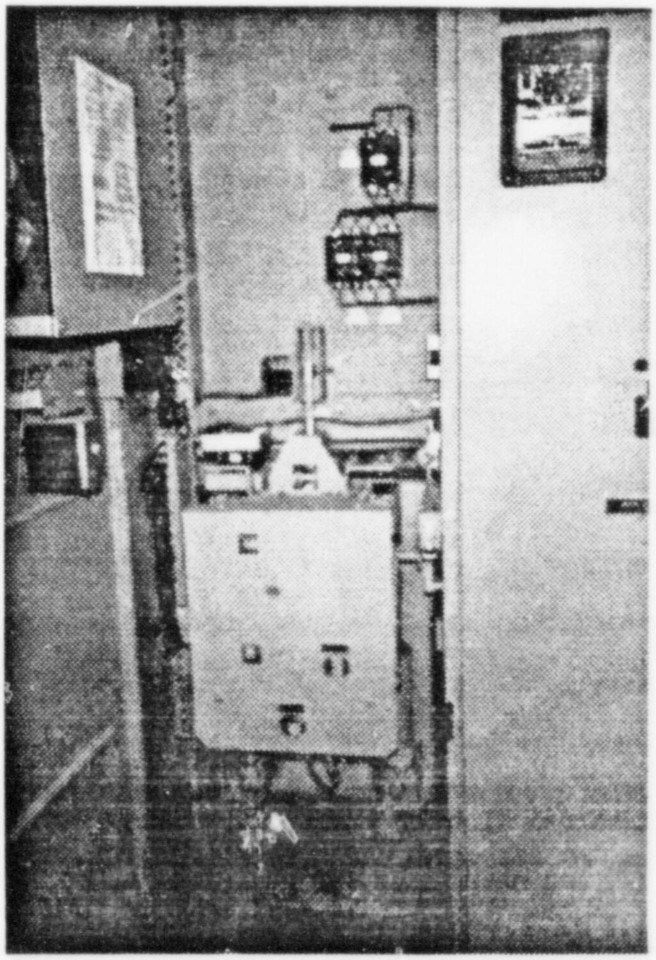


SYLMAR CONVERTER STATION
PGA: 0.50g
General Electric, 4.16 kV
Switchgear, 1970.

Figure 5-6: Comparison of Metal Clad Switchgear at Maine Yankee with data base plants.



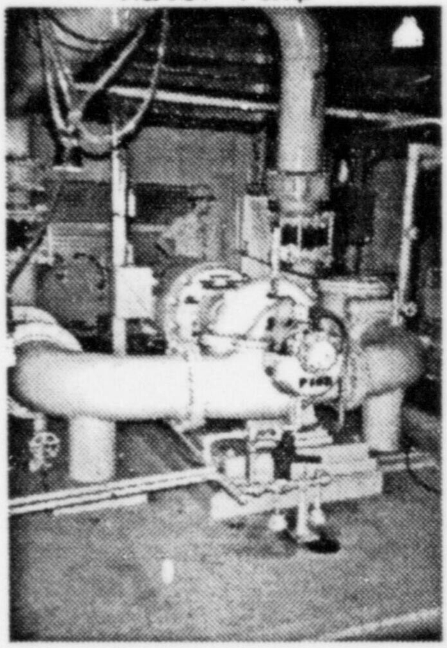
MAINE YANKEE
General Electric, Magnablast Air
Circuit Breaker,
Type AM-4.16-8HB



SYLMAR CONVERTER STATION
PGA: 0.50g
General Electric, Magnablast Air
Circuit Breaker,
Type AM-4.16-250-7H.

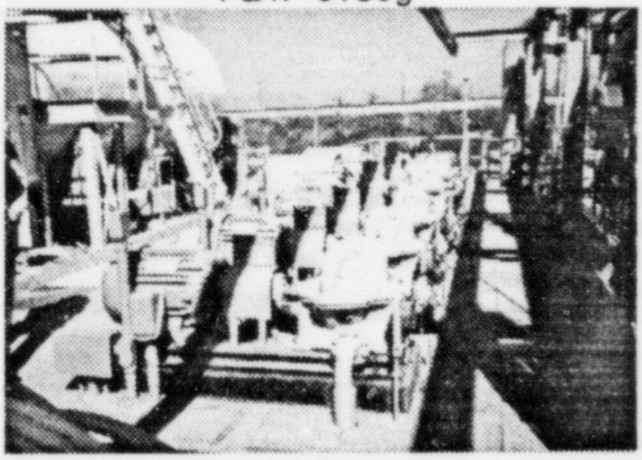
Figure 5-7: Comparison of Metal Clad Switchgear interior at Maine Yankee with a typical data base plant.

