PECO STATEMENT NO. 4

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PENNSYLVANIA PUBLIC UTILITY COMMISSION V.
PHILADELPHIA ELECTRIC COMPANY,
Docket No. R-850152

DIRECT TESTIMONY OF
JAMES J. CLAREY

LIMERICK 1 AND COMMON PLANT
CONSTRUCTION SITE MANAGEMENT
PREPARATION OF PECO EXHIBIT 2

SEPTEMBER 27, 1985

Direct Testimony of James J. Clarey

Q. Please state your name and business address.

A. James J. Clarey, P. O. Box A, Sanatoga Branch, Pottstown, Pennsylvania 19464.

Q. By whom are you employed and in what capacity?

A. I am employed in the Construction Division of the Philadelphia Electric Company. My position for the last 15 years has been the Project Manager - Construction at the Limerick Generating Station construction site. The title of my position has recently been changed to Superintendent - Limerick Section.

Q. Please briefly state your educational and employment background.

A. I received my Bachelor of Civil Engineering degree from Villanova University in 1955. Following graduation from college and a relatively short period of field engineering work for a heavy construction contractor, I joined PECO in 1957. In my 28 years with PECO, I have been consistently involved in major construction project management and my responsibilities have included managing overall field construction progress, schedule development, procurement, contract bidding, awarding and administration, estimating and monitoring project costs, quality assurance, acting as coordinator between various PECO divisions and major contractors and reporting regularly to PECO senior management. The major projects in which I have held management positions include construction of Eddystone Station Units 1 and 2 (1957-1962), additions and improvements to PECO's steam heating distribution system (1962-1964), construction of PECO's underground Independence Mall Substation (1964-1965), construction of Muddy Run Pumped-Storage Generating Station (1965-1969) and, since 1969, construction of Limerick Generating Station.

Q. Do you belong to any professional societies or organizations?

A. Yes. I am a member of the American Society of Civil Engineers and the Project Management Institute. In addition, I am a registered professional engineer in the Commonwealth of Pennsylvania.

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to describe the construction site management organization established at Limerick, to describe the site management tools used to control cost, schedule, labor effectiveness and quality, and to explain the impact of changing regulatory requirements and other external forces on construction activities. In addition, my testimony will present the results of two studies which I have performed: 1) a comparison of Limerick 1 and common plant costs and schedule duration with similar data for a group of comparable nuclear projects, and 2) a comparison of Limerick 1 and common plant commodities and unit rates with data at other plants.

1. Limerick Construction Site Management Organization

Q. Please briefly describe your role as Project Manager - Construction at the Limerick Project.

A. My role encompassed three major categories of activities. First, I was in charge of the day-to-day supervision and direction of the PECO Construction Division team at the

Limerick site. Second, I conducted PECO's coordination efforts with the site management teams of Bechtel Power Corporation ("Bechtel") and General Electric Company. Third, I regularly communicated with and reported to PECO senior management and worked with other PECO division personnel represented at the site, including the Station Superintendent, the Quality Assurance Engineer, the Electrical Engineering Division Field Engineer, the Testing Section Engineer, internal auditors and other administrative personnel. As part of my duties, I participated in regular and special PECO management meetings, including the Monthly Project Status Review Meeting chaired by the Vice President for Engineering and Research, and the Monthly Construction Review Meeting with Bechtel Construction which I chaired and which was attended by the General Superintendent of Construction and his assistant.

I was also responsible for preparing a number of major reports on the status of construction activities which were submitted for review by senior PECO management. These reports included the Construction Activities Report, the Schedule Analysis Report and the Monthly Cost Report. A further description of these reports and how they were used in managing cost and schedule is set forth later in my testimony.

Q. Please briefly describe the history of PECO's Limerick site management organization?

A. My field office was established at the Limerick site in 1970 and I have worked at the site since that time, with the exception of the period January 1972 to May 1973 when construction was suspended as a result of NRC licensing delays. Prior to the receipt of a construction permit, the Company's site forces were relatively small, consisting of five engineers. The small size of PECO's construction management organization was appropriate since only limited construction activities, such as clearing and site preparation, could be performed at that time. By the time the NRC construction permit was issued in 1974, the site team had grown to 13 PECO engineers and 1 field supervisor. This increase was due primarily to the anticipation of the start of construction activities. As the number and variety of field operations increased (i.e. civil, mechanical, piping, electrical), the staffing, in turn, increased to its peak size of 25 engineers, 10 senior mechanical and electrical field construction supervisors and 4 administrative assistants. A chart depicting this site management organization is attached to my testimony as Schedule 1.

This site management organization had been successfully used in prior construction projects, including in particular the construction of the Peach Bottom units between 1968 and 1975. Our engineers and field construction supervisors were highly experienced in appropriate engineering and construction activities. Much of this experience came from direct involvement with construction at Peach Bottom. Stated broadly, the role of the site team was to assure fulfillment of the Project's cost, schedule, quality and procurement requirements and to assure that contractor activities were carried out in an effective and efficient manner.

Q. Describe the roles and responsibilities of the various members of PECO's site management team.

A. Referring to Schedule 1, I have labeled the major branches of the organization with five functional headings: Technical Analysis, Schedule and Progress Review, Subcontract Monitoring, Cost Analysis and Quality Control. The activities of these functional groups are described below.

Technical Analysis: PECO mechanical, electrical and civil engineers reviewed the Project drawings and specifications, commenting on them or approving them in accordance with responsibilities established by the PECO Project Manager; monitored the construction activities in their discipline; recommended changes to improve the construction process or to enhance quality; and analyzed and responded to NRC inquiries regarding field activities.

Schedule and Progress Review: PECO engineers were assigned to complement the Bechtel system of dividing the Project into several geographic areas (hence the name Area Engineer or Area Superintendent) and closely followed field construction activities to assess fulfillment of Project schedule goals, field management effectiveness and the quality and completeness of the various schedules.

Subcontract Monitoring: PECO engineers reviewed and approved the various activities leading to award of subcontracts for field construction work not performed by Bechtel, including participation in pre-bid meetings, bid package preparation and selection and approval of bidders. Following award, the administration of the subcontracts and construction progress were closely monitored through to completion. This team was actively involved in reviewing and monitoring change orders and claims resolution.

Cost Analysis: PECO engineers reviewed the field labor and material quantities portions of periodic Bechtel cost estimates (called Forecasts), monitored and evaluated field labor performance, and reviewed Bechtel's field procurement practices.

Quality Control: A specially established group, using a formal Quality Assurance program developed by PECO management, performed daily inspections of selected construction activities for quality of workmanship and completeness. The scope of their work included inspection of key plant systems which were important to reliable plant operation, thus reducing unscheduled outages for repair of equipment.

In summary, the site team monitored and controlled all functional areas of Project construction. Principal regular activities performed by the site management organization included monitoring construction activities for compliance with design requirements, reviewing construction drawings, attending construction meetings, witnessing completion of significant construction activities and assessing the effectiveness of field supervision and manpower utilization. Through the performance of these functions and utilization of the management control processes described later in my testimony, the site organization effectively and efficiently controlled the construction process.

2. Cost, Schedule and Labor Control Systems

Q. Please describe the control systems employed in managing Limerick's construction.

A. The principal systems were the Limerick Resource Management System ("LRMS") and the Forecast and Control Updating System ("FOCUS"). LRMS is a computerized management control system that tracks actual materials and equipment installed and develops projections of required further quantities (i.e. "to go" installations). FOCUS is a computerized labor monitoring system which calculates actual and projected unit rates.

LRMS maintains data on quantities installed to-date as well as to-go quantities. It was a unique system and was a fore-runner of the data-tracking systems later developed on other projects. It was first developed by Bechtel with PECO support from experience gained during the construction of Peach Bottom Units 2 and 3. To-date quantities were obtained from weekly construction progress reports prepared by construction supervisors. To-go quantities were developed from engineering drawings and were revised as plant design was refined. In addition, LRMS provided computerized procurement systems for the procurement of major materials, engineered equipment and field purchases of bulk commodities. The information contained in LRMS was updated on a weekly basis and could be recalled in various forms depending upon the users' needs, i.e. total project equipment/commodity installation status, status of a particular commodity or equipment installation or status of equipment/commodity installation at a particular plant location or within a particular startup system.

FOCUS combines actual manhours expended in the field as taken from craft time sheets with quantity data obtained from LRMS to develop actual unit installation rates (i.e. manhours per unit of material installed) for each commodity. FOCUS also provides comparisons of actual and budgeted unit rates and projects to-go unit rates for each commodity. The FOCUS program was used by Bechtel at a number of its projects during the same time frame as Limerick and, as discussed later in my testimony, was the major management tool used to monitor and control labor effectiveness.

Q. What other control systems were utilized?

A. In addition to the above systems, computerized systems for the control of payroll, the payment of invoices for equipment and commodity purchases, and craft manhour expenditures were also maintained.

Q. Please describe how construction costs and progress were measured and controlled.

A. In order to control costs and measure progress, it is necessary to develop a construction plan. This was accomplished through the Project Forecasts, initially prepared by Bechtel but thoroughly reviewed and approved by PECo management. Both PECO home office and site personnel, drawing upon their experience with oversight and monitoring of actual engineering and construction activities, participated in this review and approval process. Forecasts were developed employing the LRMS and FOCUS. Estimated to-go quantities for each commodity were obtained from LRMS and combined with appropriate unit prices to develop estimated material costs. Forecasted unit rates derived from the FOCUS program were reviewed and adjusted appropriately by construction management, and then applied to the to-go quantities to calculate estimated labor manhours. Total manhours were combined with appropriate wage rates to develop total labor costs. Activities required to install the forecasted commodities were assigned a duration based on labor availability, effective work crew size and other construction practicalities, and were sequenced in a long-term Project schedule. More detailed intermediate and short-term schedules were then developed.

Progress against the cost Forecasts and schedules was monitored through a Trend Program, review of FOCUS reports, review of schedule analyses and commodity installation projections, meetings with Bechtel and direct observation of construction activities. The Trend Program was a mechanism by which Bechtel advised us of significant variations of actual design and construction from the Project plan, i.e. variations with a significant likelihood of affecting either total Project cost or schedule. Trend reports were generally supplied monthly and were carefully reviewed both by my organization and by home office personnel. FOCUS reports were supplied weekly. These reports permitted us to evaluate commodities installed, unit rates experienced and other significant measures of construction progress against the Project plan. Often, the variances were the result of regulatory or other uncontrollable factors and could not be corrected. When cost estimate changes were required, the Project plan was revised via approval of a cost trend.

One of the functions of my organization was to make a detailed analysis of the field cost portion of each Forecast, monthly trend reports and weekly FOCUS reports. Major items analyzed included material quantities, installation rates, unit rates, distributable manual labor, non-manual labor and contingency allowances. For example, material quantities were reviewed for reasonableness by comparisons with other projects and by consideration of quantities of materials used to-date at Limerick. Similarly, unit installation rates proposed by Bechtel were also compared with industry data as well as with to-date performance at Limerick. Assessments of unit rates necessary for accomplishment of the remaining work were made with consideration given to industry performance data based on the physical completion status of each commodity. Similar evaluations were regularly performed on the remaining field cost categories. The results of the site organization's evaluation of the monthly/weekly cost and scheduledata were supplied to PECO Senior Management in separate monthly cost and schedule reports which I describe further below.

Q. Please describe the schedules used by Project management.

A. There were three principal types of schedules used to manage construction activities at Limerick. First, at the lowest level, a three to four week rolling schedule was prepared and used by superintendents and area foremen to plan daily activities for their crews. These schedules were extremely detailed, containing specific information at the pipe spool, pipe hanger, etc., level. Their purpose was to insure that activities were statused and scheduled so that craft manpower would be used effectively. These schedules were reviewed and updated at weekly Bechtel field meetings attended by PECO construction engineers at which the discussions would focus on problem resolution, coordination between work crews and ways to improve schedule progress.

A second type of schedule was the 12-month schedule prepared by field supervisors and planners in order to provide mid-range planning and coordination of engineering, procurement and construction activities. This schedule was specific to each section of each plant elevation and facility, and was updated every three months to reflect completed items and remove them from the schedule, to reschedule incomplete items and to reflect the latest three months of activities. Each revision of this schedule was distributed throughout the site management organization and was reviewed by PECO Construction Division and compared to the long-term schedule. Progress was monitored by PECO through review of Bechtel prepared reports, i.e. the Monthly Earned Manhour Report, Weekly Bulk Commodity Analysis Report and Monthly Construction Management Report, through weekly and monthly meetings with Bechtel field management, through daily site tours and through informal communication with Bechtel superintendents and field engineers.

The final type of schedule employed at Limerick was for long-range planning. During the construction of Peach Bottom, it was recognized that improved schedule control was needed. As a result, we hired a consultant to develop a critical path method ("CPM") schedule for primary containment construction. In addition, we later encouraged and supported Bechtel's use of a computerized critical path scheduling system called Management Scheduling and Control System ("MSCS") at Peach Bottom. We requested that Bechtel use this same scheduling method at Limerick.

MSCS was a scheduling program developed by McDonnell-Douglas Company which provided scheduling for 3,000 to 4,000 activities on a facility/elevation and systems/commodities basis. Logic diagrams were prepared based on planning by construction supervisors and schedulers. Using the quantity information available from LRMS, the unit rates available from FOCUS and crew sizes and manpower densities established by construction supervisors, the schedulers prepared program input. Through an iterative process, final activity durations and manpower loadings were combined to yield start and completion dates for all construction activities. Further calculation yielded float information, i.e. available slack time for each activity. Activities with the least or no float constituted the critical path. Engineering and procurement activities were separately scheduled based on MSCS need dates, and MSCS construction activities were, in turn, scheduled to meet the requirements of the Project startup schedule. Thus, all phases of the Project were coordinated.

As construction shifted to the installation of bulk mechanical and electrical commodities in 1978, we recognized the need for a scheduling method that was more appropriate for this phase of the Project. Working closely with Bechtel, we developed what became known as the Intermediate Construction Schedule ("ICS"), a scheduling methodology better adapted to the dynamic nature of bulk installation activities. Regular monthly review meetings attended by the General Superintendent of PECO's Construction Division or his assistant and my group were held with Bechtel site management to review progress against the MSCS/ICS and 12-month schedules. Moreover, PECO construction engineers monitored bi- weekly Bechtel on-site meetings at which craft supervisory personnel and Bechtel site management discussed the progress of all areas of the Project in detail.

When combined with the forecasting program, these schedules completed the overall management system by which construction cost and schedule control was achieved.

