Application No.

Exhibit No.

Date

Witness

PACIFIC GAS AND ELECTRIC COMPANY

ELECTRIC DEPARTMENT

PREPARED TESTIMONY AND SUPPORTING DATA

DONALD A. BRAND

I

PREPARED TESTIMONY OF

DONALD A. BRAND

Q. Please state your name and business address.

A. My name is Donald A. Brand. My business address is 77 Beale Street, San Francisco, California 94106.

Q. What is your position with PGandE?

A. I am Vice President - General Construction.

Q. What is your background?

A. I am a registered nuclear engineer. I received B.S. and M.S. degrees from Stanford University in Mechanical Engineering. In 1962 I joined PGandE as a Field Engineer with the Station Construction Department. I advanced through various positions with the company including a two year rotational assignment in the capacity of Assistant to the Vice President - General Construction. In March of 1977, I was again assigned to the Station Construction Department as a Construction Superintendent where I remained until my appointment as Vice President - General Construction in June of 1978.

Q. What is the purpose of your testimony?

A. My testimony covers the design, the construction, and the cost of Diablo Canyon Units 1 and 2. I will pay particular attention to the factors that were responsible for the increase in cost between the

original estimates and the cost as shown in this application. A number of factors, such as regulatory requirements, inflation, and design changes have been involved, and these will be discussed individually and in detail.

Q. Why did PGandE choose to build Diablo?

A. To meet the power needs of the service area, PGandE planned several types of generating facility additions to the system -- geothermal, fossil-fueled, and nuclear. The largest of these additions were to be the Diablo Canyon Nuclear Units 1 and 2. The Company chose to construct a nuclear power plant at Diablo Canyon instead of a large fossil-fueled plant because, among other things, nuclear power was more economical and, by using nuclear power, fossil fuel resources would be conserved.

Q. What were the economic advantages of nuclear power compared to a fossil-fueled unit?

A. During the planning stages of the Diablo Canyon project, nuclear and fossil-fueled units were compared. In filings with the California Public Utilities Commission in 1966 for Unit 1, fossil-fueled cost of power was about 5.18 mills/kwh or 20% higher in cost than nuclear-fueled power. This was based on an equivalent-output fossil-fueled plant burning 80% gas at a cost of $2.01 per equivalent barrel and 20% oil at

a cost of $2.25 per barrel, operating at an 80% to 90% capacity factor. The 1968 application with the CPUC for Unit 2 showed similar relationships.

Q. Has current analysis shown that Diablo Canyon Units 1 and 2 still retain a cost advantage over other forms of thermal generation?

A. Yes. Cost of power estimates made in February of this year show Diablo Canyon Units 1 and 2 to be more economical than other potential forms of large scale generation. The decision to build a nuclear project in 1966 was an economically sound one. It remains an economically sound project today. The cost of power from a fossil fuel power plant which might have been built to meet 1979 power demands is significantly higher than the Diablo Canyon cost of power. The cost of power for coal fired generation is estimated at 29.02 mills per kwh, 42% higher than the average cost of power for Diablo Canyon Units 1 and 2 of 20.46 mills per kwh. Oil fired combined cycle generation would cost 42.19 mills per kwh or 106% higher than the cost of power from Diablo Canyon. The Diablo Canyon average cost of power of 20.46 mills/kwh should not be compared to the 33 or 27 mills/kwh cost of power set forth in the application. The cost of power estimates used here for comparison of generation types are developed for engineering planning and compare costs over the life of

the plant and exclude the effects of general inflation. The costs of power as presented in the application reflect the first year of operation only and certain of these costs will be different when spread over the life of the plant. These cost of power estimates reflect significant cost increases for both fossil and nuclear fueled power. The cost of nuclear plant investment has risen sharply. However, the price of fossil fuels, both oil and coal, have increased at an even higher rate. The increasing cost of nuclear plant investment along with corresponding shortages of fossil fuels and their increased cost have occurred in such a way that the cost of power generated by nuclear plants has always, although in varying amount, retained a cost advantage over the same time period.

In addition to cost factors, we recognized the possibility of future natural gas and oil shortages in making our 1966 decision to build Diablo Canyon. We are currently facing these shortages. The Powerplant and Industrial Fuel Use Act of 1978 prohibits new electric power plants which utilize natural gas or petroleum as a primary source of fuel. The use of natural gas or petroleum is prohibited in some existing plants prior to 1990, and, after 1990, natural gas use is prohibited except under certain specific conditions.

Q. Please outline the regulatory history of Diablo

Canyon to date?

A. Many agencies of government are involved in the regulation of generating stations in general and of nuclear generating stations in particular. I will answer your question by mentioning particular dates and administrative actions that seem to me to be the most important. A complete listing is included in appendix A.

On December 23, 1966, PGandE filed Application No. 49051 with the CPUC requesting the Commission to find that the public convenience and necessity would be served by the construction of Unit No. 1 at Diablo Canyon. On February 16, 1968, the Company filed Application No. 50028 requesting a similar finding for Unit No. 2. After many days of hearings in San Luis Obispo and in San Francisco, the Commission granted the requested certifications in its Decision No. 73278 on November 7, 1967, and in Decision No. 75471 on March 25, 1969.

On January 16 1967, the Company filed an application with the Atomic Energy Commission (now the Nuclear Regulatory Commission) for a construction permit for Diablo Canyon Unit No. 1 and on June 28, 1968, filed an application for a construction permit for Unit No. 2. After meetings with the Advisory Committee on Reactor Safeguards and hearings before the

Atomic Safety and Licensing Board, the construction permit for Unit No. 1 was issued on April 23, 1968, and on December 9, 1970, the construction permit for Unit No. 2 was issued. Many days of hearings before these Boards and others on, among other things, receipt of nuclear fuel, specific safety issues and environmental matters have continued throughout the construction period. The most recent series of hearings, which consumed 33 days, was concluded before the Atomic Safety and Licensing Board in February of this year, and PGandE is awaiting the decision of this Board on the issuance of operating licenses for the units.

Other federal agencies have also been involved with the construction of Diablo Canyon. For example, the Corps of Engineers has issued a number of permits generally under the Rivers and Harbors Appropriations Act for the installation of facilities affecting the beach and adjacent sea waters.