MAINE YANKEE
Primary Component Cooling
Water Pump

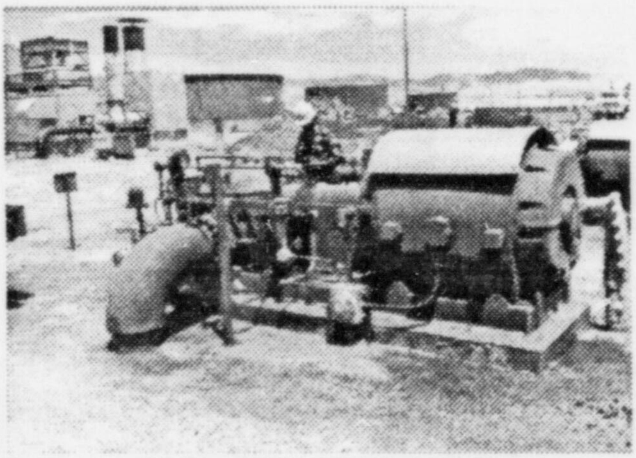


Motor - Allis Chalmers, 350 hp
Pump - DeLaval, 6000 gpm, 190 foot head

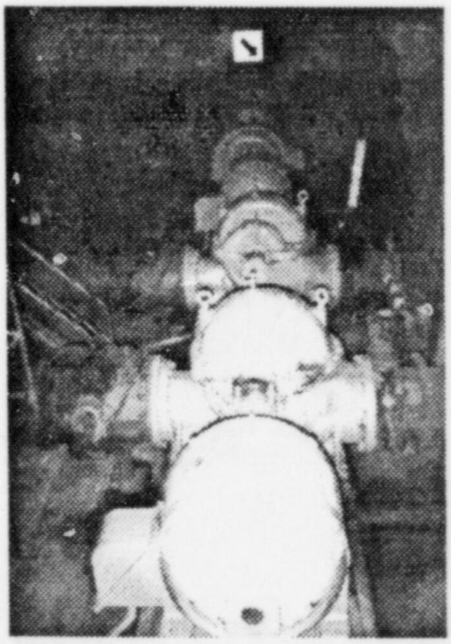
VALLEY STEAM PLANT
PGA: 0.50g



Motor - Allis Chalmers, 250 hp, 1955
Pump - No Nameplate

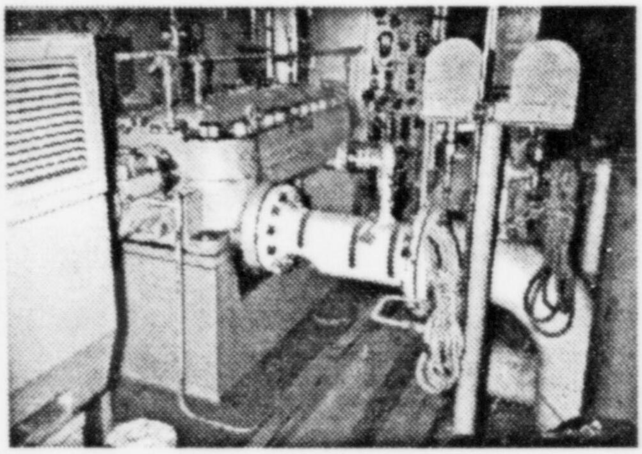


COALINGA NEAR-FIELD
Main Oil Pumping Plant
PGA: 0.60g
Motor - No Nameplate, 400 hp (est.)
Pump - Bingham, 1970, No Nameplate



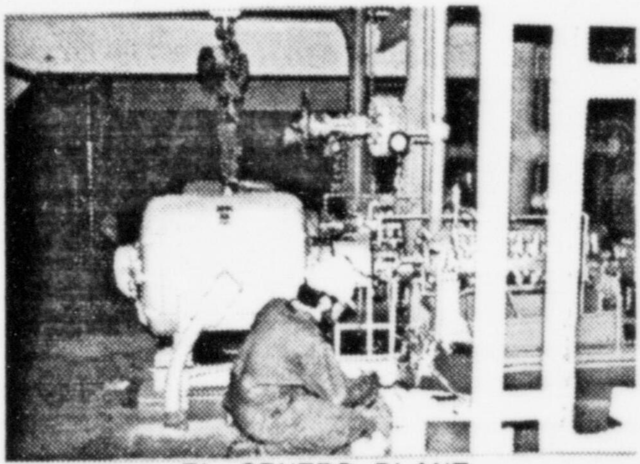
GLENDALE PLANT
PGA: 0.27g
Motor - General Electric Induction Motor, 350 hp
Pump - Ingersol Rand, 1950,

Figure 5-8: Comparison of Horizontal Pumps (centrifugal) at Maine Yankee with data base plants.

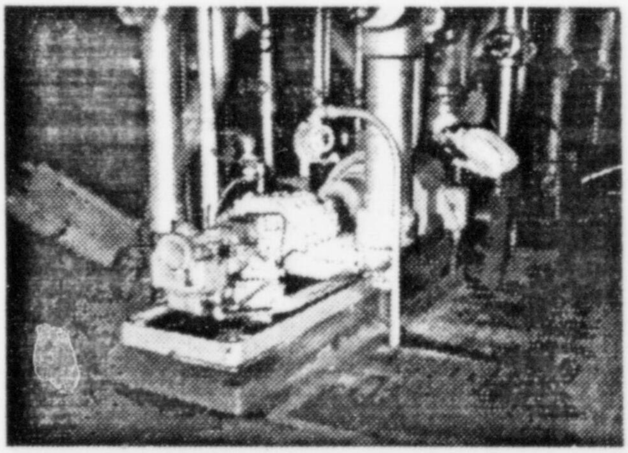


MAINE YANKEE
Emergency Feedwater Pump

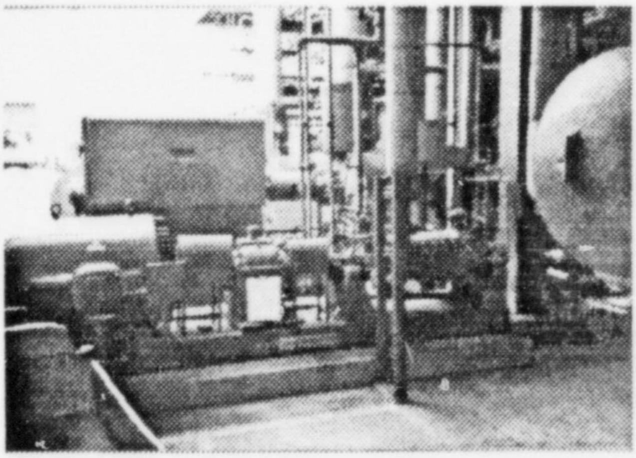
Motor - Allis Chalmers, 500 hp
Pump - Ingersol Rand Turbine Pump, 500 gpm, 2350 foot head, 1972.



EL CENTRO PLANT
PGA: 0.42g
Motor - Allis Chalmers, 600 hp
Pump - Pacific Multistage Turbine pump, 740 gpm, 2580 foot head, 1952.

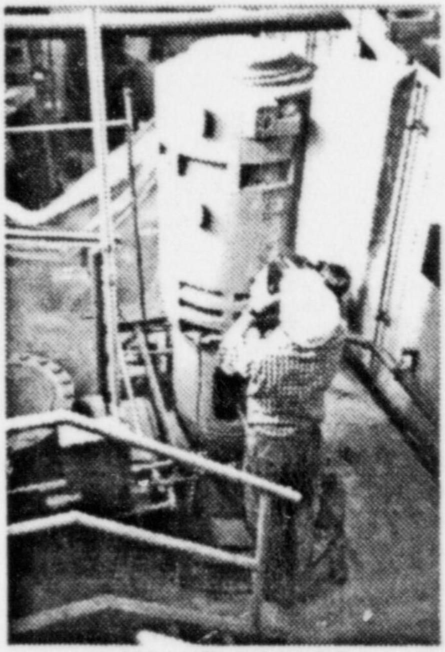


GLENDALE PLANT
PGA: 0.27g
Motor - General Electric, Type K Induction Motor, 350 hp
Pump - Pacific Boiler Feed Pump, 350 gpm, 1810 foot head, 1950.