Q. Please describe in greater detail why you decided to change from MSCS to ICS in 1978.

A. MSCS had served the Project well through the civil/structural and major equipment installation phases. However, we recognized that a critical path methodology such as that used by MSCS would not be appropriate in the bulk commodity/system completion phase. The reason for this was the traditional use by CPM of "hard" logic which is inflexible in that it demands a certain sequencing of construction activities. The civil/structural phase of the Project, by its very nature, required that a predetermined construction sequence be followed, i.e. that a certain structure or piece of equipment be installed before another. Therefore, the hard logic underlying the MSCS program was well suited for scheduling this type of work.

However, mechanical and electrical commodity installation was not benefitted by this "hard logic, rigid sequence" approach to activity planning. Unlike civil/structural work, there are an infinite variety of methods and sequences for efficient commodity installation with the most efficient often depending upon external forces which cannot be known until construction proceeds. For example, hard planning logic for the installation of piping is not appropriate because it cannot reflect the realities of spool problems, scaffolding, access, deliveries of hangers, fitting and valves, foreman preferences and hundreds of other real-life factors that determine the best method of installation on a day-to-day basis. As a result, MSCS was simply not the best method for scheduling this phase of the Project.

Q. What problems would arise from using the hard MSCS logic for the scheduling of bulk commodity installation?

A. The most serious problem was that MSCS could not be used to accurately evaluate progress or report Project status. Where departure from the established hard logic was required for proper installation of a particular commodity, the MSCS schedule would often show a negative schedule impact, i.e. negative float, until the logic was revised to reflect this change. If these activities were on or nearly on the critical path, a schedule delay of a Project milestone would be unnecessarily reported. This misinformation interfered with management evaluation of Project status and needs.

Q. What was the ICS schedule methodology and why was it more appropriate than MSCS?

A. ICS was developed by Bechtel in response to our continuing insistence that a better schedule tool was necessary to plan, schedule, assess and evaluate progress. ICS covered the same scope as MSCS, i.e. construction, testing and startup, and it was similar in format to MSCS in that work was divided by facility/elevation and the commodities in those locations were included. All remaining work was quantified and displayed in a series of line items, similar to bar charts, which had calculated calendar durations.

These line item activities had two basic logic ties.

First, detailed analyses were performed to schedule commodity completion and testing to support system turnover to startup. Second, analyses of the commodity activities at each location were made so that these activities could be scheduled to reflect interrelationships of space and time. That is "soft", rather than "hard", logic was established, i.e. goals rather than outright demands were stated. At this level of scheduling, direction as to which specific portion of the line items should be installed first, last or otherwise was not stated. Thus, construction supervision had the necessary flexibility to cope with routine day-to-day problems. They did, however, commit to meeting the goals established by the soft logic and were monitored accordingly.

In addition, ICS provided a better assessment of progress because it employed the earned value concept of schedule attainment. The earned value method assigns quantity credit on the basis of degree of difficulty and complexity with each major commodity installed to accurately status segments of the job and then the total job on a value-of-work accomplished basis. This concept provided a more accurate picture of actual progress and avoided the illusion of, for instance, faster progress resulting from accomplishment of easier work. Thus, ICS provided management with the ability to better assess electrical/mechanical commodity progress and, on a summary basis, assess total Project progress.

Q. Were there any special purpose work schedules employed at Limerick?

A. Yes. A number of special purpose work schedules were used to supplement those described above. Where work in a particular area of the plant was especially difficult or critical to meeting the overall Project schedule, a specific schedule for that work was generally prepared. These schedules provided a level of detail similar to that used in the three to four week schedules, but for a substantially longer period of time. Their purpose was to provide additional detailed scheduling for those activities which required a higher level of planning effort in order to ensure that Project completion would not be impacted. Typically, PECO construction engineers were assigned to the items covered by special purpose schedules to monitor progress and ensure that slippages in schedule were promptly addressed by Project management.

The most important of the special purpose schedules employed at Limerick was for work performed in the primary containment. Because of the complexity and limited work space in this part of the plant, construction interferences caused by regulatory design changes threatened to slow construction progress and delay overall Project completion. Regulatory changes which impacted the primary containment design and construction included Mark II modifications, Class I seismic requirements, pipe whip restraints and TMI modifications. The primary containment special schedule was used to provide detailed planning of activity sequencing in order to meet major milestones, such as the hydrostatic test of the reactor vessel and connecting piping, the structural integrity tests and the integrated leak rate test.

A number of other such schedules were developed, including specific schedules for 1) completion of systems needed for turnover to the startup group which were prepared and updated weekly; 2) systems heavily impacted by regulatory change, including control room panel modifications, installation of interior and exterior security equipment, TMI additions, etc; and 3) other miscellaneous activities, such as control rod drive installation, reactor vessel internals installation, refueling floor construction, thermal insulation of piping and the application of special coatings to walls and floors.

Q. Please describe how work force effectiveness was managed.

A. As previously discussed, quantities installed, manhours expended and unit rates for all commodities were maintained in LRMS and FOCUS. These data were then summarized and compared with forecasted unit rates through the FOCUS program. Forecasted unit rates for the various commodities were presented in the form of performance curves developed from productivity information at other nuclear construction projects in which Bechtel was involved and to-date performance at Limerick. These curves reflected the relationship between unit rate and completion progress.

Unit rate comparisons were the principal tool used to monitor labor effectiveness. These comparisons were reported and summarized in Weekly Labor Cost Reports (produced by FOCUS) which were reviewed by a PECO cost engineer who would then prepare a monthly report to PECO management presenting performance analyses for major commodities on a cumulative, annual and monthly basis. The cost engineer, in concert with the schedule engineers, would also calculate installation performance for the most recent three month period. These data were then compared with forecast unit rates. If significant deviations were revealed, the effect on schedule (i.e. installation durations) was estimated and corrective action was studied. Management was alerted to possible schedule slippage if corrective action could not be taken or was ineffective.

In addition, a number of other programs were established in order to enhance worker productivity and morale. A description of the most important of these programs follows.

Work Sampling - A special program of field study of work activities was established using statistical sampling to identify nonproductive time, i.e. time not yielding direct or indirect work. Under this program, the plant was divided into survey routes which would take approximately 30 minutes to cover, and PECO engineers were assigned to each of the routes to observe and record results on standardized survey forms of the specific activities of workers in various construction areas. The focus of this program shifted to areas of the plant where work was progressively more difficult to perform. Data were compiled, concerns of observers were summarized, and results were reviewed with contractor management on a daily and weekly basis.

Production Engineering - Where normal control procedures did not readily produce desired production rates, a group of industrial engineers were assigned to study the problem and recommend corrective action.

Industry/Academic Interface - PECO participated in a number of programs sponsored by the academic community to identify areas for improving the construction of nuclear plants. The results and recommendations from these programs were reviewed and analyzed for applicability to Limerick.

Employee Suggestion Program - We have always held a strong belief in the value of employee suggestions and have maintained such a program within the Company. During the Limerick Project, a similar program was extended to non-PECO site personnel as well.

Quality Circles - Bechtel developed a program under which non-manual employees met weekly to discuss problems and select significant items for referral to management.

Finally, PECO attempted to enhance productivity through efforts designed to improve and maintain employee morale. Examples of our efforts in this regard included the publication of a monthly job site newspaper which provided individual recognition of worker performance and human interest stories involving construction personnel; a project open-house which allowed workers to share their accomplishments with their families; and an annual series of afternoon meetings with all craft foremen, superintendents and lead-nonmanual personnel which provided an opportunity to direct questions to upper level PECO management, including the Vice President for Engineering and Research, about Project goals and other matters related to Limerick.

Q. Please describe any other management tools used to monitor and control construction costs and schedule.

A. The primary tool used to monitor and control all aspects of the Project was the Monthly Project Status Review Meeting. This meeting provided a forum in which the status of each functional area of the Project was communicated to upper management. Information on construction activities was generally provided through two sources. First, the Bechtel Project Construction Manager provided a construction report which explained the status of all construction activities and discussed major construction items in detail. As the representative of the PECO construction site team, I would comment on the various matters presented by the report and provide clarification as to the site team's position on these matters. Second, the PECO site team developed analyses of cost and schedule performance during the previous month which would be given to PECO management in advance and discussed at the meeting as necessary. As a result, potential problems in the construction area were raised and reviewed by all management groups, the impact on other areas of the Project was analyzed, and corrective measures were formulated and implemented.

Cost and schedule were also monitored through a number of regular reports prepared under my direction and supervision. One of the most important was the Construction Activities Report which was issued monthly in preparation for the Monthly Project Status Review Meeting. This report informed Construction Division Management in Philadelphia of the site team's immediate efforts and recommendations. Areas of coverage included construction status, subcontracts and procurement, PECO quality control and numerous miscellaneous items. Appendices to the report included a detailed numerical summary of PECO quality control activities and a detailed construction status report which provided completion percentages for major structural components and commodities in each facility. This report was a continuation of a method of regular communication with upper management which was instituted during the construction of Peach Bottom Units 2 and 3 in the early 1970's.

A second major report developed by my unit was the Philadelphia Electric Schedule Analysis Report ("PESA"). Each month prior to the Project Status Review Meeting, the

Construction Division prepared this report, which contained a detailed analysis of construction progress. This report was distributed to the Vice President of Engineering and Research, the Superintendent - Construction Division and the Station Superintendent - Limerick Generating Station. The PESA typically included a statement of Project status, commodity status, facility status, subcontract status, system status, critical path analyses and an areas of concern section. The report was used to provide management with the site team's independent assessment of the Project based on the data received from Bechtel and our continual involvement with work progress. As a result, our management was well-informed of problem areas prior to the Project Status Review Meeting so that proper attention could be focused on major items.

The last major report prepared by the site team was the Monthly Cost Report which was developed by the Construction Division Cost Engineer and circulated to the Vice President of Engineering and Research and the Construction Division General and Assistant Superintendents. This report provided a summary of trends since the last Forecast, manual and nonmanual manpower levels, a comparison of actual versus budgeted cash flows and a summary of the unit rate comparisons developed through FOCUS. The report also included a projection of total plant costs based on trend, FOCUS, staffing and cash flow information. The final section of the report was for special studies and covered a wide range of topics, such as potential cost increases not identified by the Trend Program, various alternatives to reduce overall plant costs (i.e. split unit security), analyses of the causes and possible solutions to less than anticipated labor performance, comparisons of Project costs and unit rates with similar data from other plants, analyses of the Project Forecasts, analyses of work sampling results and corrective action to improve labor effectiveness, and miscellaneous reviews of overtime, absenteeism, distributable costs and backcharges.

Q. Did the Limerick Project make use of scale models to facilitate design and construction activities?

A. Yes. A scale model of the Limerick power block, which included large pipe, HVAC, cable tray, equipment, structural steel, and critical small pipe was built from design drawings in order to locate and correct potential commodity interferences before the design drawings were released for construction. Bechtel's Plant Design Model Shop Group ("PDMSG"), located in San Francisco, coordinated the modelling program. The various design disciplines at Bechtel routed their design drawings to the PDMSG where they were incorporated into the model. When interferences were identified, the PDMSG notified the affected discipline to revise the design drawings to eliminate the interferences. The model was then updated to incorporate the revised design.

In addition, photographs of the model taken at various stages of its production were transmitted to the field, where they were used to assist with planning, scheduling and installing large commodities. The photographs were also distributed to the various design groups, where they were used to improve and simplify future design. The photos proved invaluable and saved both time and money. The model itself, which consisted of some ten sections, was then set up in the field for consultation and study by construction personnel.

The power block model enhanced all aspects of the project. It improved communication among plant design disciplines and between plant design and field engineering, simplified design - particularly in congested areas, simplified preparation of layout drawings, improved sequencing of commodity installation, aided field scheduling, and, most importantly, the model eliminated more than 4200 interferences. The resulting savings in cost and schedule were significant.

Apart from the power block model, several additional structural models were also prepared:

- A primary containment reinforcing steel model was developed as a design and constructibility aid. Interferences with primary containment liner plate embedments were identified and resolved. Assembly sequencing was developed and refined during model development and then duplicated during actual construction for optimal schedule and manpower efficiency.

- Full scale mock-ups of the primary containment conical wall sections were constructed to trial fit the complex geometric curves of the 2-1/4-inch diameter reinforcing steel prior to actual erection. Fabrication inaccuracies and deformation of prefabricated shapes during shipping were identified early and corrected, thus permitting continuity of the erection sequence.

- A scale model of reinforcing steel and sheathing for the post-tensioned fuel pool support girders was constructed to determine optimal assembly sequencing and constructibility. Field supervision and engineering used the model in conjunction with the design drawings to plan and schedule construction activities.

These civil engineering/construction models contributed greatly to the superior performance of the Limerick Project in these areas of work.

Q. PECO implemented an expanded quality program under which quality inspections of non-safety systems were performed. Would you please describe this program.

A. In order to enhance reliability of the plant's non-nuclear systems and components, PECO management directed that a field inspection quality control program similar to the safety-related quality assurance program be developed to perform quality inspections on certain identified non-safety items. Systems and components to be included in the program were identified by PECO engineering. The inspection program was prepared and implemented by PECO construction engineers. Staffing of the program included a Lead Quality Control Engineer, Mechanical and Electrical discipline engineers and, at peak, nine inspectors. Inspection work was performed in accordance with the detailed procedures and checklists developed in the quality assurance program manual and scoped on system drawings. The inspectors were all PECO foremen, each with a minimum of twenty years of construction experience. The experience and training of the inspectors proved invaluable in assisting Bechtel and the craftsmen in efficiently performing their work.

As a result of this program, several significant concerns were detected and corrected. For example, during the erection of the main condensers, an inspector recognized a missing vendor shop weld, an item that would normally not be inspected and would not have been discovered until a hydrostatic test was performed during startup. The immediate correction of this item resulted in the savings of hundreds of manhours to perform rework and delays in the testing program. Also, while performing the required cleanliness inspection of the reactor feed pumps, a high wear area identified from previous experience was closely inspected. The inspection revealed linear indications in the casing which would have caused premature maintenance downtime. As a result, the pumps were sent back to the vendor for repair under warranty prior to final installation.

Ultimately, the group inspected several thousand hangers, pipe spools, valves and pieces of equipment and thereby substantially assisted in increasing construction efficiency, acceptability of work and system reliability. Nine years after its start, the program was completed with the turnover of systems to plant operations staff. The overwhelming success of the program with minimum manpower and expense was seen in the efficient startup and testing of Unit 1.

3. Impact of Changing Regulatory Requirements and Labor Unavailability Upon Construction Activities

Q. Please describe how changing regulatory requirements impacted the construction process.

A. As a general matter, changing regulatory requirements have made the construction process much more difficult, costly and time consuming. Regulatory imposed design changes have added substantial additional commodities and manhours to the Project. These changes have also added to the complexity of the construction effort and increased the congestion in work areas, which, in turn, has resulted in increased costs, reduced labor effectiveness and schedule delays.