The State Lands Commission has granted permits for the use of public lands, notably tidelands.

Various other state agencies have been involved in Diablo Canyon, particularly the Department of Water Resources, Parks and Recreation, Fish and Game, Harbors and Watercraft, the Resources Agency, the Department of Public Health, Division of Industrial Safety and the California Coastal Commission.

The County of San Luis Obispo has granted permits for excavation and grading for the construction of Diablo Canyon and pertinent facilities. The San Luis Obispo County Air Pollution Control District has granted authority to operate two auxiliary boilers at the site.

Additional agencies have been involved in specific actions but those noted above are the principal ones.

Q. What were the initial cost estimates for Diablo Canyon Units 1 and 2 compared with the current estimates?

A. The initial estimate for Diablo Canyon Unit 1, prepared in the fall of 1966, was $162.3 million or $150/kw of installed capacity. The initial estimate for Diablo Canyon Unit No. 2, prepared approxmiately two years later, was $157.4 million or $142/kw of installed capacity.

These estimates were based on the best industry information available at the time. Technical data was based on Indian Point Unit No. 2 (a 873 MW pressurized water reactor scheduled to start construction in 1966) and Burlington Station Unit No. 1 (now Salem Unit No. 1, a 1040 MW pressurized water reactor scheduled to start construction in 1968). Cost information derived from this technical data was prepared based on PGandE's experience with our Humboldt Bay Unit 3 nuclear unit (a

63 MW boiling water reactor placed in service in 1962) and Moss Landing Units 6 and 7 (739 MW fossil fueled units placed in service in 1967 and 1968, respectively). The Moss Landing Units were about 3/4 the capacity of the proposed Diablo Canyon units. Since we recognized that nuclear units would require additional systems and be of greater complexity, the $150/KW estimate for Unit 1 and $142/KW for Unit 2 was deemed realistic even though the figures were substantially higher than the known cost of $91/KW for the Moss Landing units.

Both estimates were revised in May 1969 to a total of $213.3 million for Unit 1 and $192.2 million for Unit 2. These estimates were based on updated industry experience, more detailed design, and on the purchase cost of components which had been deferred to follow receipt of the AEC construction permit issued in April 1968.

The estimates were again revised in July 1971 to $330 million for Unit 1 and $290 million for Unit 2. This revision was based on then available detailed design information. In addition, these estimates included provision for escalation during the construction period, inclusion of off-shore breakwaters, increased scope of work and building

///

sizes, uprating the nuclear steam supply systems and turbine generators and revised operating dates.

Since 1971 many regulatory changes, plant optimization changes, rescheduling and increased escalation have caused additional cost increases. At the present time, the estimated cost to complete Diablo Canyon is $907 million for Unit 1 and $736 million for Unit 2.

Q. Will you please list the major reasons for the cost increases at Diablo Canyon subsequent to July 1971.

A. The major reasons for the cost increases can be broken down into five major categories:

1. Changes to the plant due to regulatory requirements.
2. Changes to the plant due to plant optimization (changes required to correct generic problems and modifications aimed at maximizing plant availability and performance.)
3. Schedule delays which caused increased costs due to the extended time period. Included in this category are on-site items such as contractors supervision, equipment, offices and maintenance expense, PGandE General Construction and Division Payroll, guard

service, construction power, insurance and other ongoing charges.

4. Other items which include escalation, the increased cost of nuclear components, the increased cost resulting from stringent quality assurance requirements, labor interruptions, delays caused by material shortages, replacing or reworking of defective materials, and cost increases of a similar nature.

5. General overheads which include allowance for funds used during construction (AFUDC), general engineering and administrative expenditures, and ad valorem taxes.

Q. Please describe changes in the plant due to regulatory requirements and their associated cost.

A. The original plant design concepts were developed in 1966 in close cooperation with the reactor vendor using Indian Point Unit No. 2 and the proposed Burlington Station Unit No. 1 (now Salem Unit No. 1) for the preliminary design basis.

Subsequent to granting the construction permit for Diablo, the NRC issued many new regulations and changes in its existing regulations. Diablo Canyon design has been continuously reviewed in light of these changing requirements. The changes resulting from this

review process have contributed to a major portion of the cost increase since the original estimates.

The following describes some of the major areas of change and their associated cost:

1. Emergency Core Cooling Systems

In June 1971, the NRC issued a major change in design criteria for nuclear power plants. This change centered around the performance criteria for the emergency core cooling systems (ECCS). These systems automatically activate in the event of a loss of reactor coolant and keep the reactor core covered with water, thereby preventing damage to the nuclear fuel. All plants had to demonstrate that they could comply with the new criteria. Each nuclear steam supplier was required to develop a new computer simulation model acceptable to the NRC to run the new analyses. As a result of this analysis, the NSSS supplier recommended that the nuclear fuel assembly design be changed from a 15 x 15 fuel rod array to a 17 x 17 fuel rod array to provide greater heat transfer margins to meet the NRC's ECCS requirements.

The cost impact of these changes is $1.5 million for Unit 1 and $1.3 million for Unit 2.

2. Pipe Break Protection

In response to new NRC requirements issued in 1972, pipe rupture restraints, pipe sleeves and

impingement barriers were added as a retro-fit. These devices serve to accommodate, without adverse safety consequences, the effect of postulated pipe ruptures in piping systems outside the reactor containment. The cost of these changes amounted to $11.3 million for Unit 1 and $8.6 million for Unit 2.

3. Blowdown Cleanup System

As a result of the issuance of appendix I (Numerical Guides for Design Objectives and Limiting Conditions for Operations to Meet the Criterion "As Low As Practicable" for Radioactive Material in Light-Water-Cooled Nuclear Power Plant Effluents) to 10 CFR 50, a steam generator blowdown cleanup system was backfitted into the plant to provide a means of controlling the potential release of radioactivity to the environment associated with a steam generator blowdown. This resulted in the design and installation of additional pressure vessels, piping, instrumentation and wiring. The cost for adding this system was $500,000 for Unit 1 and $500,000 for Unit 2.