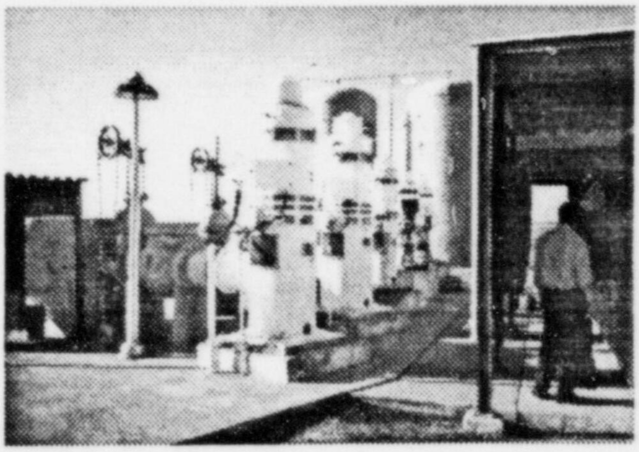
BURBANK PLANT
PGA: 0.52g
Motor - U.S. Electric, 250 hp
Pump - Worthington, Multistage Turbine Pump, 157 gpm, 2980 foot head.

Figure 5-9: Comparison of Horizontal Pumps (motor-driven, centrifugal pump) at Maine Yankee with data base plants.

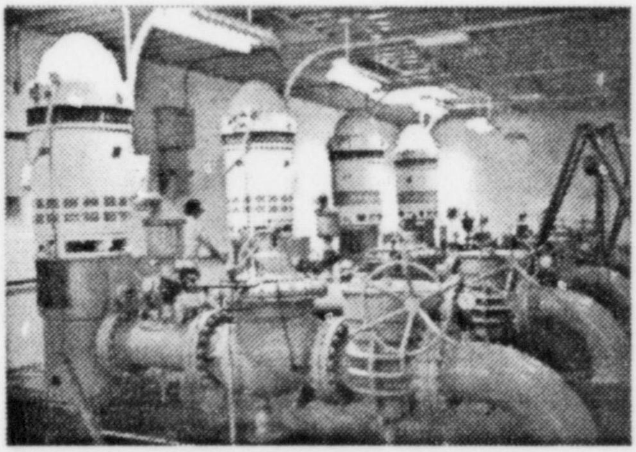


MAINE YANKEE
Service Water Pump

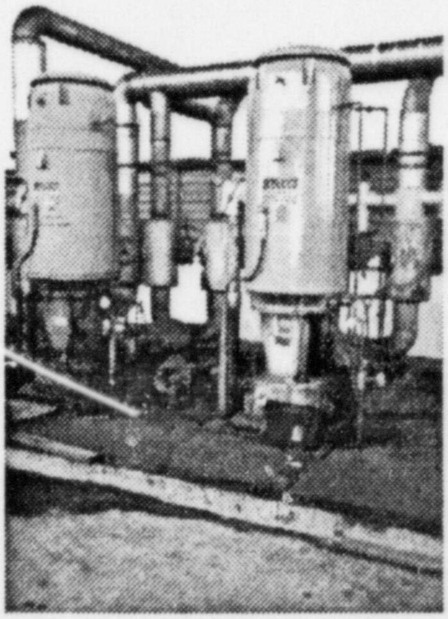
Motor - General Electric, 250 hp
460 V
Pump - Bingham Turbine Pump;
10,000 gpm, 66 foot head,
column length = 30 feet
pinned at base.



COALINGA FAR-FIELD
San Luis Canal Pumping Stations
PGA: 0.35g
Motor - General Electric, 300 hp
Pump - Johnston Turbine Pump;
column length = 20 feet,
cantilevered.

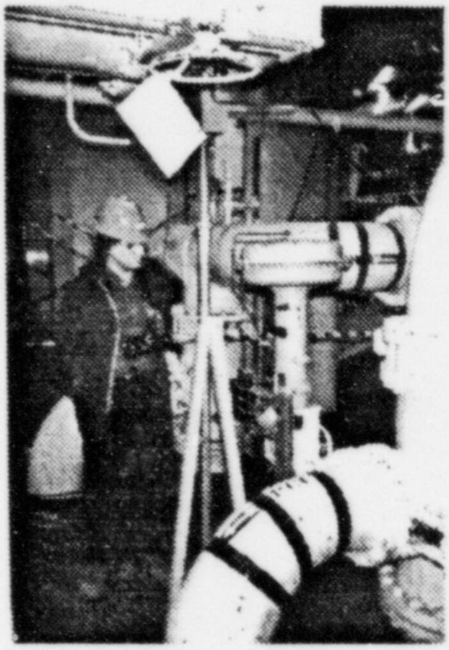


COALINGA NEAR-FIELD
Water Filtration Plant
PGA: 0.60g
Motor- U. S. Electric, 700 hp
Pump - Veriline Turbine Pump;
column length = 20 feet,
cantilevered.

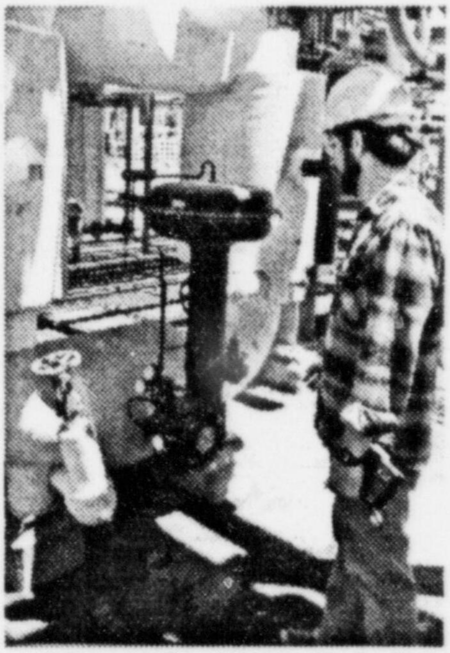


VALLEY STEAM PLANT
PGA: 0.30
Motor- General Electric, 250 hp
Pump - Johnston Turbine Pump,
200 gpm, 1600 foot head;
column length = 15 feet,
cantilevered.

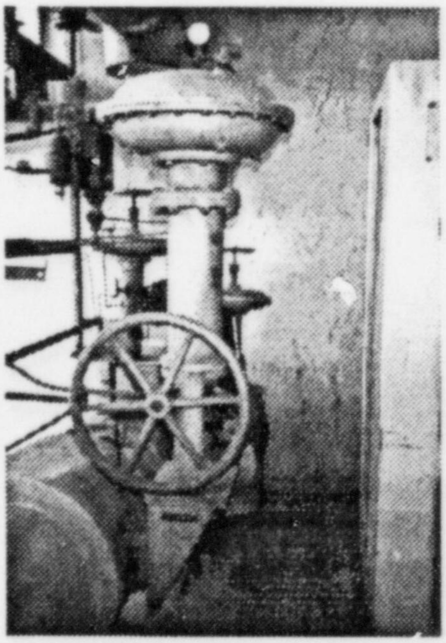
Figure 5-10: Comparison of Vertical Pumps at Maine Yankee with data base plants.