Q. An explanation of how regulatory changes adversely impacted the cost and schedule of the Limerick Project is presented in PECO Exhibit 2. Did you participate in the preparation of that Exhibit?

A. Yes, I did. I participated in the preparation of Section III of that Exhibit along with other Company personnel. I provided the description of the effect ofthe regulatory changes discussed in that Section upon construction and startup activities. Section III has been drafted to be self-explanatory, and I will be happy to answer questions respecting the analyses contained therein.

Q. Please summarize your portion of the analyses as presented in Section III of PECO Exhibit 2.

A. Section III of PECO Exhibit 2 contains two separate analyses. The first, which is set forth in subsections A and B of Section III, is an analysis of the time durations required to identify, design and construct major plant additions or modifications required by new or changing regulatory requirements. This analysis identifies in detail the additional engineering and construction activities required because of major regulatory changes and their impact upon the project schedule, particularly during the late stages of the project when construction was being completed and startup testing performed. The second analysis is set forth in subsection C and provides additional detail as to increases in project commodities and manhours (i.e. both craft and engineering) required as a result of new or revised regulatory requirements.

The preparation of subsections A and B of Section III of PECO Exhibit 2 reflects the combined efforts of several PECO witnesses. I was responsible for providing information on the timing and extent of construction activities required because of regulatory changes. This included detailed information on the duration of construction activities, increases in commodity levels, interferences in the field and disruption of construction sequencing, and the effects of regulatory changes on startup and preoperational testing activities. Detailed information as to the timing and identification of new or revised regulatory requirements and the level and duration of engineering required in response thereto, has been provided by witnesses Boyer, Helwig and Sproat, and is described in greater detail in their testimony. I prepared subsection C and am prepared to answer all questions with respect to its contents.

Q. What are your conclusions based on the analyses set forth in Section III of PECO Exhibit 2?

A. These analyses demonstrate that new and changing regulatory requirements had a substantial impact upon the project, especially during the construction completion and startup testing phases. Because of the timing of these requirements, substantial additional engineering and construction activities were required at the end of the project to modify existing systems or design and install new systems. These changes substantially increased the level of commodities and manhours beyond that which was originally anticipated. The cumulative effect of these changes was a substantial reduction in labor productivity due to field congestion and installation complexity, and delay in the turnover of completed systems to startup and completion of startup and preoperational testing. As a result, project management could not have completed construction and startup testing activities much earlier than was actually achieved.

Q. Please discuss further the higher than expected unit rates experienced at Limerick.

A. One of the major effects of regulatory change was higher than projected unit rates, i.e. a measure of labor effectiveness. By this I mean that the amount of labor required to perform specific functions on the Project was greater than anticipated.

As a result of monitoring labor effectiveness at other nuclear projects, the construction site team noticed a trend of higher unit rates (i.e. more manhours needed to install one unit of material) in the late 1970s than those budgeted at Limerick. Through analysis of these data, we realized that the budgeted goals used at Limerick, which were based on experience at Peach Bottom and other plants prior to 1975, did not adequately account for the regulatory caused increase in complexity experienced at more modern plants. As a result, the FOCUS system consistently underestimated unit rates, especially for large pipe hangers, small pipe and electrical conduit.

To remedy this problem, we requested that Bechtel reevaluate the performance models used in the FOCUS program. This reevaluation disclosed that factors affecting labor effectiveness, i.e. work space, access to work location, number of workers in the same area and congestion with other commodities, all were severely impacted by post-1975 regulatory changes. Those regulatory changes which had the greatest impact on field labor performance included TMI, fire protection requirements, ATWS, ALARA, equipment qualification, seismicity and concrete expansion bolt testing. As demonstrated in Section III of PECO Exhibit 2, these changes required the replacement or modification of commodities and equipment in areas already congested due to the relatively late stage of construction. The cumulative effect of these changes substantially increased the complexity and difficulty of the installation process and caused less than optimal construction sequencing, thus resulting in higher than anticipated unit rates. The performance models were subsequently modified to reflect the current regulatory environment, which enabled management to more accurately estimate unit rates and, therefore, control labor effectiveness.

However, even after revising the FOCUS performance models, it was determined that unit rates were still being underestimated as a result of 1) the post-TMI changes and other regulatory requirements which were issued in the 1980s, and 2) greater than anticipated adverse effects from earlier changes. As a result, and as shown in Schedule 6 of PECO Exhibit 2, we were forced to continually increase our estimates for manual manhours needed to complete construction. This resulted in further adjustments, i.e. increases, to budgeted unit rates reflected in the performance models. In making such adjustments, we recognized that a significantly greater effort (manhours per unit) would be required during the late construction and startup testing period to incorporate final changes on systems which were complete, quality control accepted, as-built, and possibly in the pre-operational testing phase. Access to systems was necessarily delayed while testing was in progress and work on tested systems was hampered as a result of increased documentation and inspection requirements to ensure that work did not cause deterioration of nearby systems. Thus, the combination of increased regulatory requirements and the timing of resolution and implementation of such requirements, i.e., causing out of sequence construction work, substantially increased unit rates at Limerick. Additional data demonstrating this effect is contained in Section III of PECO Exhibit 2.

We recognized this impact and sought to minimize it through detailed scheduling of systems, revised performance models, and programs for improvement of labor effectiveness, all of which I have previously described.

Q. Was labor unavailability experienced during the construction of Limerick 1 and, if so, how was the problem resolved?

A. During the late 1970s and early 1980s, Limerick, like many other large scale construction projects, experienced several craft labor shortages. The craft shortages were primarily among the mechanical trades, i.e. principally the pipefitter and sheetmetal welders in 1979 and the asbestos workers in 1983.

The shortage of qualified pipefitter and sheetmetal welders was unforseeable and occurred because the increasing construction of oil and petrochemical plants, nuclear power plants, the Atlantic City Casinos and fossil fuel plants resulted in an unprecedented increase in demand for those possessing these skills. For example, major construction projects in Pennsylvania and surrounding states which competed with Limerick for craftsmen included PSE&G's Salem and Hope Creek Stations, major Peach Bottom and Eddystone plant modifications, PP&L's Susquehanna Station and Atlantic Electric's Beasley Point Station. Moreover, six of the major oil refineries located in the New Jersey - Delaware - Pennsylvania area engaged in substantial construction programs during Limerick's construction, and five Atlantic City Casino Hotels were constructed during that period.

All of these projects required large numbers of pipefitter and sheetmetal welders. Consequently, the available pool of qualified welder manpower was substantially reduced.

In an effort to assist in the orderly and timely manning of the Limerick Project, several innovative plans for addressing the demand for manpower were developed and implemented. These included: 1) development of weekly welder reports which tracked and monitored the number of welders on payroll, the number terminated, the number hired and the estimated manpower needed; 2) advertisements for welders in local/regional newspapers; 3) establishment of programs to train, qualify and upgrade welders for employment at Limerick; 4) daily/weekly communication with the local and international unions concerning this problem; 5) use of subjourneymen and non-union welders; 6) increase in travel pay to attract and retain qualified welders; 7) Regional Manpower Surveys conducted to assist in estimating peak levels of manpower availability in a given region during corresponding Limerick manpower requirements; 8) development of a comprehensive file of individuals who participated in the Limerick welder training/upgrading program to ensure a back-up supply of qualified welders should the unions be unable to satisfy manpower requirements; and 9) the use of automatic welding equipment and additional training programs to enhance welder productivity.

Beginning in May 1983, Asbestos Workers Local #14 went on strike until September 8, 1983 due to the expiration of its contract. As a result of the strike's duration, coupled with the pressure to meet the fuel load schedule, each contractor at the jobsite employing asbestos workers was forced to increase original manpower estimates. A manpower shortage thus resulted, but was addressed by 1) communication with the local and international unions for assistance in resolving this problem; 2) implementation of two-shift operations, overtime and 10-hour day schedules to avoid schedule impact; and 3) development of daily and weekly manpower activity logs and charts, similar to those established during previous welder shortages, in order to assess the ongoing site manpower requirements in view of the availability of qualified asbestos workers in the region.

4. Comparative Cost and Schedule Analyses

Q. Have you performed an analysis comparing the cost and schedule of Limerick 1 with plants with similar design and licensing requirements.

A. Yes, we have prepared a cost and schedule comparison with all boiling water reactor ("BWR") nuclear generating units which had or will have commercial operation dates in 1982 or later. This comparison is set forth in Schedule 2.

Q. Please describe this comparison.

A. In general, Schedule 2 shows the direct costs and schedule duration for all stand-alone and first unit BWRs with commercial operation dates between January 1, 1982 and December 31, 1989, inclusive. In all cases, each unit includes 100% of the cost of common plant. There are a total of 12 units (including Limerick) in the comparison group. These plants are identified by code letter in column (1). Column (2) shows the NRC region responsible for inspection, design review and final licensing of each plant. The net electrical output of each unit in megawatts is in column (3). Column (4) shows the month/year each plant received its construction permit. The actual or scheduled fuel load for each unit is shown in column (5). Column (6) is the schedule duration, in months, based on the period from issuance of the construction permit to the actual or scheduled fuel load for each unit. The commercial operation date, actual or scheduled, of each unit is shown in column (7). The direct cost of each unit, including 100% of common plant is stated in column (8). This cost is exclusive of AFUDC, general overheads and realty taxes. Finally, Column (9) is the direct cost per kilowatt for each plant. This is derived by dividing column (8) by column (3) and multiplying by 1000. Column (9) is the basis for our comparisons of plant direct costs, while column (6) is the basis for comparing schedule duration.

Q. Why have you limited the comparison group to nuclear facilities with boiling water reactors that have actual or anticipated commercial operation dates of 1982 or later?

A. The comparison group was so limited to include only those plants with construction costs that were affected by the same factors present at Limerick, i.e. principally plant design and regulatory environment. Only BWRs were included because differences in design have increased their costs relative to plants having a pressurized water reactor ("PWR") design. For example, the BWR containment design has resulted in greater congestion within the primary containment and in more equipment being exposed to radioactive materials.

This, in turn, has resulted in higher costs associated with reduced labor effectiveness and additional engineering and materials needed to meet ALARA (i.e. As Low As Reasonably Achievable) radiation concerns. Moreover, design differences have caused BWRs to experience different technical problems, different regulatory-mandated backfits and other changes which have had different effects upon their schedule and costs than upon PWRs. Examples of these BWR-unique technical problems include the Mark II phenomenon and Intergranular Stress Corrosion Cracking.

Finally, the time limitation for commercial operation, i.e. the post-1981 period, was chosen because it ensured that all units in the comparison group were affected by approximately the same regulatory changes that impacted Limerick.

Q. Please summarize how the cost and schedule of Limerick 1 compares with the 11 other BWRs included in your comparison group.

A. The cost of Limerick compares very favorably with the other plants. Limerick 1, at $2,234/kwe, is 4% less expensive than the average of $2,329/kwe, and is the fifth least expensive of the 12 BWRs in the study. The schedule duration of Limerick 1 at 124 months is only slightly longer (4%) than the average of 119 months.

Q. What other comparisons does Schedule 2 permit?

A. Analysis of the data shows that plants in the Northeast United States with a cost of $2,605/kwe are approximately 20% more expensive than plants outside that area ($2,132/kwe). In addition, durations for Northeast plants average 15 months (13%) longer than other non-Northeast plants. A review of similar data for PWRs indicates that Northeast PWRs also cost more to build and take longer to construct than PWRs located elsewhere in the country.

Q. Please explain why there are significant differences between plants located in the Northeast and those located in other parts of the country.

A. We believe some of the differences are the result of 1) labor rates and conditions in the northeast which result in higher costs, and 2) additional costs associated with winter construction. However, we feel that the major reason for higher costs at Limerick and perhaps other Northeast plants is the regulatory environment. Plants in the Northeast are located closer to major population centers than are plants in other regions, and have therefore received a higher degree of NRC regulatory scrutiny. Moreover, our experience at Limerick and knowledge of other plants indicates that Northeast plants have generally been subjected to a greater level of intervention by opponents to their construction. Such intervention complicates licensing, creates uncertainty, increases pressure for regulatory imposed design changes and lengthens project durations.

Q. How does Limerick compare to the other Northeast plants.

A. The direct cost of Limerick 1 and common plant of $2,234/kwe is significantly less (14%) than the average of all 5 Northeast plants at $2,605/kwe. The Limerick 1 schedule is slightly shorter (i.e. 3%) than the average of all Northeast plants. Furthermore, both Limerick's cost and schedule are the second best of the five Northeast BWRs.

Q. What conclusions have you drawn based on these comparisons of Limerick 1 to other BWRs of the same vintage?

A. Despite adverse conditions specific to BWRs located in the Northeast United States generally, and to Limerick in particular, the direct costs associated with constructing Limerick 1 are lower than the industry average and the schedule is, at worst, only slightly longer than the average for all BWRs in this study. This demonstrates, in my opinion, that when evaluated against projects constructed under similar conditions, we have been able to effectively control cost and schedule, and the management team at Limerick has performed well.

Q. Have you prepared a comparison of Limerick 1 and Common Plant commodity quantities and unit rates with industry data?

A. Yes, I have. Schedules 3 and 4 present a comparison of

Limerick 1 and Common Plant commodity quantities and unit rates with industry data compiled under my supervision. The data in this comparison were compiled from a questionaire sent to utilities representing 11 single and first unit BWRs with commercial operation dates between 1982 and 1989, inclusive. This sample was selected based on regulatory environment and design similarity as I described above. Responses were received for 10 units on a confidential basis. I should note that comparisons such as those presented in these schedules are of limited value in evaluating nuclear plant construction parameters. Although the greatest possible care was taken in obtaining and tabulating the data, differences in plant configuration and utility accounting systems render the data substantially uncomparable. All that can be said of this presentation is that a particular utility's data may be generally within the range of industry experience. This is the case for the Limerick 1 and Common data as Schedules 3 and 4 demonstrate.

As these schedules show, Limerick is below or approximately equal to the average for nine of eleven commodity quantity levels and for nine of eleven unit rates. Where Limerick is above the average for these data, the differences can generally be attributed to Limerick unique design requirements and/or differences in site accounting systems.

For example, Limerick 1 is above the average for quantities of large and small pipe. There are many reasons for quantity differences between plants such as plant size, location, design preference, operational reliablity, unit availability, radiation exposure and maintainability. The design at Limerick incorporated many features which enhanced reliability, availability and maintainability, and reduced radiation exposure (ALARA enhancement), including 1) sixth stage feedwater heaters, 2) separate drainage systems for clean and dirty liquid radwaste, 3) a second steam jet air ejector, 4) dual instrument air headers, 5) demineralized water piping to more areas in the plant, and 6) more extensive piping of equipment vents and drains. These requirements all resulted in additional piping at Limerick which was not included in the design of all plants in the survey. Thus, while Limerick 1 has higher quantities of pipe, the reliability, availability and maintainability of that unit should be better than average. In addition, radiation exposure to plant workers should be below average.