4. Hosgri Seismic Modifications

In 1972, PGandE became aware of an earthquake fault, now known as the Hosgri Fault, off shore from the plant. Extensive evaluation by PGandE, NRC consultants, and the USGS was conducted over the next four years. While evaluation by various PGandE seismic

consultants showed that the original plant design was adequate to withstand any reasonably postulated ground movement produced by this fault, in April 1976, PGandE agreed to undertake analysis for a postulated 7.5 M earthquake along the Hosgri fault. PGandE did not and still does not agree with the predicted magnitude of this postulated earthquake along the Hosgri fault. Nevertheless, we made the requested analysis and resultant design changes in an effort to get this vitally needed plant on line.

Early in June 1977, the Company filed with the NRC a report, which now consists of seven volumes, containing PGandE's seismic evaluation of the NRC postulated Hosgri earthquake for the Diablo Canyon units and responses to the comments of the Advisory Committee on Reactor Safeguards (ACRS) consultants.

Analysis of the plant showed that major modifications were required to the turbine generator building and to piping seismic supports. The following lesser modifications were also required:

a. Fuel handling building supports, containment annulus platforms, and spent fuel bridge and hoists were stiffened.
b. Outdoor tanks were braced.
c. Miscellaneous NSSS System work was performed.
d. Diesel fuel oil pipe supports were added.
e. Seismic reactor trip system was added.
f. Miscellaneous platforms were modified.
g. Electrical raceways, 4.16 kw switchgear, and 480 v. switchgear were upgraded.

///

h. Additional instrumentation for the steam dump was provided.
i. Miscellaneous architectural work was performed.

The above changes had a significant impact on design and construction costs. The costs associated with these changes for Unit 1 are $31.8 million and $29.3 million for Unit 2.

5. Fire Protection

In September 1976, the NRC staff requested that the Company conduct a re-evaluation of the fire protection program for the Diablo Canyon units. Late in July 1977, the Company filed with the NRC a single-volume report on PGandE's review of the fire protection system.

This review and subsequent requirements imposed by the NRC staff resulted in the following modifications:

a. Fire hose reels and automatic sprinklers were added.
b. Seismic qualification of hose reel system and of new sprinkler systems was performed.
c. Halon system for safeguards rooms was added.
d. Smoke detectors were added.
e. New fire barriers were added and existing barriers were upgraded.
f. Doors in fire barriers were upgraded.
g. Ventilation systems were modified.
h. Portable fire pumps were added.
i. Electrical circuitry was fireproofed.
j. Flame traps in floor drains were installed.
k. Guard pipe for hydrogen line was added.
l. Electrical supervision of fire system valves in yard loop was added.
m. Dedicated safe shutdown instrumentation was provided.

n. Electrical circuits were modified.
o. Position switches for fire dampers on 4 kv switchgear were added.

The cost of these changes amounted to $2.4 million for Unit 1 and $2.6 million for Unit 2.

6. Plant Security

On August 24, 1978, new NRC regulations went into effect relative to plant security. On March 28, 1979, the NRC staff issued its "Security Plan Evaluation Report."

As a result, the following modifications to the plant were required:

a. Construction of a security building and armed security force training facilities
b. Enclosure of the outdoor storage tanks in concrete
c. Installation of additional detection aids and physical barriers
d. Addition of a comprehensive electronic security monitoring system.

The cost increase due to these changes was $7.7 million for Unit 1 and $5.3 million for Unit 2.

7. Environmental Monitoring

As a result of amendments to the Federal Water Pollution Control Act in October 1972, a waste and heat discharge monitoring program was established at the site. In addition, extensive studies were performed on

the power plant cooling water system. A laboratory and related facilities have been constructed and additional personnel hired to man these facilities. Field studies are continuing. The demonstration program requires one year of field data collection under fairly consistent power plant operations. Costs for this effort will continue to be accumulated after operation commences.

Also, NRC staff review of the Technical Specifications has resulted in changes to the meteorological and radiological monitoring programs. These changes primarily consist of additional facilities, instrumentation and associated circuitry.

Costs associated with the above changes are estimated to be $5.3 million for Unit 1 and $5.1 million for Unit 2.

In addition to the direct cost of the above changes, each of these changes had an effect on the project schedule, AFUDC, and other owner costs which are not included in the costs listed.

Q. Were additional costs incurred due to the required seismic modifications?

A. Yes. Unit 1 was essentially ready for fuel loading and operation in the spring of 1976. Due to NRC concerns about a potential earthquake from the Hosgri fault, licensing of the plant was suspended. This delay in licensing caused a full 39 months

extension of the construction schedule. The delay added $112 million in AFUDC to the cost of the plant. I have made no attempt to quantify additional indirect and incidental costs such as plant maintenance and the cost of replacement power during this time.

Q. Did other regulatory changes affect the cost of Diablo Canyon?

A. Yes. In April 1969, the NRC issued 10 CFR 50 appendix B, entitled "Quality Assurance Criteria for Nuclear Power Plants," for public comment. PGandE immediately began developing a more comprehensive quality assurance program to comply with 10 CFR 50, appendix B. It was submitted to the NRC in September 1969 with the application for the Unit 2 construction permit. With the issuance of the Unit 2 construction permit in December 1970, PGandE began the detailed implementation of this quality assurance procedure.

PGandE has been aware of the need for special care or "Quality Assurance" from the very outset in the construction of nuclear plants. We sponsored participation in the ASME Committee on Nuclear Quality Assurance and actively took part in writing and developing industry standards which were issued by the American National Standards Institute and endorsed by the NRC in Regulation Guides.

///

10 CFR 50 appendix B contains eighteen criteria to assure the quality of the design, construction and operation of nuclear power plants. Simply stated, it is a formal program to verify and document that inspections, checks, and controls for every phase of nuclear power plant design, manufacture, construction and operation have taken place. To comply with these regulations, PGandE established a separate department reporting directly to an Executive Vice President. The Engineering and Construction departments developed quality control departments within their organizations. Contractors and suppliers acted likewise.