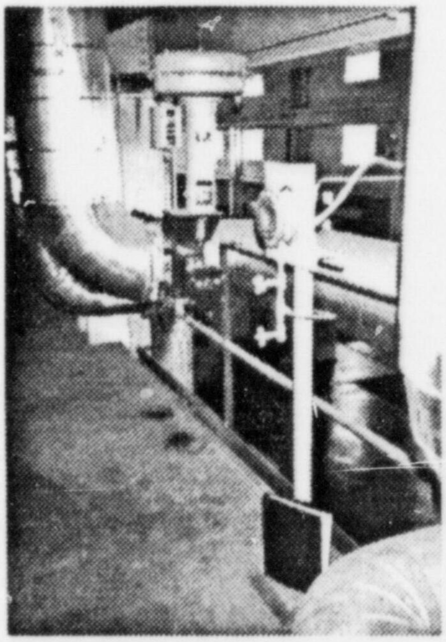
MAINE YANKEE
Fisher Size 60,
Type 656
Pipe Diameter - 10"
Operator Height - 38"



COALINGA NEAR-FIELD
Union Oil Butane Plant
PGA: 0.60g
Fisher Governor,
Type 1052-V100, 1980
Pipe Diameter - 6"
Operator Height - 35"

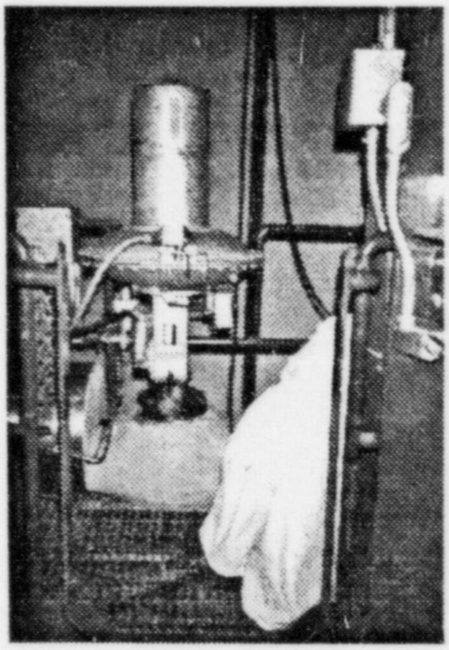


VALLEY STEAM PLANT
PGA: 0.50g
Mason-Neilan, 1955
Pipe Diameter - 6"
Operator Height - 40"

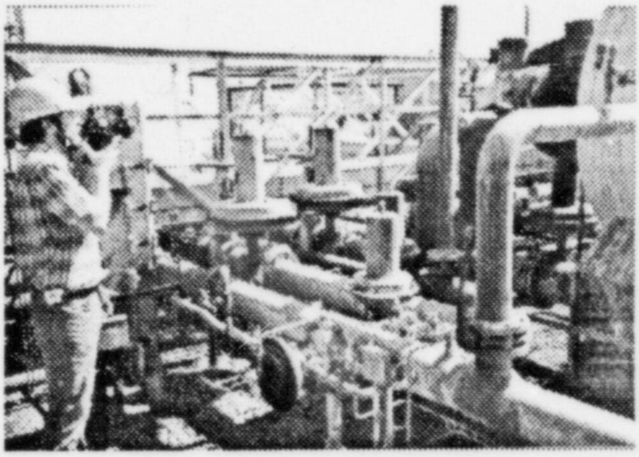


EL CENTRO PLANT
PGA: 0.42g
Keiley-Mueller Governor
Pipe Diameter - 6'
Operator Height - 36

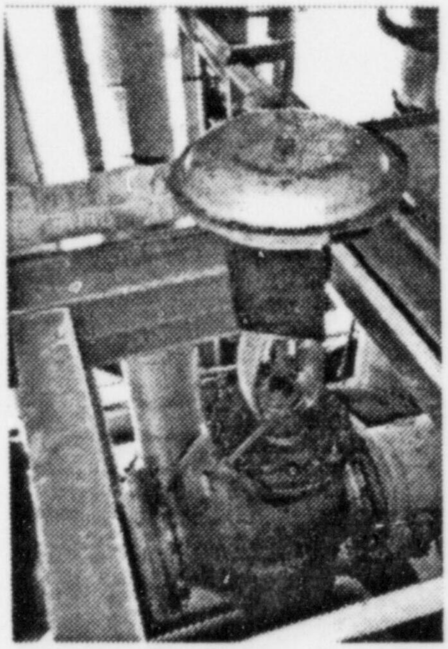
Figure 5-11: Comparison of Air Operated Valves (diaphragm type) at Maine Yankee with data base plants.



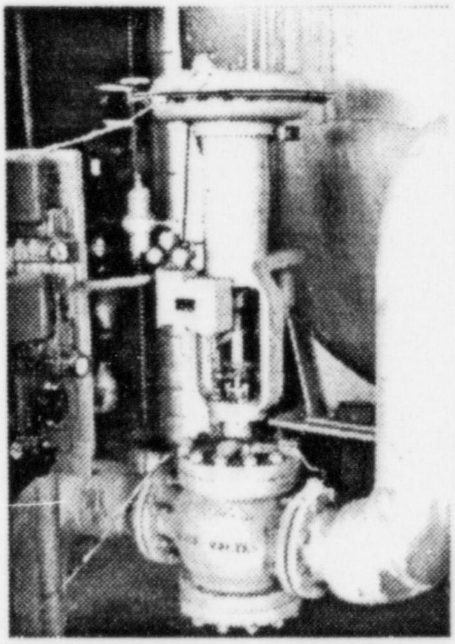
MAINE YANKEE
HCV-1001, Worthington Controls.
Pipe Diameter = 6"
Operator Height = 50"



COALINGA NEAR-FIELD
Shell Water Treatment Plant
PGA: 0.60g
Dover-Norris, 1980.
Pipe Diameter = 6"
Operator Height = 30"