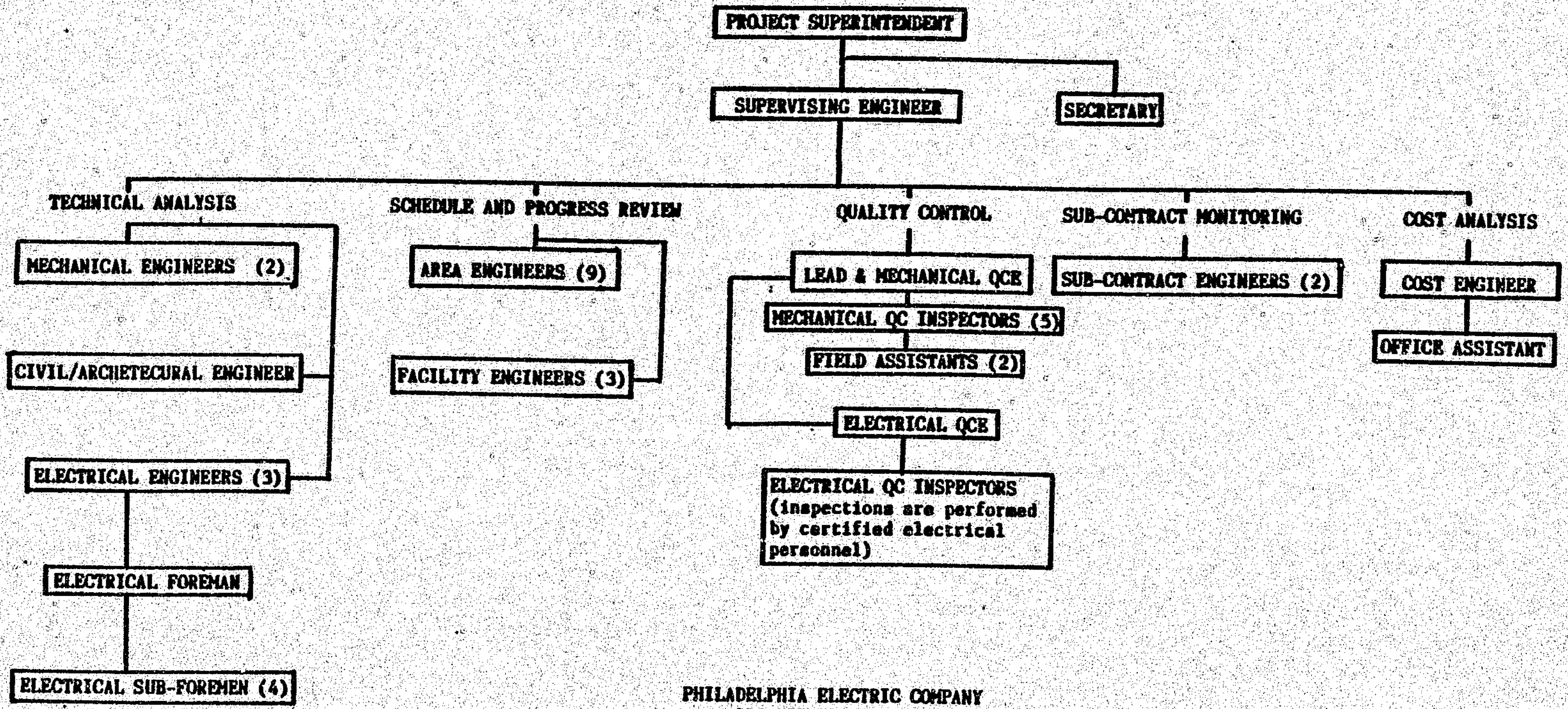
Similarly, unit rates for Limerick 1 are above the average for large pipe hangers and conduit. Differences in large pipe hanger unit rates are the result of several factors, including 1) spacing and complexity of hangers, 2) seismic requirements at each site and the site-specific soil characteristics, and 3) quantity accounting practices. Conduit unit rates are also determined by several factors, including 1) seismic requirements (hangers are included in the unit rate), 2) size of conduit used, and 3) plant complexity and congestion. However, without performing a detailed analysis of each plant's cost tracking system and design criteria, a total explanation of differences in unit rates is not possible.

In summary, Schedules 3 and 4 demonstrate that the Limerick 1 quantities are generally less than those of the average BWR designed and constructed under today's regulatory environment. Similarly, Limerick 1's unit rates are generally less than or the same as the average achieved by the other units in the sample. In addition, I should note that this comparison is biased by an indeterminant degree against Limerick. Approximately 25% of the units contained within this comparison have substantial construction yet to be completed. Based on the history of recent nuclear project construction, their total reported commodities are virtually certain to rise and their unit rates increase as they advance towards completion. From a construction standpoint, Limerick is already complete and its data thus already reflects this phenomenon.

Q. Does that conclude your testimony?

A. Yes, it does.

LIMERICK GENERATING STATION



PHILADELPHIA ELECTRIC COMPANY
ORGANIZATION CHART
CONTRUCTION DIVISION
JUNE 1984

Schedule 1

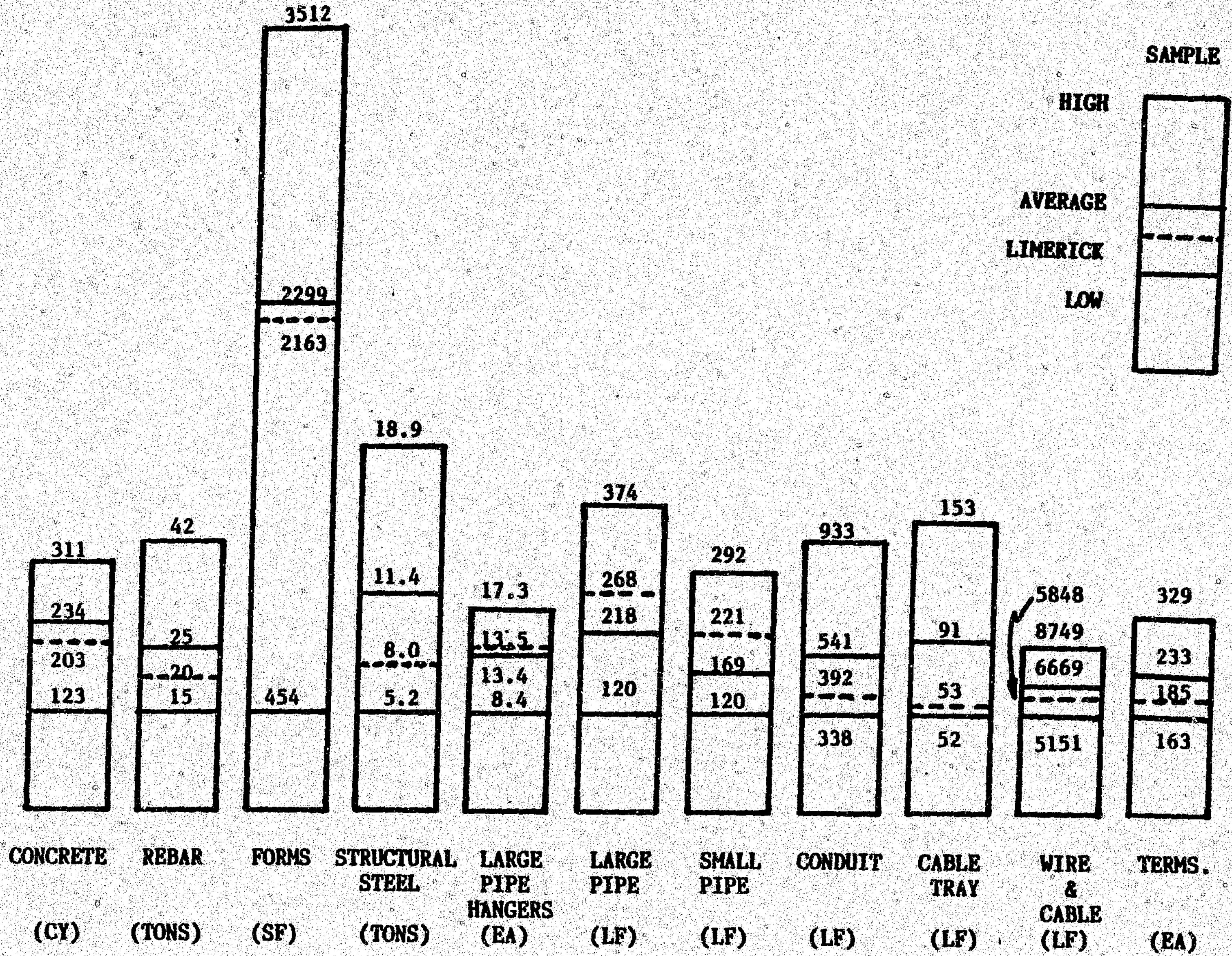
PHILADELPHIA ELECTRIC COMPANY
LIMERICK GENERATING STATION
CONSTRUCTION DIVISION

COMPARISON OF BWRS WITH COMMERCIAL OPERATION DURING 1982 TO 1989
(EXCLUDING AFUDC)

(1) PLANT	(2) NRC REGION	(3) NET MW	(4) DATE CP ISSUED	(5) FUEL LOAD	(6) DURATION C.P. TO F.L. (MONTHS)	(7) C.O.	(8) TOTAL DIRECT COSTS (MILLIONS)	(9) COST PER KW
A	3	1078	9/73	4/82A	103	10/82A	1043	968
B	1	1050	11/73	7/82A	104	6/83A	1611	1534
C	2	1250	9/74	6/82A	93	2ndQTR/85S	2028	1622
D (LIMERICK)	1	1055	6/74	10/84A	124	2/86S	2357	2234
E	3	1139	9/72	3/85A	150	10/85S	2543	2233
F	5	1103	3/73	12/83A	129	12/84A	2500	2267
G	3	1205	5/77	6/85S	97	12/85S	2762	2292
H	3	950	2/76	1/86S	119	7/86S	2502	2634
I	1	1067	11/74	1/86S	134	12/86S	2865	2685
J	4	934	3/77	6/85S	99	12/85S	2720	2912
K	1	809	4/73	11/84A	139	10/85S	2650	3276
L	1	1084	6/74	2/86S	140	10/86S	3570	3293
ALL BWRS			12 PLANTS		1431		29122	27922
			AVERAGE		119		2429	2329
NON - NORTHEAST BWRS			7 PLANTS		790		16098	14927
			AVERAGE		113		2300	2132
NORTHEAST BWRS			5 PLANTS		641		13024	12995
			AVERAGE		128		2611	2605

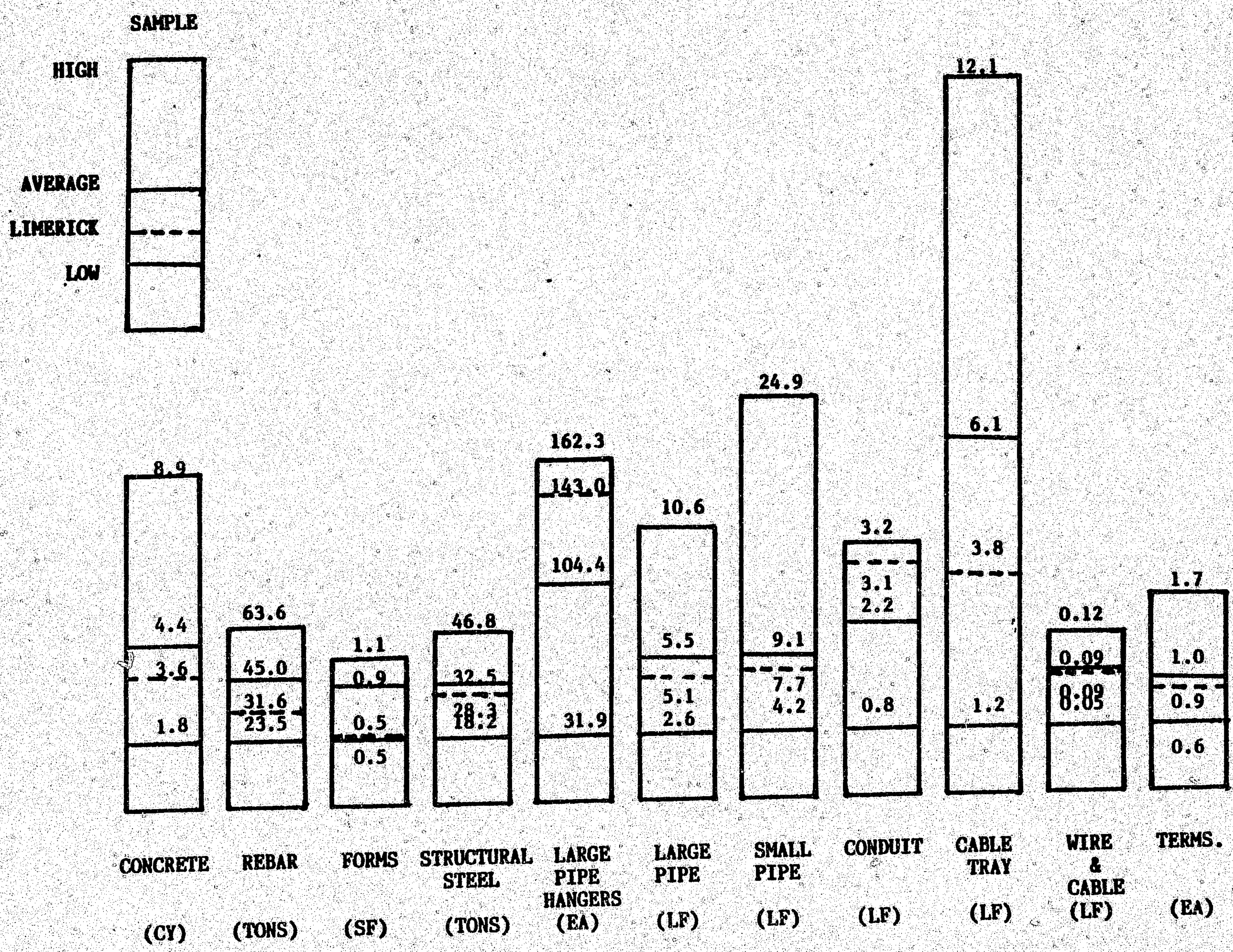
BWR COMMODITY COMPARISON

(ALL VALUES X 1000)



Schedule 3

BWR UNIT RATE COMPARISON



Schedule 4

PECO STATEMENT NO. 5

R-850152
12-18-85
Hlg jat

PENNSYLVANIA PUBLIC UTILITY COMMISSION
v. PHILADELPHIA ELECTRIC COMPANY,
DOCKET NO. R-850152

DIRECT TESTIMONY OF
DAVID R. HELWIG

LIMERICK 1 AND COMMON PLANT
PREPARATION OF PECO EXHIBIT NO. 2

September 27, 1985

TESTIMONY OF DAVID R. HELWIG

Q. Please state your name and business address.

A. David R. Helwig, 2301 Market Street, Philadelphia, Pennsylvania 19101.

Q. By whom are you employed and in what capacity?

A. I am Supervising Engineer of the Nuclear Services Branch of the Engineering and Research Department for Philadelphia Electric Company.