I stress that PGandE is concerned about the quality of every plant, and Diablo Canyon is no exception. We did not, however, anticipate the detail in documentation and independent inspection of workmanship which would be required by the NRC. For instance, simple field changes to avoid physical interference between components (which would be made in a conventional plant in the normal course of work) had to be documented as an interference, referred to the engineer for evaluation, prepared on a drawing, approved, and then released to the field before the change could be made. Furthermore, the conflict had to be tagged, identified and records maintained during the change process. These change processes took time (days

or weeks) and there were thousands of them. In the interim the construction crew must move off of this piece of work, set up on another and then move back and set up on the original piece of work again when the nonconformance was resolved. Installation of wire must be done according to written procedure and must be documented. Every foot of nuclear safety-related wire purchased is accounted for and its exact location in the plant is recorded. For each circuit we can tell you what kind of wire was used, the names of the installing crew, the reel from which it came, the manufacturing test, and production history. The tension on the wire when it is pulled is recorded and the tensioning device is calibrated on a periodic basis.

None of these requirements were in existence when Diablo Canyon was planned. Hundreds of requirements similar to these give us assurance of the quality of the Diablo Canyon plant. While this assurance is very costly, a precise cost cannot be assigned to this program.

Q. What changes were required to improve plant availability and reliability and what was their cost?

A. Certain changes in the plant were necessary to insure the best possible plant reliability and availability to the PGandE system. During the early

design and construction stages of Diablo Canyon, other utilities were gaining operating experience on similar type reactor plants. Due to the operating experience of these other utilities it was apparent that there were several areas where design changes would, in the long run, be less costly to implement at a time prior to the plant's operation.

The following list describes some of the major areas of change to improve plant availability and reliability and their associated cost:

1. Reheater Drain System And Moisture Separator Reheaters

Modifications to the reheater drain system were found to be necessary as a result of flooding of reheater tube bundles that had been experienced at other operating plants. These changes resulted in additional pressure vessels, valves, piping rerouting and instrumentation.

Modifications to moisture separator reheaters consisted of adding vent chambers for each moisture separator reheater tube bundle in order to increase plant reliability by eliminating tube to tube plate weld failures due to thermal cycling.

Costs associated with these modifications are $700,000 for Unit 1 and $700,000 for Unit 2.

///

2. Additions To Make-Up Water Systems

As a result of steam generator tube corrosion problems at operating plants, the NSSS supplier made a complete change in its water quality requirements for the secondary side of the plant by requiring a change from phosphate to all volatile treatment of the feedwater. All volatile water treatment requires extremely low levels of seawater inleakage to the condenser. In addition, the water quality requirements for the make-up to the secondary side of the plant became much more stringent. All of these changes were made after the condensate and make-up water systems were designed, purchased and installed. These changes resulted in the procurement of additional equipment, retubing the condenser with titanium tubes, rerouting of piping, and installation of instrumentation and wiring changes.

Further changes in secondary system water quality criteria has resulted in the following:

a. A new ion exchanger is being added to each unit to polish the seawater evaporator distillate.

b. A reverse osmosis system is being provided to treat Diablo creek water prior to processing it through the existing make-up water system demineralizers. The reverse osmosis system will provide a back-up when the

///

seawater evaporators are out of service either for maintenance or when nuclear steam is not available.

The cost of these changes were $4.9 million for Unit 1 and $2.7 million for Unit 2.

3. Turbine Reblading

As a result of corrosion problems and turbine blade failures experienced by other utilities, the supplier recommended that the row L-3 low pressure turbine blades be replaced with redesigned blades before operating the unit. This work was completed and costs were shared by PGandE and the turbine supplier.

Approximately two years later, the turbine supplier recommended, as a result of additional operating experience, that the existing L-4 row of low pressure turbine blades be replaced with better designed blades prior to operating the unit because of stresses and resultant stress corrosion in the steeple region. The cost impact of these changes was $920,000 for Unit 1 and $947,000 for Unit 2.

4. Additional Spare Parts

As a result of operating experience gained from other utilities and to improve the reliability and availability of the Diablo Canyon units, additional spare parts were purchased for the nuclear steam supply system and the turbine-generator. Some examples of these spare parts are:

a. Interchangeable low pressure turbine rotors

b. Mechanical seals for reactor coolant pumps

c. Safety injection pump and charging pump rotating assemblies

The cost associated with these changes are $16.1 million for Unit 1 and $9.5 million for Unit 2.

5. Additional Storage Facilities

In order to optimize the storage requirements for chemicals and solid wastes and to protect safety-related equipment from possible hazards, chemical and gas storage vaults, radwaste storage vaults and related facilities were constructed in the hill on the east side of the Auxiliary Building.

The cost of these changes was $1.5 million.

Q. In addition to the changes and direct costs which you have discussed, have additional indirect costs resulted due to the timing of these changes?

A. Yes. The changes I have discussed were made after construction had progressed to a significant degree. In addition to the cost of the added items, there are significant costs incurred due to working on or around completed items. There is the cost of the original work which must be removed, and the cost of the removal and/or relocation of existing equipment even though that equipment has little or nothing to do with the change. There are significant inefficiencies in trying

to design to fit existing buildings and installed components. Work has to be done out of sequence in a restricted access and work area. Existing installations are exposed to the hazards of construction. While they may be protected, some are inadvertently damaged. In the case of structural work due to changes in seismic criteria, the contractor and labor force had been released from the site. This factor created additional costs for the contractor as well as lost production due to the need to train a mostly new labor force.

Engineering manpower (both in-house and consultants) has continually fluctuated throughout the design stages for Diablo Canyon. The Company's original manpower requirements were based on our experience with the Dresden, Vallecitos and Humboldt Bay nuclear power plants and the first large steam units at Moss Landing. As additional analysis and design changes were required to meet changing regulatory requirements and to improve plant reliability, the Company adjusted its manpower requirements accordingly. PGandE has attempted to maintain an efficient and economical level of manpower in-house. However, engineering consultants have been used to supplement PGandE's in-house capabilities during peak manpower periods. Increased manpower

requirements clearly contributed to the increased cost of the plant.

Q. Did other items related to the actual construction process cause schedule extensions and cost increases above those originally planned?

A. Yes. The labor productivity level for the plant was originally projected on the basis of our experience in the construction of conventional fossil plants. The increased number of components and technological complexities of nuclear power plant construction, together with the vastly increased scope of quality control with inspection documentation and audit resulted in lower levels of productivity than originally estimated.

The availability of qualified craft labor is more limited in Central California than in the Los Angeles basin or the San Francisco Bay Area. There is little industry in the vicinity to attract or train skilled craftsmen in heavy industry. PGandE anticipated this shortage of skilled craftsmen but not to the extent that it eventually developed. There was a heavy industry construction boom in California and the Western United States. Many jobs were worked on an extended work week basis in the Los Angeles and San Francisco areas. This work was closer and more attractive financially to the skilled craftsmen.