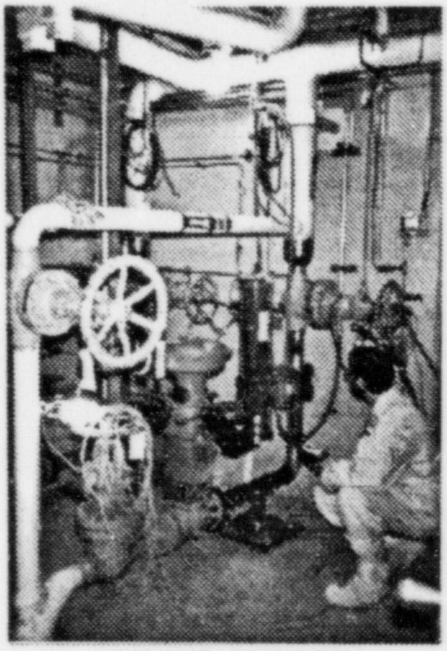


VALLEY STEAM PLANT
PGA: 0.30g
Fisher Controls
Pipe Diameter = 6"
Operator Height = 30"

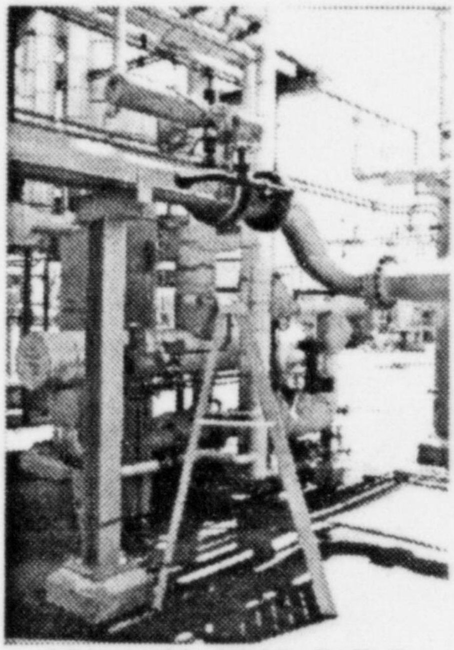


EL CENTRO PLANT
PGA: 0.42g
Keiley-Mueller, Type 1250-R, 1968
Pipe Diameter = 6"
Operator Height = 44"

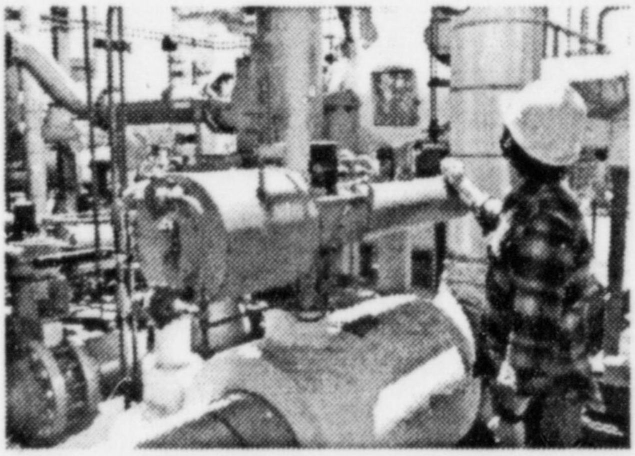
Figure 5-12: Comparison of Air Operated Valves (diaphragm type) at Maine Yankee with data base plants.



MAINE YANKEE
Fisher Type 657, size 45
Pipe Diameter - 3"
Operator Height - 32"

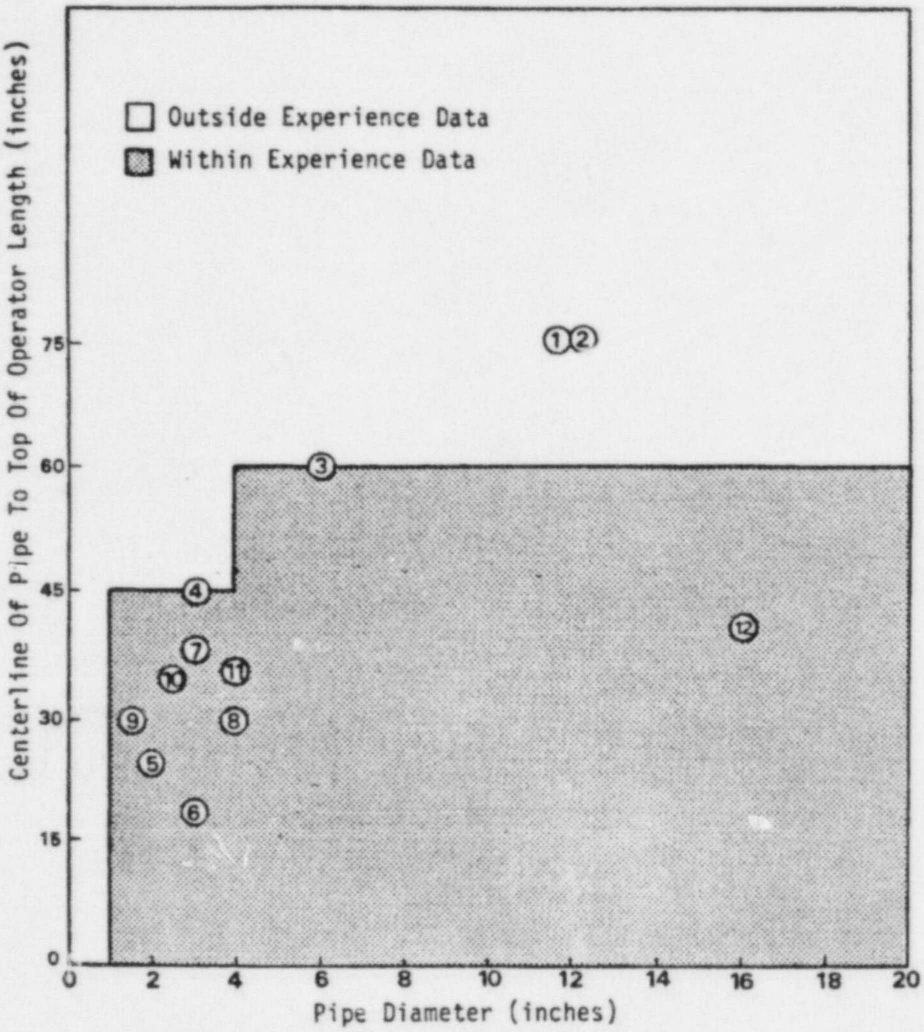


COALINGA NEAR-FIELD
Union Oil Butane Plant
PGA: 0.60g
Pipe Diameter - 6"
Operator Height - 20"