Q. What is your educational background?

A. I received my Bachelor of Science Degree in Mechanical Engineering from the University of Delaware in 1973, my Master of Science Degree in Mechanical Engineering from the University of Pennsylvania in 1977, and have currently fulfilled approximately one-half of the academic requirements for a Master of Business Administration Degree at Widener University.

I have also attended and/or run a number of continuing professional education courses in the nuclear power field, including:

—Nuclear Power Plant Components

—Inservice Inspection for Nuclear Power Plants

—Fire Prevention and Control in Power Plants

—BWR Simulator Training

—Radioactive Waste Management

—Engineering Economics

—Security of Nuclear Facilities

—Qualification of Nuclear Safety-Related Equipment

—Materials for Power Plant Applications

Q. Please describe your work experience at PECO, including your duties and responsibilities in your current position.

A. In 1973 I was employed by PECO as an Engineer in the Hydraulics Branch of the Engineering and Research Department where I worked until 1976. In this position, I had direct engineering responsibility for the hydraulic and hydrologic aspects of the Company's fossil, nuclear and hydroelectric generating stations. This included the completion of design work and startup activities for the river water systems at PECO's Eddystone Generating Station Units No. 3 and 4 and Peach Bottom Atomic Power Station Units 2 and 3, as well as technical reviews and studies for the Delaware and Susquehanna River Basin Electric Utilities Groups.

Additionally, I was responsible for the engineering of the various river water systems and the hydraulic and hydrologic aspects of the licensing of the Limerick Generating Station with the Atomic Energy Commission, Delaware River Basin Commission, Pennsylvania Department of Environmental Resources, and the U.S. Army Corps of Engineers. My responsibilities included the review of the design of these facilities, the specification and purchase of all major equipment, system analyses and the development of automatic control schemes for their operation.

In 1976 I was assigned to the Power Plant Services Section of the Engineering and Research Department. In this position, I had direct engineering responsibility for a significant number of systems at both Peach Bottom and Limerick. These included the gaseous radwaste system, various containment systems, fuel handling and storage equipment, process sampling systems, gas analyzers, emergency diesel generators, service and cooling water systems, instrument air systems, etc. Since 1979, I have supervised an engineering group within the Power Plant Services Section which had responsibility for these areas. In 1983, I was made Branch Head of the Nuclear Services Branch which was formed to handle these activities and in 1984 I was promoted to Senior Engineer.

My specific responsibilities related to Peach Bottom have involved the evaluation of operational problems and new regulatory requirements and the design of modifications which they have required. Work in each of these areas has included responsibility for licensing, safety analysis, conceptual and detailed design, procurement and the direction of installation and testing.

My activities related to Limerick have included review of system design, specification and procurement of major equipment, preparation of Safety Analysis Report Sections, review of the Probabilistic Risk Assessment, specification of startup test requirements and review of test results, preparation of operating procedures, response to NRC questions and resolution of all licensing issues within these areas of responsibility. A major aspect of my design review responsibility was to assure that relevant Peach Bottom operating experience was considered in the design of Limerick. Additionally, I have acted as the point of contact between the Engineering and Startup organizations for all preoperational testing activities, and between the Engineering and Operations organizations for the preparation and review of all operating procedures.

I have been deeply involved in the assessment and resolution of TMI Lessons Learned Requirements for Peach Bottom, Limerick and for Boiling Water Reactors generically. I have been responsible for the development of generic positions, design assessments, licensing and the implementation of modifications or design changes associated with the following TMI requirements:

Short-term Accident Analysis and Procedures Review;

Reactor Coolant System Vents;

Plant Shielding;

Post-Accident Sampling;

Dedicated Hydrogen Control Penetrations;

Containment Isolation Dependability;

Accident Monitoring Instrumentation;

Instrumentation for Detection of Inadequate Core Cooling;

Qualification of Accumulators On ADS Valves;

Evaluation of Depressurization With Other Than ADS;

Primary Coolant Outside Containment;

Control Room Habitability;

Containment Hydrogen Control; and

Emergency Procedure Guidelines.

I have also been involved with Peach Bottom and Limerick work in response to other regulatory requirements and changes. The following are examples of such topics with which I have been directly involved for Limerick:

Assessment of preoperational and startup testing requirements;

Development of the seismic impact program;

Evaluation of Mark II mass/energy phenomenon;

Evaluation of combustible gas hazards;

Determination of environmental conditions for use in equipment qualification reviews;

Selection of equipment locations;

System designs forALARA considerations;

Specification of ASME code requirements for equipment procurement, repairs, and periodic inspection;

Study of IGSCC mitigative measures;

Reviews of compliance with NRC regulatory guides;

Preparation of Technical Specifications;

Preparation and amendment of the FSAR;

Review of the Probabilstic Risk Analysis;

Design and analysis of the ultimate heat sink;

Implementation of the Quality Assurance Plan, including preparation of the project Q-list;

Review and selection of reactor coolant system leak detection equipment;

Design of containment inerting and post-accident combustible gas control equipment and systems;

Design of the augmented offgas treatment system; and

Review of containment isolation and leak testing provisions.

Q. Do you belong to any professional organizations or have any professional registrations?

A. Yes, I am a Registered Professional Engineer in the Commonwealth of Pennsylvania. I have also worked on committees of and been affiliated with the American Society of Mechanical Engineers, American Nuclear Society, Atomic Industrial Forum and Philadelphia Science Council. A list of these committees and positions held are set forth in Schedule 1.

In addition, I have participated in and chaired committees of the Boiling Water Reactor Owners' Group (BWROG) related to a number of the above and other issues. I served as Vice Chairman and Chairman of the BWROG from August 1982 to October 1983 and October 1983 to November 1984, respectively. In this capacity, I managed the resolution of virtually all TMI items which had generic impacts on BWR's, managed the resolution of other generic BWR issues, and represented the BWR Owners before the NRC Staff and various other industry organizations. I am currently Chairman of the BWROG Regulatory Response Group, Industry Degraded Core Rulemaking Program (IDCOR) Review Committee and Decay Heat Removal Committee.

Q. Do you have any prior experience in testifying before a regulatory agency?

A. Yes, I have made presentations to the Delaware River Basin Commission and the Susquehanna River Basin Commission on behalf of PECO and the Basin Electric Utility Groups. Additionally, I have represented PECO and the BWROG before the Advisory Committee on Reactor Safeguards (ACRS) and the NRC on a large number of technical issues related to Peach Bottom, Limerick and BWR's in general. These have included virtually all of the topics enumerated above.

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to describe my role in the development of PECO Exhibit 2.

Q. Please describe your role in developing the analyses set forth in Section II of PECO Exhibit 2.

A. My role in the development of the analysis which supports Section II of PECO Exhibit 2 was threefold.

First, I acted as the single point of contact for TB&A in obtaining project documentation and input from Bechtel and PECO. In this capacity, I assured that TB&A was afforded access to all relevant project documentation related to cost growth and its causes, assisted in the definition of the causation factors, assured consistency with project unitization practices, and obtained technical input from cognizant PECO and Bechtel personnel. I generally maintained an overview of all activities associated with the analysis of Limerick cost growth, commented to assure consistent treatment of technical issues, and performed reasonableness checks of the results based on my Limerick experience and knowledge of the engineering issues which affected BWR's in general.

Second, I supplied TB&A with data necessary to reconcile the various PECO accounts comprising the total project cost as defined in the Capital Authorization and its Supplements.

Third, I performed a detailed review of all materials related to the description, cost, categorization and unitization of all changes which fell under my areas of responsibility as described above. In this regard I acted as one of a number of PECO reviewers each with particular areas of experience and expertise. Further, I coordinated and assisted TB&A in obtaining comments and verification from the other PECO and Bechtel reviewers on specific technical subjects covered in the analysis.

Q. Please describe in more detail the reconciliation of the PECO accounts.

A. The charges against each subdivision of the PECO Capital Authorization (C.A.) were examined to determine the cause of their cost growth between the original C.A. in December 1970 and C.A. Supplement 3 in July 1984. In this manner, all increases in PECO costs were identified for TB&A's use in their review of overall project cost growth.

The C.A. contains approximately 75 accounts or subdivisions. A number of these accounts pertain to specific areas of activity (e.g. - emergency notification, technical support center), and were thus directly assignable to their causation factor. In a number of other instances, the accounting for particular purchase and change orders was used to identify the cost increases attributable to specific causes. This method of analysis was used in the reconciliation of the nuclear steam supply system, materials procurement, and consulting subdivisions. Other subdivisions were not supported by project records which facilitated the assignment of their costs to specific causes (e.g. - engineering, construction supervision). In these instances, the cost increases were determined to be a function of the total ongoing level of work and were thus identified to TB&A for inclusion with other indirect and distributable project costs.

Q. Based on your role in Section II's preparation as you have described it above, what is your opinion as to the accuracy of the analysis?

A. As explained in TB&A's testimony, an accounting system to precisely track project cost by causation factors was unneeded for project control purposes and would have been burdensome to implement. However, recognizing that accounting precision is not possible, I believe that the quantification of cost increases by regulatory and other causative factors as set forth in Section II is a reasonable estimate of such costs and can be relied upon for making decisions in this proceeding.

Q. Please now describe your role in developing the additional analyses set forth in Section III of PECO Exhibit 2.

A. Section III of PECO Exhibit 2 provides engineering and schedular details regarding a number of major regulatory requirements which occurred during the construction of the Limerick project. Because of my involvement with these issues, my involvment with the BWROG, and my position on the PECO management team, I was able to provide perspective on these issues and/or validate the detailed information presented. Where I had a personal knowledge of the subject matter, I provided, reviewed, or verified the accuracy of the description of the nature and timing of the regulatory change, and the accuracy and completeness of the work descriptions. Where I did not have a direct involvment in a particular topic, I obtained the same level of review from other congnizant PECO engineers. Additionally, I reviewed the materials presented for consistency with the findings in Section II of this Exhibit and for reasonableness of the information based on my knowledge of the engineering issues which affected all BWR's during this period. Topics covered in Section III for which I had review responsibility include TMI (including Emergency Response Facilities and Post-Accident Sampling), Fire Protection (including Sprinkler Additions, Structural Steel Coating, and Penetration Sealing Program), Anticipated Transients Without Scram (ATWS), Seismicity, High Energy Line Break (HELB)/Moderate Energy Line Break (MELB), As-Built Piping Reconciliation (I&E Bullentin 79-14), NRC I&E Bullentin 80-11 (Masonry Walls), and ASME Section III Requirements.

Q. Does this conclude your testimony?

A. Yes, it does.

List Of D.R. Helwig's
Profesional Affiliations

American Society of Mechanical Engineers

- Member 1972 to present
- Committee on Nuclear Air and Gas Treatment, Gas Processing Subcommittee
  - Member 1979 to present
  - Vice Chairman 1981 to 1983
  - Chairman 1983 to present
- Philadelphia Section, Nuclear Engineering Division
  - Member 1973 to present
  - Secretary 1973 to 1976
  - Vice Chairman 1976 to 1977
  - Course Director 1975, 1976, 1979
  - Chairman 1977 to 1978
- Philadelphia Section, Utilities & Industries Section
  - Chairman 1978 to 1979
- Philadelphia Section, Professional Development Committee
  - Chairman 1979 to 1980
- Philadelphia Section, Professional Divisions
  - Chairman 1980 to 1981
- Philadelphia Section, Attendance Committee
  - Chairman 1981 to present

American Nuclear Society

- Member 1972 to present

Philadelphia Science Council

- Board of Directors 1980 to present

Atomic Industrial Forum, IDCOR Committee

- Technical Advisory Group, 1983 to present
- BWR Advisor, 1985

PECO STATEMENT NO. 6

12/18/85 Hbg
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PENNSYLVANIA PUBLIC UTILITY COMMISSION v.
PHILADELPHIA ELECTRIC COMPANY,
Docket No. R-850152

DIRECT TESTIMONY OF
EDWARD F. SPROAT, III

LIMERICK 1 AND COMMON PLANT
PREPARATION OF PECO EXHIBIT NO. 2

September 27, 1985

DIRECT TESTIMONY OF EDWARD F. SPROAT, III

Q. Please state your name and business address.

A. Edward F. Sproat, III, 2301 Market Street, Philadelphia, Pa.

Q. By whom are you employed and in what capacity?

A. I am the Supervising Engineer of the Nuclear Generation Branch of the Electrical Engineering Division in the Engineering and Research Department of Philadelphia Electric Company.

Q. What is your educational background?

A. I received my Bachelor of Science Degree in Electrical Engineering from the University of Pennsylvania in 1973. I have currently fulfilled approximately one-third of the academic requirements for a Master of Science Degree in Management Science at the University of Pennsylvania.

I have also attended a number of continuing professional education courses including:

- Fundamentals of Nuclear Power
- Engineering Economics
- Quality Assurance
- BWR Simulator Training
- Qualification of Nuclear Safety-Related Equipment
- Modern Power Plant Practices

Q. Please describe your work experience at PECO, including your duties and responsibilities in your current position.

A. I joined PECO in June 1973 as an Assistant Electrical Engineer and was assigned to the Limerick Project Group in the Electrical Engineering Division. In this position, I reviewed and approved electrical schematic and single line diagrams, and specifications and requisitions for certain major Limerick electrical equipment. I also coordinated the in-house review of bid evaluations for these electrical purchase orders, and was responsible for the electrical construction criteria drawings which covered the installation of grounding, raceway, wire and cable, lighting, communications systems and the fire alarm system. In this position, I had extensive communications with the Architect/Engineer (Bechtel) and the Nuclear Steam Supplier (General Electric Company).

I continued in this position from 1973 until August 1978, during which time, I was responsible for reviewing and developing responses to U.S. Nuclear Regulatory Commission Regulatory Guides which affected the electrical design of the plant. Regulatory Guides which caused extensive redesign in the electrical area during this period and with which I was personally involved included R.G. 1.75, "Physical Independence of Electrical Systems", R.G. 1.47, "Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems", R.G. 1.81, "Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants", R.G. 1.29, "Seismic Design Classification", R.G. 1.89, "Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants," and R.G. 1.106, "Thermal Overload Protection for Electric Motors on Motor-Operated Valves." For each of these Regulatory

Guides, I directed the development of electrical design changes required to bring Limerick into compliance with this NRC guidance.