Consequently, a shortage of skilled craftsmen was a chronic problem at the Diablo Canyon site.

Starting in early 1971, and continuing for most of the year, various construction delays and work slowdowns resulted from the slow release of engineering and design information. The delays in producing designs can be attributed to lack of timely information on equipment and components because of the PGandE policy to delay purchase of major equipment prior to receipt of the construction permit, to a shortage of engineering and design manpower, precipitated by an underestimation of the complexity and difficulty in nuclear plant design and to the imposition of extensive and complex design check and review procedures to accommodate NRC Quality Assurance regulations.

Labor interruptions have caused inefficiencies and delays during the entire construction period. Late in 1969, the Operating Engineers were on strike for two months, causing a major work slowdown. In the summer of 1970, there was a two-month carpenters' strike which halted carpentry and concrete work at a critical time in the construction of the Diablo Canyon structures. In mid-1974, major labor problems were encountered Two hundred electricians stayed off the job for eight days, 500 welders and pipefitters stayed off the job for five days, and 125 carpenters and millwrights were off for

three days. Finally, a series of labor disputes and strikes shut down the site for essentially four months starting in July 1974. These stoppages were craft-management disputes general to California and not isolated to Diablo Canyon. Since 1974, occasional site labor disputes of short duration have had an impact on construction progress. Over the 10 year construction period, labor disputes have contributed an estimated 1.5 million lost man-hours.

Q. Have any other factors had a significant impact on the construction schedule?

A. Yes. For example, bomb threats at the Diablo Canyon site have had an impact on construction. To date we have had a total of 50 bomb threats. Each of these has an impact on the construction schedule to varying degrees. In some cases, selected work areas were shut down. In others, the entire project was shut down for the entire working day. During these work stoppages, workmen on the project are paid only for hours worked. Disruptions causing lost time result in reduced paychecks. Some of the skilled craftsmen then become frustrated with the loss of work situation and leave the project for more stable work conditions. This loss of skilled manpower adds to the problems of insufficient skilled labor already described.

///

Q. Please describe the need for and the costs involved in equipment maintenance during the extended construction period.

A. Essentially all construction for Diablo Canyon Unit 1 Operating Systems was completed in late 1975. Hot Functional Testing was performed in anticipation of licensing and commercial operation in 1976. Since the plant did not go into operation at that time, it became necessary to institute a significant plant layup and maintenance program to prevent equuipment degradation. This program consists of routine maintenance, inspection, equipment cleaning and preservation. Significant manpower is also expended to periodically run equipment at near operating conditiors to assure that its capability has not been degraded. Total manpower dedicated to this effort has been on the order of 125 full-time craft and technical people. These figures are difficult to quantify since these same personnel are also involved in some new construction work.

Major pre-operational tests are required within a short time prior to initial fuel loading and operation. Since the construction was thought to be completed in 1976 and again in 1977, these major tests, such as the containment leak rate test and the hot functional test, have been repeated twice. These tests take two to four

weeks each and require significant investment in equipment, shift coverage and data logging.

Q. Did the extended construction period effect our dealings with private contractors working on the Diablo project?

A. Yes. Most of the original construction contracts for the Diablo Canyon Project were awarded as lump-sum fixed price contracts. As construction progressed, it became evident that the increased scope of work was such that the contractors could no longer reasonably be expected to perform on a fixed price basis. The structural, electrical, air conditioning, and other major contractors were eventually converted to a recoverable cost plus basis. In some cases, scopes of work had so significantly changed that it was necessary to convert contracts to a cost plus basis for work that had originally been performed under a fixed price contract.

In today's environment of large nuclear projects of long duration, it is not uncommon to have all of the work awarded from the beginning on a cost plus basis. This practice is done since both utilities and contractors now recognize that the work scope at the beginning of a nuclear project cannot be accurately defined to accommodate the seven or eight year construction span the industry is now facing.

Q. What other factors occurred during the period of construction that contributed to the cost of the project?

A. Inflation or escalation has made a major contribution to the cost increases at Diablo Canyon. As late as 1969, escalation rates used to estimate Diablo Canyon costs were 2.5 percent per year for materials, 3 percent per year for finished equipment, and 5 percent per year for labor. These rates were based on the then current projections of PGandE's Economics and Statistics Department.

The Nuclear Plant Construction Index and the Fossil Fuel Plant Construction Index of the Handy-Whitman Index for the Pacific Coast Area have risen 130 and 146 percent, respectively, from January 1967 to July 1978. The Engineering News Record Construction Cost Index went up 157 percent from January 1967 to January 1978, and the EBASCO Composite Index of Direct Cost for Electric Generating Plants rose 140 percent from January 1967 to December 1977. As it actually turned out, the average rate of escalation over the Diablo Canyon construction period has been between eight and nine percent per year compounded, about twice the rates assumed in early estimates.

///

These inflation rates reflect not only inflation in the general economy but an even higher inflation rate for the nuclear industry in general. Nuclear component prices increased rapidly in the early 1970's for two primary reasons. Orders for equipment were extremely high, overtaxing the manufacturing capability of the many special supporting industries. Also, manufacturers were exposed to the same changing regulatory requirements that PGandE was experiencing at this time. Increased quality control documentation, special component testing, and seismic qualifications are examples of costs passed on to PGandE by equipment suppliers.

The extended construction period also impacted the cost by adding to the AFUDC required. Not only was interest paid over a much longer period, but interest rates increased from a 5 percent level to almost an 8 percent level in 1978. In 1966, the Unit #1 total GM estimate was $162.3 million, of which $17.5 million, or 11 percent, was estimated to be AFUDC. Of today's total estimate, $309 million or 34% is AFUDC.