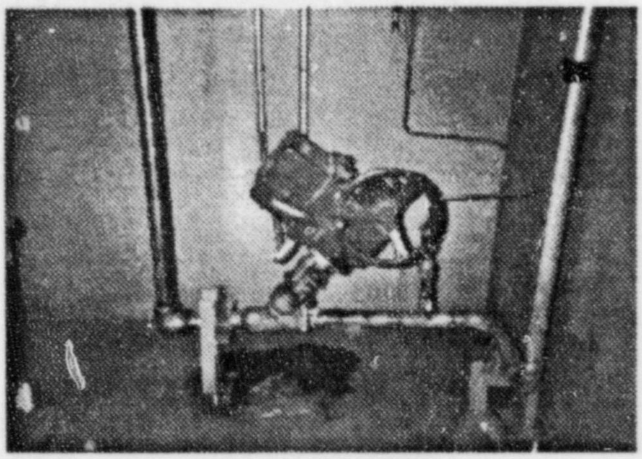
COALINGA NEAR-FIELD
Union Oil Butane Plant
PGA: 0.60g
Pipe Diametar - 6"
Operator Height - 20"

Figure 5-13: Comparison of Air Operated Valves (piston type) at Maine Yankee with a typical data base plant.

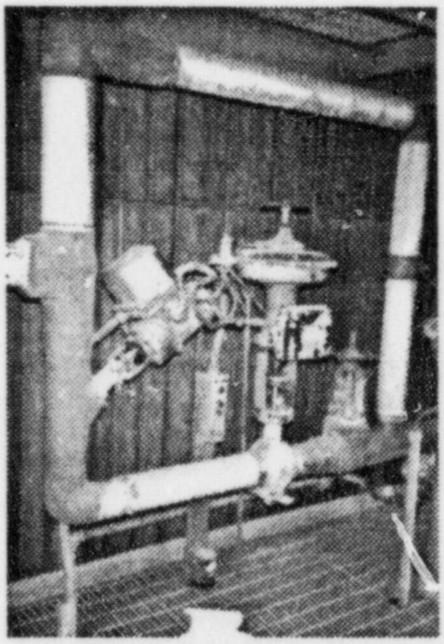


1. RHR Heat Exchanger Outlet (RH-T-12)
2. RHR Heat Exchanger Outlet (LSI-F-59)
3. Decay Heat Release (MS-A-162)
4. HPSI Pump Discharge (CH-A-32)
5. Steam Generator Blowdown Containment Isolation (BD-T-21)
6. Emergency Feedwater Isolation (AFW-A-338)
7. Diesel Cooling Water Outlet (PCC-A-493)
8. Diesel Cooling Water Throttle (PCC-T-305)
9. Seal Cooling Supply to RHR Pump P-12A
10. Emergency Feedwater Control (AFW-A-101)
11. PCCW Containment Isolation (PCC-A-270)
12. SCCW Seismic Boundary (SCC-A-460)

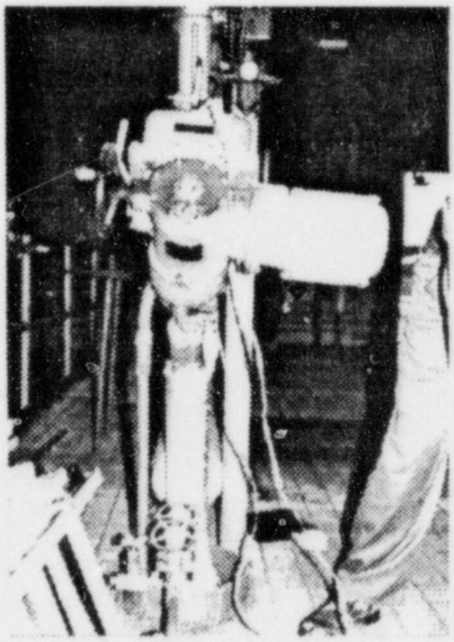
Figure 5-14: Restrictions on the size of air-operated valves applicable to seismic experience data showing sample AOVs from the Maine Yankee plant.



MAINE YANKEE
Valve CHM-86, Limitorque, 1972
Pipe Diameter = 2"
Operator Height = 24"

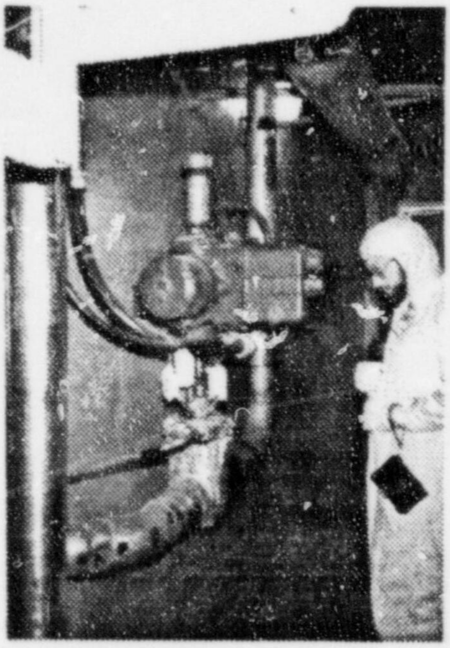


BURBANK POWER PLANT
PGA: 0.32g
Limitorque, 1958, 100 lbs
Pipe Diameter = 2"
Operator Height = 26"

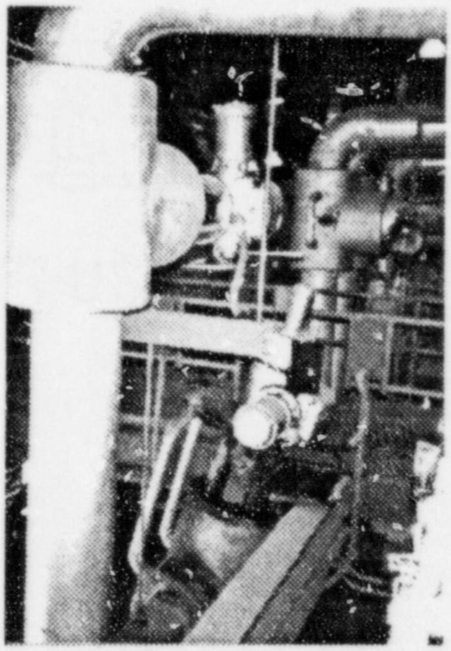


GLENDALE PLANT
PGA: 0.27g
Limitorque, 1959, 100 lbs
Pipe Diameter = 2"
Operator Height = 24"