From September 1978 to August 1980, I was temporarily assigned to Gas-Cooled Reactor Associates in LaJolla, California. In this position, I performed a number of market and economic analyses of the High Temperature Gas-Cooled Reactor (HTGR). In September 1980, I returned to my former position in the Limerick Project Group. At that time, I was given oversight responsibilities for the development of electrical design changes that were responsive to late regulatory requirements. These areas included Startup Transient Test Monitoring, Plant Security, Emergency Response Facilities and Fire Protection.

In February 1982, I was promoted to the position of Limerick Electrical Project Engineer. In this position, I was responsible for the completion and licensing of the electrical design of Limerick and directly supervised four engineers and one technical assistant in the Limerick Project Group. I also coordinated and monitored the activities of approximately fifteen other PECO electrical engi neers working on Limerick as well as the efforts of the Bechtel and General Electric engineers working on the electrical design.

As part of my responsibilities at PECO, I wrote numerous responses to NRC requests for additional information and conducted several meetings with NRC reviewers and management. These meetings were generally on topics where the Limerick design provided a cost effective alternative to the standard NRC requirements. Specific topics covered by such meetings included fire protection shutdown capability, internal control panel wiring separation and redundant raceway separation criteria. In all of these cases, the PECO alternative was ultimately accepted.

In addition to the above licensing activities, I was also directly involved in two major technical areas: Fire Protection Shutdown Capability and Electrical Separation. In both cases, I developed the strategy upon which the Limerick design is based. For the former, I developed the methodology used to determine which cables were to be fireproofed. This resulted in a reduction of approximately 9,000 feet in the amount of raceway which would have required fireproofing due to the original Bechtel analysis. For the latter, I developed and managed two test programs which advanced the state of the art in electrical separation criteria and justified the Limerick unique criteria to the NRC, thereby avoiding the rework that would be needed to comply with NRC standard criteria. These test programs have received industry-wide recognition and several utilities have expressed interest in their purchase and use.

Finally, in October 1984, I was promoted to my present position of Supervising Engineer of the Nuclear Generation Branch. In this position, I directly supervise fourteen engineers, a technical assistant and one clerk. My responsibilities include supervising the Limerick Electrical Project Engineer and his group, the Peach Bottom Electrical Project Engineer and his group, and the Equipment Environmental Qualification Group.

Q. Do you belong to any professional organizations or have any professional registrations?

A. I am a Registered Professional Engineer in the Commonwealth of Pennsylvania. I am a member of the Institute of Electrical and Electronics Engineers (IEEE) and three societies of that organization, including:

- Power Engineering Society (PES)
- Nuclear and Plasma Sciences Society
- Engineering Management Society

I am also active in the nuclear standards writing activities of the IEEE. I served on the working group which wrote IEEE Standard 649-1980, "Standard for Qualification of Class 1E Motor Control Centers for Nuclear Power Generating Systems." I am currently Chairman of the working group which is revising this standard. I am also a member of the Nuclear Power Engineering Committee (NPEC) of the PES and a member of NPEC Sub-Committee 2, Equipment Qualification.

Q. Do you have any prior experience in presenting testimony before the NRC or other regulatory bodies?

A. Yes, I testified before the Atomic Safety and Licensing Board (ASLB) during the Limerick Operating License hearings concerning a contention on the adequacy of the Limerick environmental qualification program. The contention was found to be without merit.

I have also made a presentation to and answered numerous questions from the Advisory Committee on Reactor Safeguards (ACRS) during its review of the Limerick design. My presentation covered the electrical system designs and their reliability under degraded conditions. The Limerick design was found to address all of the Committee's concerns.

I have also made numerous presentations to NRC Staff members in meetings as outlined in my testimony above.

Q. What is the purpose of your testimony?

A. The purpose is to describe my role in developing the analyses contained in Section III of PECO Exhibit 2.

Q. Please describe that role.

A. Section III of PECO Exhibit 2 provides engineering and schedule details on major regulatory requirements which occurred late in the construction schedule. Because of my personal involvement with a number of these items and my position on the Project management team, I was able to provide details of the integration of these changes into the existing design and to analyze their effects on overall project schedule. This information was then used in the generation of parts of Section III of PECO Exhibit 2.

Q. Please provide a description of the major regulatory requirements listed in PECO Exhibit 2, Section III with which you were involved.

A. As Electrical Project Engineer, I was involved in the implementation of all requirements which affected the electrical and control systems of Limerick. As described in PECO Exhibit 2, not only did TMI and many other electrical system regulatory changes occur late in the Project, but some continued to be changed and refined into 1983.

After their issuance, PECO analyzed each requirement. Engineering of design changes began immediately and the required number of engineering manhours were estimated. The engineering schedule was coordinated with the construction schedulers so that the final design would arrive at the site in a pre-arranged, optimal sequence along with the required materials. These schedules were met in practically all cases.

The specific design changes with which I was most intimately involved are listed below.

<u>Emergency Response Facility Data System (ERFDS)</u>. I coordinated the selection of the system supplier and design of system installation. The installation was extremely complex and costly because it required connections into several hundred existing instrument loops in numerous panels. Each of these connections required that several drawings be revised.

The system was installed primarily in response to NUREG-0737 to provide a Safety Parameter Display System, but it also was utilized to provide the transient recording capability required by Regulatory Guide 1.68. It eliminated the need for a separate startup transient recording system which was estimated to cost several million dollars uninstalled.

<u>Fire Protection</u>. I devised the methodology utilized by Bechtel to analyze and document Limerick's compliance with the safe shutdown capability requirements of BTP CMEB 9.5-1. My involvement peaked after Bechtel's preliminary analysis showed that approximately 12,000 feet of raceway would require fireproofing. This quantity could not have been completed to support an October 1984 fuel load. As the result of the revised methodology, total fireproofing was reduced to approximately 2,700 feet which was completed in August 1984. The fireproofing cost approximately $1,000 per foot installed.

I also defended the methodology before the NRC during their fire protection audit in August 1984 in which Limerick was found to have no violations of NRC criteria. Limerick was one of the first plants to successfully pass this NRC audit.

<u>Control Room Panel Modifications</u>. Panel modifications resulted from a number of late design changes required by regulatory changes, as described in PECO Exhibit 2. The design changes for separation criteria required to complywith Regulatory Guide 1.75 were minimized by PECO's efforts to develop Limerick unique separation criteria through the use of test results and analysis. As mentioned earlier in my testimony, I developed a test program and authored a test report which was accepted by the NRC as an

innovative method of justifying lesser separation requirements than those listed in the Regulatory Guide. Compliance with the current NRC requirements would have required essentially a complete redesign of the Control and Auxiliary Equipment Rooms at significant cost and schedule delay. The test methodology and results avoided this.

Equipment Qualification (EQ). The EQ effort was managed by PECO Electrical Engineering with work conducted at Bechtel and General Electric. Through our involvement in IEEE Standards activities and our leadership roles in other industry groups, we were able to complete the qualification effort prior to fuel load as compared to numerous operating plants which have still not completed their EQ efforts. This was accomplished through maximizing the use of data bank or shared information with other utilities and by our knowledge of the requirements to eliminate unnecessary testing and analysis. Because this item was the subject of a licensing contention, slippage of this effort most certainly would have caused a delay in issuance of the Operating License. Moreover, by completing this effort, we have eliminated the need for such expenditures after commercial operation as has occurred at some other plants.

Other modifications described in PECO Exhibit 2 which I have had experience with and provided information on are those associated with Security, Anticipated Transients Without Scram (ATWS), Safety Relief Valve Position Indication, the Radiation and Meteorological Monitoring

System (RMMS) and the electrical aspects of the Emergency Response Facilities. The discussion of these items in PECO Exhibit 2 is fully explanatory, and I am available to answer any questions which relate to these matters.

Q. Does this conclude your testimony?

A. Yes, it does.

PECO STATEMENT NO. 2

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PENNSYLVANIA PUBLIC UTILITY
COMMISSION v. PHILADELPHIA ELECTRIC
COMPANY, Docket No. R-850152

DIRECT TESTIMONY OF
JOHN S. KEMPER

LIMERICK 1 AND COMMON PLANT
PROJECT MANAGEMENT

September 27, 1985

TESTIMONY OF JOHN S. KEMPER

Q. Please state your name and business address for the record?

A. John S. Kemper, 2301 Market Street, Philadelphia, PA 19103.

Q. By whom are you employed, Mr. Kemper, and in what capacity?

A. I am Vice-President of the Engineering and Research Department for Philadelphia Electric Company.

Q. What is your educational background?

A. I received my Bachelor of Science Degree in Electrical Engineering from the University of Pennsylvania in 1950. In 1959, I attended the Nuclear Power Station Training Program for Reactor Supervisors at the Shippingsport Atomic Power Station in Shippingsport, PA.

Q. Please describe your work experience prior to your current position.

A. In 1950, when I joined Philadelphia Electric Company, I was assigned to the Southwark Generating Station as a Test Engineer. In late 1950, I was inducted into the Army and, after serving for two years, returned to PECO where I was assigned to the Schuylkill Generating Station also as a Test Engineer. In this position, I performed and evaluated tests on the major equipment and control systems at the Schuylkill Station. After almost a year, I was transferred to the Cromby Generating Station where two major generating units were under construction. At Cromby, I managed construction of the plant's control systems and acceptance tests and was promoted to Results Engineer with supervision over all Test Engineers in the Station.

In 1957, I was transferred to the Eddystone Generating Station as Plant Engineer and became involved in the construction of that station. My specific duties included the development of operator training procedures, alarm lists and maintenance and lubrication programs, as well as the supervision of all startup testing activities. Two years later, I was assigned to take the Nuclear Power Station Training Program at the Shippingsport Atomic Power Station. On completion of that program, I was temporarily assigned to the Detroit Edison Company for three years where I worked as a Shift Supervisor at their Enrico Fermi Atomic Power Plant. In 1962, I was transferred to General Atomic Company and while there worked with the designers of the Peach Bottom Atomic Power Station, Unit No. 1.

In 1963, I returned to PECO as Plant Superintendent of Peach Bottom Unit 1, with complete responsibility for the operation and maintenance of the station, which was nearing completion at that time. While on this assignment, I successfully passed the Atomic Energy Commission's Senior Licensed Operator examination. In 1967, I was transferred to PECO's main offices in Philadelphia and was named Superintendent of the Station Economy Division of the Station Operating Department. In 1968, I was appointed Manager of the Engineering and Research Department and served in that position for 12 years until January of 1980, when I was elected Vice-President of that Department.

Q. Please describe your experience and responsibilities in your prior position as Manager and your current position as Vice-President of the Engineering and Research Department.

A. As detailed above, prior to my appointment as Manager of the Engineering and Research Department, I had direct experience with the engineering, construction, startup testing, operations and maintenance of nuclear, fossil and hydro generating units. As Manager and now as Vice-President of the Engineering and Research Department, I have been generally responsible for the design and construction of all of the Company's generating facilities, as well as its Research and Development Program. My experience includes direct management responsibility for design and construction of the Peach Bottom Atomic Power Station - Units 2 and 3, including engineering, construction, procurement, quality assurance, licensing and startup activities. I have been and am similarly responsible for recommending and implementing necessary capital modifications made after the commercial operation of those units. Also, I have had and currently have direct management responsibility for the engineering design and construction of the Limerick Generating Station. All such functional management organizations on the Limerick project operate under my immediate direction and supervision and I in turn report to Senior PECO Management, including the Board of Directors and the President.

During the period that I was Manager of the Engineering and Research Department, I shared these responsibilities and reported to the then Vice-President, Mr. Vincent S. Boyer. Since Mr. Boyer's election as Senior Vice-President - Nuclear Power, I have consulted with him in the development of major programs and the resolution of difficulties respecting Limerick licensing, engineering and construction. I have concentrated primarily on direct management of contractors and site activities, while Mr. Boyer has concentrated on the licensing process and relationships with regulatory agencies having jurisdiction over the Project.

Q. Have you been active in any professional organizations?

A. Yes, I have worked on committees of and been affiliated with the American Nuclear Society, the Electric Power Research Institute, the Institute of Electrical and Electronic Engineers, the Association of Edison Illuminating Companies, the

Engineers Club of Philadelphia and other organizations. A list of these committees and my positions in them are attached as Schedule 1. I am also a Registered Professional Engineer in the Commonwealth of Pennsylvania.

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to describe the project management organization used at the Limerick Project, to describe the management tools and systems employed to monitor and control cost, schedule and construction quality of the Project, to explain the reasons why Project cost and schedule duration have exceeded our original estimates and to provide an overall assessment of the performance of Project management at Limerick.

1. Summary of Limerick Project Management

Q. Please describe PECO's objective in managing the Limerick Project and whether it achieved that objective.

A. The Company's objective has always been to ensure that a safe, reliable and licensable plant is constructed at a reasonable cost. To achieve this objective, the Company has continuously maintained a substantial and active role in all areas of Project management and in cost and schedule control. Although we have relied on outside consultants to provide both technical expertise and management services, we have always recognized that we must maintain close control and supervision over the Project. In addition, the Company has maintained a high commitment to quality at Limerick in order to ensure plant safety, reliability and licensability.

Although Limerick has cost significantly more and has taken longer than we originally projected, I believe that we have been successful in achieving our objective. In completing the plant and obtaining its license, we have had to overcome a number of unanticipated problems, including NRC-mandated, continuous changes in the design requirements for licensing, lower than anticipated cash resources to devote to construction and labor shortages, all of which were beyond our control. These problems and the inter-related and unanticipated impact which they had on the Project made Project management an extremely challenging and, often, very frustrating process. I believe that we have responded to these problems appropriately and have resolved them in an efficient and effective manner. This can be seen by recognizing that, despite these problems, Limerick's cost is no greater than the average plant constructed today. Further, we have avoided the exceedingly high cost levels, or worse yet - the apparent quality failures which will prevent plant completion and operation as have been experienced at several contemporaneous projects. Accordingly, I believe that we have achieved our objective of constructing a safe, reliable and licensable plant at a reasonable cost.

2. Limerick Project Management Organization.

Q. Please describe the management organization which you employed at Limerick.

A. Responsibility for management of the Limerick Project was assigned to the Vice-President of the Engineering and Research Department by Corporate Management. My and my predecessor's role was to manage and coordinate the activities of the various departments at PECO which were charged with the day-to-day management of all functional areas of the Project. These departments included Engineering and Research, Purchasing and General Services, Electric Production, Finance and Accounting, and Legal. The organization chart set forth in Schedule 2 provides an overview of this management organization.