Q. How have each of the changes you have discussed affected the total cost of Diablo Canyon Units 1 and 2?

A. I have identified many reasons for the cost increases at Diablo Canyon. Since the revised estimates of 1971, the cost of Diablo Canyon Unit 1 has

increased $577 million and Unit 2 has increased $446 million. The regulatory changes account for 11.8 percent of the Unit 1 and 13.5 percent of the Unit 2 cost increases. The changes to improve plant availability and reliability account for 4.5 percent of the Unit 1 and 3.6 percent of the Unit 2 cost increases. Schedule delays account for 12.5 percent of the Unit 1 cost increase and 12.5 percent of the Unit 2 cost increase. The cost increase due to other items is 17.8 percent for Unit 1 and 17.9 percent for Unit 2. General overheads account for 53.4 percent of the Unit 1 and 52.5 percent of the Unit 2 cost increases. The costs for each of these categories is presented in appendix B.

Q. Have other utilities been exposed to similar schedule delay and cost increases with their nuclear power plants?

A. Yes. All nuclear power plants constructed during this period have been exposed to schedule delays and cost increases above original estimates. These delays and cost increases have occurred for many of the same reasons as the Diablo Canyon increases. Regulatory changes, labor productivity, updating of designs to increase reliability, material delays, and changing economic conditions are not unique to Diablo Canyon or to California.

Appendix C is a graphic representation of the cost per kilowatt for nuclear units placed in service or scheduled for operation in 1977 to 1980. The average cost of these units per killowatt net capacity ($/kW) is $719/kW. Diablo Canyon Unit 1 cost is $837/kW or 16% above the average. The Diablo Canyon Unit 2 cost of $665/kW is 7.5% below the average. Considering the extremely adverse cost impact of changes and schedule delays due to the postulated 7.5m Hosgri earthquake, it is significant that PGandE has been able to construct Diablo Canyon while maintaining costs close to the average of other units coming on line during the same relative time period.

Q. Do you believe that $907 million is a reasonable cost for Unit No. 1 and $736 million a reasonable cost for Unit No. 2?

A. Yes. In my opinion these costs are reasonable for nuclear units of their size which were designed and built during this period. While the cost of the Diablo Canyon units is higher than our original estimates, these cost increases were due to various factors, already described, which could not have been anticipated in our original estimates. The cost of power from Diablo Canyon will be much lower than any similar-sized fossil-fueled plant which might have been constructed for 1979-1980 operation. PGandE is

committed to provide safe, reliable power at the lowest possible cost to our rate payers. Diablo Canyon fulfills this commitment.

APPENDIX A

DIABLO CANYON UNITS 1 AND 2
REGULATORY HISTORY

This appendix describes the various licenses, permits and other actions which have taken place regarding the Diablo Canyon Project. It is divided into three sections:

I. CALIFORNIA PUBLIC UTILITIES COMMISSION

II. NUCLEAR REGULATORY COMMISSION

III. OTHER FEDERAL, STATE AND LOCAL AGENCIES

CALIFORNIA PUBLIC UTILITIES COMMISSION

PGandE filed Applications Nos. 49051 and 50028 with the California Public Utilities Commission (CPUC) on December 23, 1966, and February 16, 1968, for Diablo Canyon Units 1 and 2, respectively. In these applications, PGandE presented extensive data on the cost of power, safety factors, service reliability, and the environmental effects of the plant. PGandE presented evidence in support of the applications through numerous witnesses, including scientists and representatives of governmental agencies, and 64 exhibits. Those opposed to the project presented 20 witnesses and 32 exhibits. The CPUC held a total of 20 days of public hearings on Unit 1 and 3 days of public hearings on Unit 2 from February 16 to December 12, 1968, in San Luis Obispo and San Francisco.

In Decision Nos. 73278 and 75471, dated November 7, 1967, and March 25, 1969, for Units 1 and 2, respectively, the CPUC found PGandE's requests for the two generating units to be in the public interest.

On March 22, 1971, a complaint filed against PGandE by Consumers Arise Now alleged that PGandE and others were making plans to build nuclear power plants alorg the California coastline. It requested that the CPUC issue an immediate cease and desist order regarding planning or construction of coastal nuclear power plants. The CPUC denied this order, striking complainant's allegations as being within the purview of the Nuclear Regulatory Commission.

In mid-1975, the Northern California Public Interest Group, Inc. petitioned the CPUC to issue a General Order requiring utilities to include, once each year, with each customer's billing statement, instructions explaining emergency steps the customer should take in the event of an incident. This petition was also dismissed as being outside the jurisdiction of the CPUC and as being inconsistent with the provisions of the Emergency Services Act.

NUCLEAR REGULATORY COMMISSION

PGandE submitted an application for a construction permit for Diablo Canyon Unit 1 on January 16, 1967. For approximately one year, the Staff of the Atomic Energy Commission (now the NRC) scrutinized the plant, requesting and receiving additional information from PGandE. The review culminated in a full Advisory Committee on Reactor

Safeguards (ACRS) committee meeting in December 1967, an Atomic Safety and Licensing Board (ASLB) public hearing in San Luis Obispo on February 20-21, 1968, and the issuance of a construction permit by the AEC on April 23, 1968.

The application for construction of Unit 2 was filed on June 28, 1968. The review progressed to a meeting of the full ACRS committee on October 10, 1969, and on January 13-14, 1970, public hearings were held by the ASLB in San Luis Obispo. On August 7, 1970, these hearings were reopened to hear the intervenors' alleged new evidence on geology. Finally on December 9, 1970, the construction permit for Unit 2 was issued by the AEC.

On July 10, 1973, the application for an operating license, the Final Safety Analysis Report (FSAR), was submitted by PGandE. The FSAR was considered by the AEC to be incomplete. PGandE revised it, resubmitted it on September 26, 1973, and it was docketed on October 2, 1973.

From 1973, right up to the present time, the NRC staff and its consultants and the ACRS and their consultants, have reviewed, analyzed and examined the Diablo Canyon design. The extent and depth of the review in the areas of seismology and geology was without precedent. Seventy-eight amendments have been made to the FSAR, over 70 meetings were held between NRC Staff and PGandE, and countless information requests were made and answered. In summation, ten ACRS subcommittee meetings and three full committee meetings were held, each of the latter resulting in an ACRS letter. The last ACRS letter was issued on July 14, 1978. The ACRS stated that it had completed its review and gave favorable recommendation for the operation of Diablo Canyon. The NRC Staff did likewise.

ASLB hearings were concluded Febraury 15, 1979. A favorable decision regarding the safety of the Diablo Canyon Plant is expected at any time.