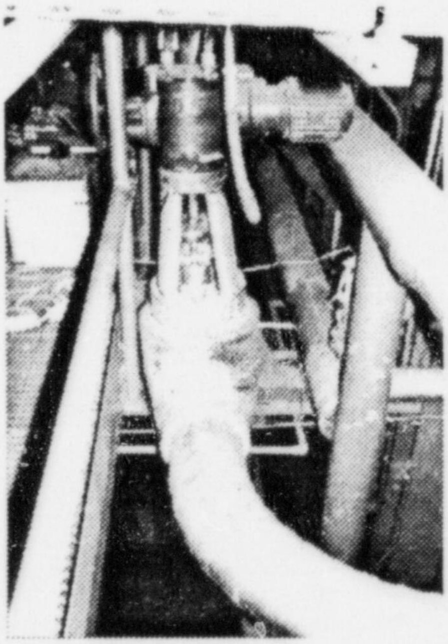
Figure 5-15: Comparison of Motor Operated Valves at Maine Yankee with data base plants.



MAINE YANKEE
Valve CHM-1, Limitorque, 1972
Pipe Diameter = 4"
Opeator Height = 30"



VALLEY STEAM PLANT
PGA: 0.30g
Limitorque, 1953, 650 lbs
Pipe Diameter = 10"
Operator Height = 70"



GLENDALE PLANT
PGA: 0.27g
Limitorque, 1959, 300 lbs
Pipe Diameter = 6"
Operator Height = 44"

Figure 5-16: Comparison of Motor Operated Valves at Maine Yankee with data base plants.

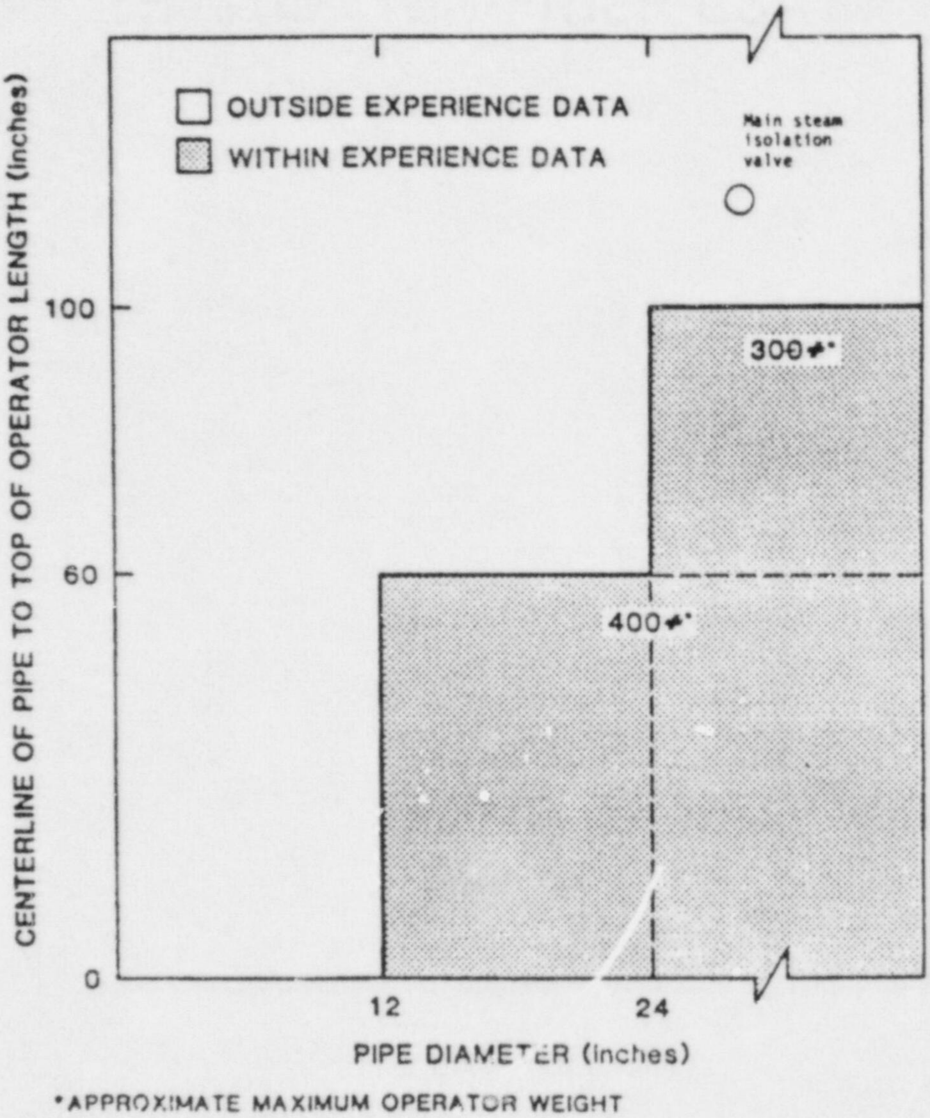
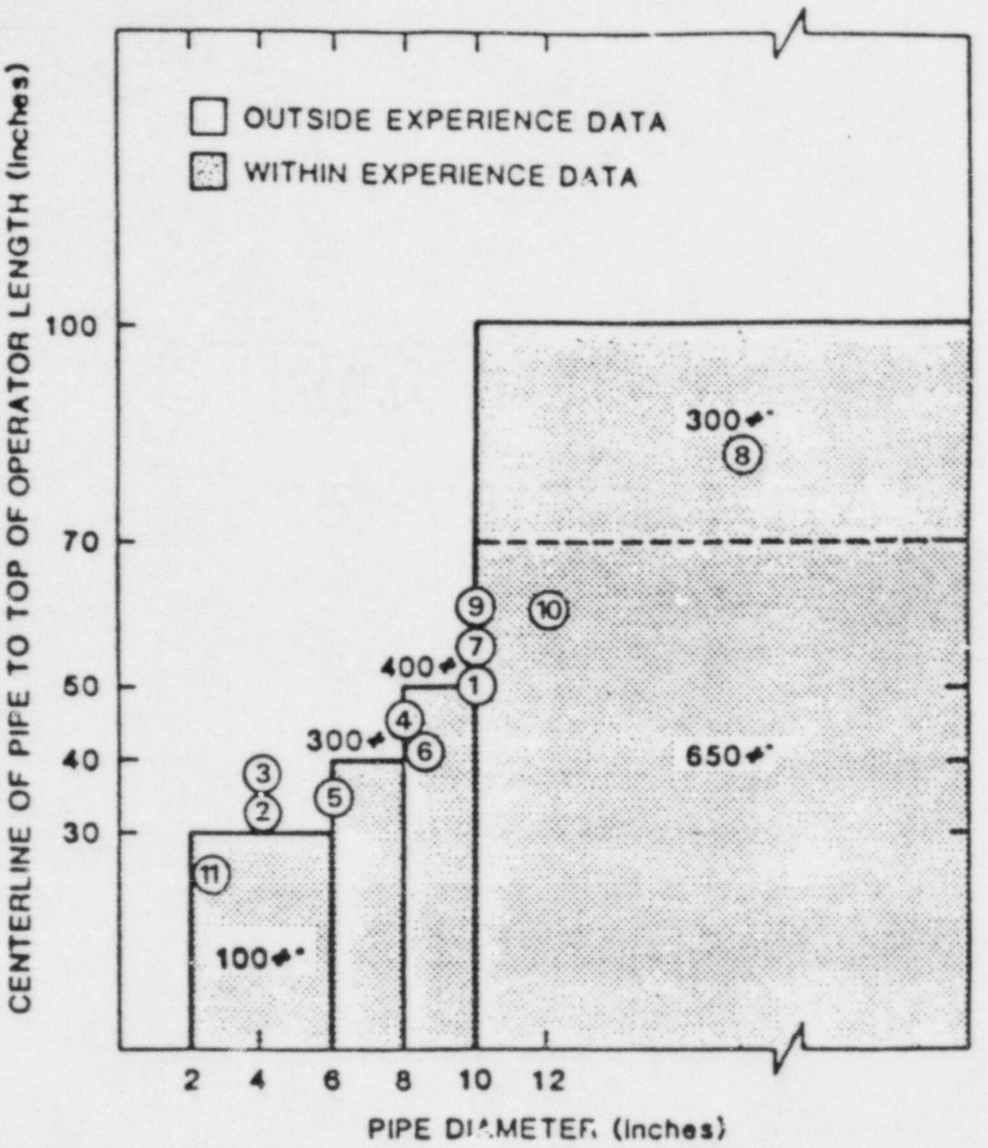