Q. Please describe in greater detail your role and responsibilities in managing the Limerick Project.

A. My primary function has been to provide overall guidance and direction for the Limerick Project and day-to-day control over the resolution of significant Project related matters. I have been responsible for making major policy determinations which affect various functional areas of Project management, i.e. construction, engineering, quality assurance, etc. A substantial portion of my time has been devoted solely to managing the Limerick Project. As described below, I have maintained daily communication with the Company's Project Managers, participated in and directed major management meetings and regularly reviewed a substantial number of Project reports in order to obtain necessary information concerning Project status and to provide management direction.

Q. Please describe the functions of the several Company Departments who participated in the management of the Limerick Project?

A. Following the Limerick commitment decision and the selection of General Electric Company and Bechtel Power Corporation as the major contractors, the Engineering and Research Department created a Project management organization to manage future Limerick planning, design and construction activities. The focal point of this group was the Limerick Project Manager, who was responsible on a day-to-day basis for Project administration and coordination. The Project Manager reported administratively to the Chief Mechanical Engineer, but, as respects significant Limerick Project matters, he communicated directly with me. The Project Manager's responsibilities included the following: 1) coordination of Company groups involved in the design, procurement and construction of Limerick, including groups located both within and outside of the Engineering and Research Department; 2) coordination of the development of Project schedules, budgets, forecasts, capital authorizations and supplemental capital authorizations; 3) monitoring Project costs, schedules and performance; 4) establishing priorities for review of Project documents; 5) establishing and maintaining an interface between PECO and Bechtel, General Electric and other equipment suppliers; 6) conducting periodic and ad hoc meetings to review Project status and resolve Project difficulties; and 7) preparation of reports, meeting minutes, memoranda and other documents required to keep appropriate PECO personnel abreast of Project status. The Project management group also included the Resident Project Manager, located in Bechtel's San Francisco home office, who provided additional monitoring and control over engineering activities.

The Mechanical Engineering Division was responsible for reviewing the mechanical design work of Bechtel and General Electric to ensure a safe, operable, reliable and economical plant. Additionally, the Mechanical Engineering Division was responsible for plant licensing, nuclear fuel procurement and fabrication, and environmental considerations.

The Electrical Engineering Division was responsible for electrical design review and for instrument and control systems review. Such reviews were directed and administered by the Electrical Project Engineer. These reviews entailed a detailed assessment of the plans for safety, system operability, reliability and economy.

The Construction Division, through the Limerick Project Manager - Construction was responsible for monitoring all Limerick site construction activities, including cost and schedule, and for development and implementation of a Quality Control System which was applied to non-nuclear equipment and systems. Actual day-to-day control over construction activities was maintained by the site management team, the organization and responsibilities of which are described at greater length by Mr. Clarey. I communicated with Mr. Clarey on almost a daily basis as to significant Project matters.

The System Planning Division was responsible for issuing periodic reports on costs, preparing and updating budgets, reviewing capacity needs and making economic evaluations related to the generation of electricity by various methods. With input from various Project entities which report costs, this division monitored all billings both by account and in the aggregate and continually made comparisons with budget amounts. The results of these activities were set forth in Monthly Expenditure Reports. In addition, the System Planning Division developed a computer program to calculate taxes, overhead and AFUDC which were necessary for preparation of total Project cost estimates.

The Engineering Design Division was responsible for reviewing drawings, maintaining records and files, and receiving the many thousands of drawings at the completion of the Project.

The Research and Testing Division served as a consultant on metallurgical and welding concerns and tested and calibrated plant instrumentation.

Finally, the Quality Assurance Section was responsible for ensuring that the design and construction of Limerick met the requirements of 10 CFR 50, Appendix B. In implementing its program, this Section conducted numerous inspections, audits and surveillances of PECO and contractor activities. The results were forwarded to the appropriate Project entity, usually Bechtel or General Electric, under the Project Manager's signature. In the few cases where significant problems were discovered, reverification of the corrective action was performed through the audit process.

The Company's Purchasing and General Services Department was responsible for reviewing and approving recommendations generated by various Project entities for the purchasing of equipment and materials and for the awarding of contracts and subcontracts for services. Insurance requirements as well as stores and salvage needs were also directed to this department. Purchasing personnel have a diversity of technical experience, including engineering, construction, production, and electric and gas distribution, as well as experience in finance and accounting.

The Electric Production Department, through the Station Superintendent, reviewed plant equipment and systems design, as well as arrangements of plant facilities. Based upon his broad operating experience, the Superintendent frequently forwarded comments and recommendations on matters of improved plant safety, reliability and operability through the Project Manager to the appropriate Engineering and Research Department group for action and resolution. In addition, as described further below, the Electric Production Department had primary responsibility for organizing and controlling startup and preoperational testing activities.

Finance and Accounting provided accounts payable, plant accounting and internal auditing functions. The Accounts Payable Division was responsible for payment of vendors' invoices after appropriate review and approval by project entities. The Plant Accounting Division was responsible for the proper accounting and record keeping as prescribed by the Federal Energy Regulatory Commission, including the additions made by the Company in plant and equipment for the

Limerick Project. The Internal Auditing Division performed audits of Bechtel and vendor billings and subcontract amendments, which entailed detailed verification of reported work completion, material delivery and accuracy of the billings or amendments. These audits were performed by four resident auditors who were stationed at the Limerick site on a full-time basis because of the size and importance of that Project. The auditors performed over 70 detailed audits, the results of which were reported directly to the Manager of Internal Auditing in PECO's Finance and Accounting Department, who in turn submitted monthly reports to PECO's Chairman of the Board and met personally with the Chairman twice a year.

Finally, the Legal Department served as the interface between PECO and various regulatory agencies with respect to licensing and other matters.

Q. Please describe the use of outside contractors by the Company as part of the Limerick Project management organization.

A. Outside contractors were hired where it was determined that additional technical expertise or specialized management services were needed that were not available from within the Company. On this basis, the Company hired Bechtel, General Electric and various other subcontractors as needed. Although relying on these outside experts, we have always retained ultimate control over the Project and have closely supervised their activities through an experienced Project management organization and a comprehensive cost and schedule control system. Daily supervision of and communication with these contractors was primarily the responsibility of the Limerick Project Manager, the Resident Project Manager, the Project Manager-Construction and the Startup Director.

Q. Why did you adopt this organization?

A. First, this organizational approach provided for the creation of centralized, executive responsibility placed upon myself and the Project management team, while at the same time involving in the Project needed expertise from all organizations within the Company. We believe that this approach, used successfully at Peach Bottom, best served Project management needs. Second, this approach maximized the availability of experienced personnel in Company-wide operations. It must be remembered that during Limerick's engineering and construction period, the Company was also completing startup testing, supporting initial operation and, during later periods, making major post-TMI and other NRC-required changes to Peach Bottom. Third, adoption of this structure assured a transfer of knowledge and experience gained from Peach Bottom startup and operations to Limerick. This facilitated the early, low cost correction of potential problems or regulatory backfits at the Limerick plant. Finally, and most importantly, this organizational structure had been successfully used in managing the design and construction of the Peach Bottom units.

3. <u>Description of Limerick Project Management by Functional Project Area.</u>

Q. What is the purpose of this section of your testimony?

A. This section describes specific management tools and processes which we employed to manage major Project areas, i.e. engineering, procurement, construction, licensing, startup and quality assurance.

A. <u>Engineering Management</u>

Q. Please describe those controls and processes used in engineering management.

A. Throughout the Project, we maintained a competent engineering staff which was responsible for monitoring engineering activities and establishing and maintaining high standards of design quality. Indeed, we directly managed many technical programs, defined requirements, established technical and schedule objectives, monitored engineering costs and progress, and managed consultants with specialized experience in the investigation and resolution of work tasks requiring such experience.

The conceptual design of the Project, completed in 1969-1971, was developed in conjunction with Bechtel and General Electric. Our original purpose was to duplicate the Peach Bottom design at Limerick with certain modifications to reflect site-specific conditions. This approach was adopted because use of a standardized design would result in a significant reduction in the amount of engineering and original design work to be performed. It was estimated that the design for 33 systems at Peach Bottom could be directly transferred to Limerick, resulting in substantial savings. Further, standardization of our nuclear plant designs would result in significant operating and maintenance cost savings over their lifetime.

Prior to the receipt of a construction permit in 1974, a significant amount of engineering was performed. During the pre-construction period, engineering management was primarily achieved through quarterly Project status review meetings and reports which began in 1969. These meetings were the predecessors to the Monthly Project Status Review Meetings and Reports discussed later in my testimony, and were used to discuss key events, schedules, procurement, subcontracts, costs and any other subjects that required immediate action or decision. In attendance at these Project status review meetings were myself and/or my predecessor, the division heads of the Engineering and Research Department, the PECO Project Manager and Project Manager - Construction, PECO Quality Assurance management, Bechtel's and General Electric's Project

Managers, Bechtel Engineering and Procurement Management, and Bechtel's Field Management.

Monthly meetings and reports by the PECO Mechanical and Electrical Engineering Divisions were also begun in 1969. These meetings were conducted by the Project Manager or Electrical Project Engineer, and were attended by the Section heads from the Mechanical and Electrical Engineering Divisions and covered a variety of topics, including property acquisition, site investigation, PSAR development, quality assurance, design studies, licensing, procurement, engineering status, construction activities, and cost estimates and control. These meetings, in addition to providing a forum for more detailed discussion and resolution of Project difficulties than was available in the quarterly and later monthly Project meetings, generated data and proposals for consideration at those later meetings. Also, numerous meetings were held between PECO and Bechtel engineers on an as-needed basis to review the design of various systems and components that were of particular concern. Although infrequent in the beginning, these latter meetings were held more often as the plant design progressed and the need for them occurred.

Q. Please describe how management of the engineering function evolved after receipt of the construction permit.

A. During the period 1974-1980, the design of the plant became more complete and the engineering forces were faced with the task of analyzing and incorporating the increasing multitude of regulatory imposed design changes.

In response to these needs, the position of Resident Project Manager was established in October 1975. This position formalized a function which had been performed by PECO personnel since 1973. The Resident Project Manager was resident in the Bechtel San Francisco Home Office where the great majority of design work was performed. His function was to provide Bechtel and General Electric with a direct channel of communication to PECO Management, to provide a local source of authoritative guidance as to PECO Management policy, and to monitor Project activities occurring at Bechtel and General Electric home offices. Specifically, the Resident Project Manager participated in substantially all Bechtel engineering meetings and reviewed most of the Bechtel internal engineering reports dealing with engineering staffing, cost and schedule progress, and resolution of technical problems. The Resident Project Manager provided our management with a direct and contemporaneous source of information as to the performance of Bechtel and General Electric engineering forces.

During this period and through the end of the project, overall Project performance was monitored and coordinated through the Monthly Project Status Review Meeting, which is described in greater detail later in my testimony. All major Project organizations participated in this meeting and engineering status was a major topic of discussion. The Limerick Project Manager's Bi-weekly Meeting was a further means of controlling engineering cost, schedule and quality. This meeting was divided into two portions, the Project Manager's Report and the Mechanical Engineering Section Head Reports. Engineering topics covered in this meeting included engineering cost and schedule performance, design change and modification control, NRC concerns and action items identified by the Resident Project Manager or other management groups. Another control tool, initiated in 1982, was a weekly conference between the Project Manager and the Bechtel and General Electric Project Managers located either at the construction site or in San Francisco in order to review engineering progress and any major design problems. As described above, special purpose meetings were also held as needed to facilitate Project progress.

As engineering design was completed, it became necessary to expand our design control mechanisms. Accordingly, a special mechanism was created, i.e. the Notice of Change in Design ("NCD"), to achieve such control. The NCD was used to document changes to the original engineering scope that required engineering manhours over and above those budgeted. Significant increases in estimated engineering manhours required the approval of the PECO Chief Electrical or Mechanical Engineer prior to Bechtel proceeding with the work.

In 1980, with planned design work approaching completion but with the need for substantial additional design efforts to satisfy new regulatory requirements, further control efforts were imposed. A policy was established by PECO whereby all design changes, regardless of origin, would be minimized through the use of detailed categorization, prioritization and approval procedures. As a general matter, design changes were proscribed unless required for licensing, or to achieve clearly apparent and needed plant safety, operability and reliability benefits. Approval for such changes had to be obtained from the Chief Mechanical or Electrical Engineer and was subject to my concurrence. In 1982, design changes were further scrutinized through the use of the Jobsite Review Board which was comprised of representatives from Bechtel field forces, startup and PECO construction. The purpose of the Jobsite Review Board was to control implementation of all design changes to ensure timely turnover of systems from construction to startup. Similar procedures were in existence in the Bechtel organization, and significant Bechtel proposed changes were subject to our approval.

Q. How did PECO ensure that adequate technical quality was attained in the design of Limerick?

A. Based on our experience at Peach Bottom and at other projects, we recognized that a high degree of technical quality in engineering design was required to obtain a safe, reliable and licensable plant. To achieve such quality, we developed an extensive design review program which consisted of three levels. At the first level, Bechtel prepared specifications, drawings, procedures and inspection plans to include all applicable regulatory, code and Safety Analysis Report requirements. The preparation of these design documents was closely coordinated so that collectively the documents formed an effective, cohesive program which provided the construction forces with clear and detailed work instructions.

The second level consisted of design verification by individuals or groups within Bechtel, other than those who performed the original design. The scope and depth of this design verification by Bechtel was detailed in its quality assurance manuals, which were consistent with our imposed quality requirements. The third level was performed by us. We independently reviewed Bechtel's design documents to assure that they met our stringent quality requirements. This third level of review was, to the best of my knowledge, more extensive than was typical in the industry. I have provided in Schedule 3 a list of the many Bechtel design documents which we reviewed. Through the combined efforts of PECO and Bechtel in the preparation, review and approval of the above documents, I believe that a high degree of quality in engineering design has been attained.

Q. Have there been any independent reviews of Limerick engineering management and, if so, what was the result of these reviews?

A. Yes, there have been such reviews. For example, in the November 1984 Independent Design Verification of the Limerick 1 core spray system performed by Torrey Pines Technology, it was concluded that "an adequate documented design control procedural system existed for the designers of the Limerick Generating Station Unit No. 1, mainly Bechtel and G.E." (Vol. 2, p. 80). Torrey Pines further concluded that implementation of the design control process was adequate, that construction generally conformed to the requirements of design documents and that an adequate design resulted from the implementation of the design control procedural process.