DIABLO CANYON
NRC LICENSING PROCEEDINGS
THROUGH APRIL 1979
DOCKETS 50-275; 50-323

Application for Unit 1 CP filed	January 16, 1977
ACRS subcommittee	October 4, 1967
ACRS full committee	October 5, 1967
ACRS full committee	December 7, 1967
Public hearings on Unit 1 CP	February 20-21, 1968
Decision of Atomic Safety and Licensing Board (ASLB) directing AEC to issue Unit 1 CP	April 23, 1968
Application for Unit 2 CP filed	June 28, 1968
ACRS subcommittee	October 1, 1969
ACRS full committee	October 10, 1969
Public hearings on Unit 2 CP	January 13-14, 1970
Hearings reopened to hear Intervenors' alleged new evidence on geology	August 7, 1970
Decision of ASLB directing AEC to issue Unit 2 CP	December 8, 1970
Atomic Safety and Licensing Appeal Board (ALAB) affirms ASLB decision granting Unit 2 CP	June 14, 1971
AEC denies Intervenors' appeal from ALAB Order	July 21, 1971
AEC denies motion for reconsideration	August 16, 1971
AEC Order granting Intervenors' request for hearing on supension of CP's pending NEPA review	April 21, 1972
Public hearings re whether CPs should be suspended pending NEPA review	May 17-20, 1972

ASLB decision permitting continued construction during NEPA review but forbidding removal of cofferdam	June 5, 1972
NEPA hearing (nit 2)	September 17-21, 1973
OL application (FSAR) for Units 1 and 2 filed	September 28, 1973
ASLB decision permitting removal of cofferdam	November 23, 1973
Reopened NEPA hearing to consider energy conservation	March 27-28, 1974 April 30, May 1-2, 1974
ASLB Decision on environmental effects (NEPA) authorizing continued effectiveness of CP for Unit 2	August 2, 1974
ACRS subcommittee	September 12, 1974
ALAB affirms ASLB NEPA decision	January 16, 1975
ACRS subcommittee	February 18-19, 1975
ACRS subcommittee	May 23, 1975
ACRS full committee	June 5-7, 1975
ACRS letter	June 12, 1975
Public hearing on receipt of nuclear fuel for Unit 1	December 9-12, 1975
ASLB Order permitting receipt of nuclear fuel for Unit 1	December 23, 1975
AEC Order directing ALAB to hear appeal of ASLB Order re receipt of fuel	February 5, 1976
ACRS subcommittee	May 21, 1976
ALAB decision affirming ASLB decision re receipt of nuclear fuel	June 22, 1976
ACRS subcommittee	June 25-26, 1976
ACRS subcommittee	October 11, 1976
Further NEPA hearings Units 1 and 2	December 7-17, 1976
ALAB ruling regarding limited access to security plan	June 9, 1977
ACRS subcommittee	June 21-23, 1977
ACRS subcommittee	August 2, 1977
ACRS full committee	August 11-13, 1977
ACRS letter	August 19, 1977

ASLB hearings on remaining non-seismic safety issues other than adequacy of the security plan	October 18-19, 1977
ASLB decision re NEPA issues	June 12, 1978
ACRS subcommittee	June 14-15, 1978
ACRS subcommittee	June 21, 1978
ACRS full committee	July 6-8, 1978
ACRS letter	July 14, 1978
ASLB hearing	December 4-23, 1978
ASLB hearing	January 3-16, 1979
ASLB hearing	February 7-15, 1979

Agency	Licenses, Permits Approvals	Statutory Or Other Authority
FEDERAL LICENSES, PERMITS AND APPROVALS		
Corps of Engineers (U.S. Army)	Permit to install wave recorder	Section of the Rivers and Harbors Appropriations Act of 1899, sections 403 and 404 of title 33 of the United States Code
	Permit to construct breakwater and intake	Section 10 of the Rivers and Harbors Appropriations Act of 1899, sections 403 and 404 of title 33 of the United States Code
	Permit tor barge landing	Section 10 of the Rivers and Harbors Appropriation Act of 1899, sections 403 and 404 of title 33 of the United States Code
	Permit for cofferdam, roads, soil removal for discharge	Section 10 of the Rivers and Harbors Appropriation Act of 1899, sections 403 and 404 of title 33 of the United States Code
Bureau of Land Management	Right-of-way for breakwater and filled areas	Acts of February 15, 1901 (16 U.S.C. 522) and March 4, 1911 (16 U.S.C. 523), and section 2234.4-1 of title 43 of the Code of Federal Regulations
Federal Aviation	Determination of no hazard for meteorological mast	Section 1101 of the Federal Aviation Act of 1958 (49 U.S.C. 1501), and part 77 of title 14 of Code of Federal Regulations
	Amendment to "determination," resulting from height change of meteorological mast	Section 1101 of the Federal Aviation Act of 1958 (49 U.S.C. 1501), and part 77 of title 14 of Code of Federal Regulations

Agency	Licenses, Permits Approvals	Statutory Or Other Authority
Federal Aviation (continued)	Determination of no hazard for containment structures	Section 1101 of the Federal Aviation Act of 1958 (49 U.S.C. 1501), and part 77 of title 14 of Code of Federal Regulations
	Determination of no hazard for tower crane	Section 1101 of the Federal Aviation Act of 1958 (49 U.S.C 1501), and part 77 of title 14 of Code of Federal Regulations
	Amendment to "determination," resulting from removal of lighting from meteorological mast	Section 1101 of the Federal Aviation Act of 1958 (49 U.S.C. 1501), and part 77 of title 14 Code of Federal Regulations
STATE OF CALIFORNIA LICENSES, PERMITS AND APPROVALS		
Dept. of Fish and Game	Approval for culvert and fill	Sections 1601 and 1602 of the California Fish and Game Code
State Lands Commission	Lease of submerged lands for wave height transducer	Division 6 of California Public Resources Code
	Boundary line agreement	Section 6357 of the California Public Resources Code
	Lease for intake basin	Division 6 of California Public Resources Code
	Extension of lease for wave height transducer	Division 6 of California Public Resources Code
	Right-of-way for discharge channel	Division 6 of California Public Utilities Resources Code
	Industrial lease right-of-way for road and cofferdam	Division 6 of California Public Resources Code