Figure 5-17: Restrictions on size of motor-operated valves applicable to seismic experience data bounded by the Type A response spectrum showing a sample MOV from the Maine Yankee plant.



*APPROXIMATE MAXIMUM OPERATOR WEIGHT

1. HPSI Suction from RWST (2 valves)
2. HPSI Pump Discharge (3 valves)
3. HPSI Loop Isolation (3 valves)
4. SCAT Isolation (2 valves)
5. PCCW Pressure Boundary (PCC-M-90)
6. PCCW Pressure Boundary (PCC-M-150)
7. PCCW Containment Isolation (PCC-M-219)
8. LPSI Suction from RWST (2 valves)
9. LPSI Discharge to RCS (3 valves)
10. RHR Suction from RCS (2 valves)
11. PORV Block (2 valves)

Figure 5-18: Restrictions on the size of the motor-operated valves applicable to seismic experience data bounded by the Type C response spectrum showing sample MOVs from the Maine Yankee plant.

5. CONCLUSIONS

A review was performed of the seismic adequacy of selected critical equipment at the Maine Yankee plant, based on eight representative types of equipment. These equipment types cover the range of important parameters that determine the ability of electrical and mechanical power plant equipment to resist damage in earthquakes. The evaluation is backed by the successful performance of power plant and industrial equipment in past earthquakes comparable to or in excess of a reasonable design basis earthquake for the Maine Yankee Plant.

This application of seismic experience data to Maine Yankee equipment leads to the following general conclusions:

1. Maine Yankee equipment is well represented by the seismic experience data base of equipment surviving PGAs of 0.2g to 0.6g or greater in past earthquakes.

2. Based on the specific performance of data base facilities, and the type of seismic damage they experienced (Chapter 3), the reviewed equipment items at Maine Yankee are generally not susceptable to damage in earthquakes that are much stronger than the Maine Yankee design basis earthquake.

3. The performance of the various data base facilities in past earthquakes (Chapter 3) provides no indication of operability problems in mechanical or electrical systems with one exception. Large electro-mechanical protective relays have shown a tendency to spurious actuation in past earthquakes. Maine Yankee will continue to pursue resolution of this potential generic issue through active participation in the SQUG and the EPRI Seismic Center Programs.

REFERENCES

1. Program for the Development of an Alternative Approach to Seismic Equipment Qualification, Volumes I and II, prepared for the Seismic Qualification Utilities Group by EQE Incorporated, San Francisco, September 1982.

2. Seismic Experience Data Base, Data Base Tables for Eight Types of Equipment, prepared for the Seismic Qualification Utilities Group by EQE Incorporated, San Francisco, December 1984.

3. Seismic Experience Data Base, Average Horizontal Data Base Site Response Spectra, prepared for the Seismic Qualification Utilities Group by EQE Incorporated, San Francisco, December 1984.

4. Investigation of Equipment Performance in Foreign Earthquakes and the 1964 Alaska Earthquake, prepared for the Seismic Qualification Utilities Group by EQE Incorporated, San Francisco, December 1984.

5. The Performance of Industrial Facilities and Their Equipment in the Coalinga, California Earthquake of May 2, 1983. Prepared for the Seismic Qualification Utilities Group by EQE Incorporated, San Francisco, August 1984.

6. The Effects of the April 24, 1984, Morgan Hill Earthquake on Industrial Facilities, prepared for the Seismic Qualification Utilities Group by EQE Incorporated, San Francisco, November 1984.

7. "Enclosures for Industrial Controls and Systems", ANSI/NEMA Standards Publication No. ICS 6-1978, National Electrical Manufacturers Association, Washington, D.C.

8. "American Standard for Switchgear Assemblies Including Metal-Enclosed Bus", No. C37.20, American Standards Association, Incorporated, New York, New York.

REFERENCES (Continued)

9. "Industrial Control Equipment", No. UL 508, Underwriters Laboratories, Incorporated.

10. Use of Past Earthquake Experience Data to Show Seismic Ruggedness of Certain Classes of Equipment in Nuclear Power Plants. Prepared for the Seismic Qualification Utilities Group by the Senior Seismic Review and Advisory Panel, February 1984 (Revised January 1985).

11. Seismic Qualification of Equipment in Operating Plants. Status Report, Unresolved Safety Issue A-46. U.S. Nuclear Regulatory Commission (NUREG-1018).