Agency	Licenses, Permits Approvals	Statutory Or Other Authority
Resources Agency Dept. of Conservation Water Resources Parks & Recreation Fish & Game Harbors & Water-crafts	Agreement	No statutory requirements. Agreement sets forth certain commitments by PGandE which will assist in the protection of the natural resources of California
Central Coast Regional Water Quality Control Board, the Resources Agency	Waste discharge requirements	Section 13263 of California Water Code (Stats. 1969, Ch. 482 Fed. Water Pollution Control Act of 1972
	Permit for plant discharges, Units 1 & 2	Federal Water Pollution Control Act - 1972
	Approval of 316(a) demonstration that present requirement for closed cycle cooling is more stringent than necessary	Section 316(a) of Fed. Water Pollution Control Act - 1972
	Approval of 316(b) study program to monitor effects of discharges	Section 316
State Water Resources Control Board, the Resources Agency	Water quality certification	Section 401 of the Federal Water Pollution Control Act and title 23, chapter 3, subchapter 11, of the California Administrative Code
Dept. of Public Health	Program of radiological monitoring	Section 25607 of California Health and Safety Code
Division of Industrial Safety	Misc. reviews of code requirements, construction safety, pressure vessels, elevator permits, etc.	

Agency	Licenses, Permits Approvals	Statutory Or Other Authority
Port San Luis Harbor District	Lease	Section 6074 of the California Harbors and Navaigation Code - Port San Luis Harbor District
California Coastal Commission	Claim of exemption	

LOCAL LICENSES, PERMITS AND APPROVALS

County of San Luis Obispo	Use permit for plant site	None. County Ordinance Code section 11-481 (3) as amended by County Ordinance 875 states that the plant is a permitted use at its location provided it is constructed with the approval of the California Public Utilities Commission
	Excavation and grading permit for access road	San Luis Obispo County Ordinance 756 and by reference portions of the Uniform Building Code (specifically section 7003 of chapter 70)
	Excavation and grading permit for borrow area	San Luis Obispo County Ordinance 756 and by reference portions of the Uniform Building Code (spec. section 7003 of chap. 70)
	Excavation and grading permit for Point Patton to Elevation 85'	San Luis Obispo County Ordinance 756 and by reference portions of the Uniform Building Code (spec. section 7003 of chap. 70)

Agency	Licenses, Permits Approvals	Statutory Or Other Authority
County of San Luis Obispo (continued)	Excavation and grading permit for Point Patton - Elevation 85' to 75'	San Luis Obispo County Ordinance 756 and by reference portions of the Uniform Building Code (spec. section 7003 of chap. 70)
	Excavation and grading permit for Unit 2	San Luis Obispo County Ordinance 756 and by reference portions of the Uniform Building Code (spec. section 7003 of chap. 70)
	Excavation and permit for barge landing	San Luis Obispo County 756 and by reference portions of the Uniform Building Code (spec. section 7003 of chap. 70)
	Excavation and grading permit for temporary laydown area	San Luis Obispo County Ordinance 756 and by reference portions of the Uniform Building Code (spec. section 7003 of chap. 70)
	Conditional use permit for trailer housing	Division 5, chap. 11, section 451.2, San Luis Obispo County Ordinance Code
	Building permit for Unit 1 - below elevation 85'	Title 19.04.030 of San Luis Obispo County Ordinance
	Building permit for Unit 1 - above elevation 85'	Title 19.04.030 of San Obispo County Ordinance
	Building permit for meteorological towers	Title 19.04.030 of San Luis Obispo County Ordinance
	Building permit for barge landing	Title 19.04.030 of San Luis Obispo County Ordinance

Agency	Licenses, Permits Approvals	Statutory Or Other Authority
County of San Luis Obispo (continued)	Building permit for gate house	Title 19.04.030 of San Luis Obispo County Ordinance
	Building permit for conference and construction office	Title 19.04.030 of San Luis Obispo County Ordinance
	Building permit for warehouse	Title 19.04.030 of San Luis Obispo County Ordinance
	Building permit for compressor building	Title 19.04.030 of San Luis Obispo County Ordinance
	Building permit for quality assurance laboratory and office	Title 19.04.030 of San Luis Obispo County Ordinance
	Building permit for concrete batch plant	Title 19.04.030 of San Luis Obispo County Ordinance
	Building permit for 230 kv switchyard control building	Title 19.04.030 of San Luis Obispo County Ordinance
	Building permit for 500 kv switchyard control building	Title 19.04.030 of San Luis Obispo County Ordinance
	Building permit for Unit 2	Title 19.04.030 of San Luis Obispo County Ordinance
San Luis Obispo County Air Pollution Control District	Permit to operate two auxiliary boilers	
Resources Agency	Approval to construct cofferdam depositing fill material in the ocean	n/a (Dec. 1966 agreement)

DIABLO CANYON UNIT 1 COMPARISON OF ORIGINAL ESTIMATE TO DECEMBER 1, 1979 OPERATING DATE ESTIMATE

		($1,000)	% OF INCREASE
PGandE Original Estimate (1966)		$162,000	
Increase based on the Revised Estimate		168,000	
Revised Estimate (1971)		$330,000	
I. Regulatory Changes	$ 68,000		11.8
II. Plant Optimization Changes	26,000		4.5
III. Schedule Delays	72,000		12.5
IV. Other Items	103,000		17.8
V. General Overheads	308,000		53.4
	TOTAL	$577,000	100.0
Estimate based on an operating date of 12/1/79		$907,000	

DIABLO CANYON UNIT 2 COMPARISON OF ORIGINAL ESTIMATE TO AUGUST 1, 1980 OPERATING DATE

		($1,000)	% OF INCREASE
PGandE Original Estimate (1968)		$157,400	
Increase based on the Revised Estimate		132,600	
Revised Estimate (1971)		$290,000	
I. Regulatory Changes	$ 60,000		13.5
II. Plant Optimization	16,000		3.6
III. Schedule Delays	56,000		12.5
IV. Other Items	80,000		17.9
V. General Overheads	234,000		52.5
	TOTAL	$446,000	100.0
Estimate based on an operating date of 8/1/80		$736,000	

NUCLEAR PLANTS
1977-1980 OPERATION
$/kw. COMPARISON