The Company's efforts to resolve important technical engineering issues were also praised in the NRC's Systematic Assessment of Licensee Performance ("SALP") Report, dated April 18, 1983, as follows:

> "Generic re-evaluations of suppression pool hydrodynamic forces identified deficiencies in the design of downcomer supports. The applicant's active participation in the BWR owners group and significant resource allocations to this problem resulted in satisfactory resolution with modifications being completed without major problems. After this assessment, the applicant completed a full scale test of the Unit 1 suppression pool to verify the theoretical analysis of the hydrodynamic forces. This is indicative of the firm management commitment to satisfactory resolution of technical issues." (p. 7)

Similarly, in the next SALP Report, dated January 16, 1984, the NRC concluded:

> "The applicant's resolution of technical issues has been demonstrated during this period by a clear understanding of the issues, the election of a conservative approach when the potential for safety significance existed and timely response to issues in most cases. The applicant's approach reflected a sound knowledge of the current industry-wide status of technical issues, usually due to their involvement with the issue on the Peach Bottom operating plant or participation in industry groups seeking a resolution to technical issues (e.g., BWR Owners Group). The applicant's approach reflected a thorough knowledge of the design of the Limerick plant and the safety significance of issues." (p. 20)

B. Procurement Management

Q. How was the procurement of equipment and materials managed?

A. Management of procurement was delegated to our Purchasing Department with Bechtel serving as procurement agent to take advantage of its substantial expertise. The types of purchases made during the Project included bulk materials, equipment and various services. The general procedures used for procuring materials and equipment were developed early in the Project. Bechtel defined material and equipment needs in the form of specifications, developed bidders lists and prepared bid analyses and award recommendations. We approved all initial purchase orders exceeding $100,000 and change orders in excess of $25,000. All Bechtel-developed specifications, bidders lists and award recommendations also required our review and approval.

In addition, PECO assumed direct responsibility for handling the purchase of certain major pieces of equipment. Based upon our success in managing the procurement of equipment at Peach Bottom, we elected to act as our own purchasing agent for a number of major items. These are listed on Schedule 4. For these major pieces of equipment, Bechtel prepared all necessary material requisitions and specifications, performed all engineering analyses and submitted bid recommendations to PECO. After PECO approved the recommendation, Bechtel then prepared engineering and drawing schedules for the selected bidder and forwarded these materials to PECO for inclusion in the purchase order. PECO would then issue a revised material requisition for purchase and negotiate any differences in the commercial terms and conditions.

To assist in monitoring and controlling the procurement process, a computerized tracking system was developed. This system was patterned after a similar system employed at Peach Bottom and was implemented at Limerick in 1973-1974, or prior to the receipt of a construction permit. This system used a comprehensive database which permitted tracking of all engineered plant equipment components from purchase order to installation. Our construction site management team was responsible for managing the procurement of bulk materials and also relied upon several generally accepted state-of-the-art control tools, such as construction schedules identifying additional items needed, material expediting "buck sheets", management attention lists identifying equipment problems that might cause delay, and material receiving reports. The purpose of these control tools was to assure that engineered equipment and materials/construction supplies were obtained at the lowest reasonable cost level and in time to support construction activities. In my opinion, as the result of these efforts, no significant procurement problems were experienced at Limerick.

C. Construction Management

Q. Please describe the management of construction at Limerick.

A. In order to manage construction, we established a site management organization with extensive construction experience gained in building the Peach Bottom Station and other power projects. This site organization monitored and controlled costs, schedule and quality through careful review and evaluation of Project data, attendance at meetings with contractors and subcontractors (i.e. both meetings which we instituted and those held by Bechtel) and by direct observation of construction activities. The results of these efforts were reported to me by Mr. James J. Clarey, Project Manager - Construction.

To assist in the management effort, we implemented a comprehensive and sophisticated control system. This system included computerized and manual databases that permitted the development of materials and manhour forecasts and the monitoring of actual performance against those forecasts. In addition, a multilevel scheduling program was developed to ensure that construction would be supported by other project functions such as engineering and procurement, and would be supportive of system turnover and startup testing activities. Variances from forecasts and schedules, as well as other problems with a potential cost or schedule impact, were identified through the Project Trend Program, meetings and reports prepared by both Bechtel and our site organization. Recommended solutions were developed by our site team, by contractors and jointly at Project construction meetings. The status of any corrective measures underway were reported on a regular basis through various reports and at the meetings I have described. One of the most important of these reports was the Philadelphia Electric Schedule Analysis Report which provided an overview of construction progress and was a significant input into the Monthly Project Status Review Meeting. As was true with engineering, this monthly meeting was the central management tool at which construction status was communicated, problems were identified and corrective action was implemented.

A more detailed description of our site management organization and the management tools used to monitor and control the construction process is presented by Mr. Clarey.

D. Startup Testing Management

Q. Please describe the management of startup testing.

A. PECO's Limerick Station Superintendent had the overall responsibility for all startup activities, reporting to the Vice-President, Electric Production Department. PECO's Startup Director, who reported to the Limerick Station

Superintendent, was responsible for directing and coordinating day-to-day startup activities. Below the Startup Director was an integrated startup organization in excess of 300 PECO and Bechtel personnel at its maximum size. The startup organization was structured to most effectively monitor and manage progress in startup activities through the use of an integrated team approach. It must be noted that although startup was primarily the responsibility of the Electric Production Department, the construction organization played a significant role in ensuring the completion of startup activities on schedule. A particularly useful tool in achieving this objective were completion schedules for individual plant systems whose completion was important to achieving startup milestones.

Once systems were turned over to the startup organization, a number of management tools were used to manage and control startup activities. Startup management attended the Monthly Project Status Review Meeting and a Startup Status Summary and addendum report was contained in the meeting handouts. Startup management also attended or conducted numerous other meetings to communicate and receive pertinent information. For example, the Assistant Project Startup Engineer conducted daily a "3 day plan of the day" meeting utilized for detailed planning and coordination of working level activities. This meeting was attended by personnel from construction, engineering and operations as well as startup. Management of startup activities also used a variety of computerized and other control processes to manage costs and achieve schedule progress.

Q. Did changes in regulatory requirements adversely affect startup activities?

A. Yes, they did. Regulatory change seriously impacted the Project during the 1979 to 1982 time frame, imposing new and unanticipated design and construction requirements, adversely impacting the cost and rendering more difficult the achievement of startup schedule objectives. This occurred for three reasons: 1) these new requirements, along with other construction activities, delayed the completion of construction, thus compressing the time available for startup and necessitating the use of overtime and increased contractor personnel to maintain schedule; 2) certain retrofits were required to previously tested systems, therefore necessitating retesting of these systems; and 3) certain regulatory changes directly impacted the cost of startup by increasing its complexity and documentation requirements, and requiring procedure redrafting and additional testing time. Examples of regulatory changes which had a significant impact on startup included modifications to fire protection systems, changes resulting from equipment qualification requirements, human factors requirements which resulted from TMI, modifications to the PGCC control panels resulting from TMI, ATWS and Regulatory Guide 1.97, and changes to Regulatory Guide 1.68 which established additional requirements for startup testing procedures and training.

Despite these problems, the October 1984 fuel load schedule was maintained. Innovative management efforts which achieved this result included: 1) specialists and consultants in various fields were brought to the site to assist in the resolution of special and significant startup problems; 2) the pre-operational test procedure writing effort was moved from San Francisco to the Limerick site; 3) a systems completion group and post turnover completion group were organized in the construction organization to minimize startup work lists and construction punch lists at turnover; 4) special training and qualification programs were initiated at appropriate times to maximize startup activity, and improve productivity and quality; 5) portable water demineralizer plants were brought to the site and were utilized to supplement installed equipment, speeding completion of the required flushing activities; and 6) integrated Project management teams were formed of construction, startup, operations and scheduling organizations to resolve startup worklist activities. Also, the Superintendent of the Electric Production Department-Nuclear Generation Division, the Bechtel Project Manager and I were in residence at the site during the critical preoperational test interval (i.e. May-October 1984) to assist site management with timely decisions and bring the necessary resources to bear to assure achievement of the fuel load date.

Through these innovative and extensive efforts, we were successful in overcoming regulatory changes and other problems. PECO succeeded in completing all startup activity from initial equipment energization to fuel load in 27 months. This startup duration is among the shortest recently achieved in the industry.

Q. Have there been any third party reviews of startup management and, if so, what have been their conclusions?

A. In the 1984 and 1985 SALP Reports, the NRC concluded that:

> "As systems entered their construction completion phase and were subsequently turned over from Construction to the Startup Organization, the two organizations developed controls to effect the turnover in the form of site job rules and administrative procedures. System turnovers are well managed and assured system quality. By established policy and management direction, systems were not accepted unless they were completed to the extent required to support required test activities." (January 16, 1984 Report, p. 9).

> "The preoperational test program was completed during this assessment period, with the exception of closing test exceptions. Based on an extensive review of tests and test results by the NRC, it appeared that the test program had been adequately managed to assure satisfactory performance of those plant systems covered by it. Much of the success of the test program was due to the quality, scope and depth of the reviews made by the licensee's Test Review Board which reviewed and approved test procedures and test results, including the closure of all test exceptions." (January 14, 1985 Report, p. 12).

E. Licensing and Regulatory Relations Management

Q. Please describe how licensing activities and regulatory relations were managed and controlled.

A. Early in the Project, PECO established an organization to closely monitor and control the licensing process by coordinating, tracking and monitoring the numerous regulatory commitments and proposed requirements. This organization evolved over time to meet the increasing demands placed upon the Project by the regulatory environment.

During the construction permit application phase, PECO dedicated two full-time engineers from the Mechanical Engineering Division who had previous licensing experience at Peach Bottom to monitor all licensing activities. Bechtel, General Electric and other contractors provided resources to assist in preparing the Preliminary Safety Analysis Report ("PSAR") and developing the licensing schedule.

As the level of complexity and number of safety and environmental requirements increased, so did the Company's management efforts. After receiving the construction permit, PECO developed a status summary tracking program for licensing activities. This system tracked NRC I.&E. Bulletins, Circulars and Notices, and findings of NRC site inspections. The system identified the responsible Project organization, the licensing commitment and the response date. Information from this system was widely distributed throughout the Project to attract significant management attention. This system ensured a timely and effective response to an increasingly complex body of regulatory requirements.

Moreover, between 1974-1981, PECO benefitted significantly from Peach Bottom experience. Normally, a construction permit holder receives little information or guidance from the NRC on new regulatory interpretations during the construction period. It is only when an application for an operating license is filed and the Final Safety Analysis Report ("FSAR") containing the "as-built" description is reviewed by the NRC, that the licensee through questioning becomes fully aware of the extent to which newly generated design criteria or regulatory interpretations must be backfit to the plant. PECO received information from the NRC during this interval because of operation of the Peach Bottom units. PECO continually reviewed this information and guidance for applicability at Limerick.

The operating license phase at Limerick occurred subsequent to the TMI accident in March 1979. As a result of this accident, the NRC Staff did not review any post-TMI operating license applications between March 1979 and early 1981. Thus, when the Limerick application was filed for predocketing review in March 1981, it was caught in a backlog of applications. It was not until March 1982, that questions on PECO's docketed FSAR from the NRC Staff branches were received. PECO responded to the questions by providing information in FSAR Revisions. The process of responding to NRC questions through FSAR Revisions continued until December 1982, at which time a majority of the more than 1,200 questions asked by the NRC Staff on Limerick had been received. It was during this time that PECO recognized that some extraordinary steps would have to be taken if the NRC Staff review was to be completed in time to support the scheduled fuel load date.

First, a computer program was developed by PECO to replace the manual system of scheduling and tracking the progress of each question. This computer system identified each open question, scheduled the development of responses based on commitment dates, grouped the questions by NRC branch, FSAR Revision and the PECo inter-disciplinary team responsible for providing a response, and identified any potential problem areas. We soon recognized the benefits of this computer program and expanded it to monitor all licensing activities. In addition, Bechtel's home office in San Francisco was provided a terminal to access this system in order to ensure that the current status of all licensing activities was maintained. This computer system enabled PECO to manage the flow of NRC questions and other open licensing items without substantially increasing the personnel devoted solely to licensing activities.

Second, PECO recognized that the answers supplied to the NRC Staff had to be fully responsive to the NRC Staff's concerns since the fuel load schedule did not permit an iterative process of NRC letters requesting additional detailed information. Accordingly, licensing management developed an innovative and aggressive program to meet this challenge. To assure accurate and thorough responses to NRC questions, PECO organized inter-disciplinary teams of in-house and contractor licensing and technical experts to prepare the needed responses. The results of these efforts were that over 90% of the responses were accepted by the NRC Staff without further inquiry.

Third, PECO's licensing management maintained continuous contact with the NRC Project Manager and Staff reviewers responsible for the Limerick Project. In addition, individuals within the Company's licensing group were assigned to act as liason with each NRC Staff branch to assure timely and complete resolution of that branch's concerns. PECO Licensing Coordinators contacted the NRC Staff upon receipt of questions to gain clarification of the precise information that the Staff needed in order to complete their review and to advise the NRC Staff of the PECO schedule for providing information to facilitate scheduling of NRC review efforts.

Fourth, as responses to NRC questions became available for incorporation into an FSAR Revision, a letter was transmitted to the NRC Staff containing the requested material. By providing the Staff with the same information which would appear in a subsequent FSAR Revision, elimination of up to a month delay was achieved. Partial responses to questions were also provided where appropriate, thus enabling partial Staff review while the remainder of requested data was in preparation.

Finally, meetings were held frequently with various NRC Staff branches for the purpose of resolving differences between the Limerick design and current NRC Staff requirements. PECO, Bechtel and General Electric technical experts, licensing personnel, and Project management attended these meetings. Senior PECO management also attended these meetings when critical path activities were involved. In nearly every instance, licensing issues were resolved in PECO's favor.

Q. Have the Company's licensing efforts been evaluated by independent third parties and with what result?

A. The NRC has repeatedly evaluated PECO's licensing management process. For example, it recognized the value of the computer tracking system in its April 18, 1983 SALP Report: "For NRC questions and PECO responses, PECO has implemented a computerized tracking system that enhances the ability for improved responsiveness to NRC initiatives." (p. 17) This report further stated:

"Management involvement in assuring quality is evidenced by attendance by middle and upper level managers at the appropriate technical meetings, the evidence of prior planning and adequate management review of decisions related to the goals to be attained in these meetings, the generally thorough and technically sound presentations made in these meetings and related submittals, and the high quality of communications from the PECO licensing staff."

Additionally, the January 16, 1984 SALP report stated, in part:

"...Management involvement has been evidenced by the appropriate level of management attendance at technical meetings, prior planning and review of the preparations for these meetings, the thorough and technically sound presentations made in related submittals, and in the quality of communications from the PECo licensing staff..." (p. 20)

...Staffing has been sufficient to meet the licensing needs for the Limerick plant during this period. The training and qualifications of the applicant's staff in the licensing functional area has resulted in a well prepared and professional organization." (p. 21)

Similarly, in the Jaunary 14, 1985 SALP Report, the NRC stated:

"The licensee's management participated actively in virtually all licensing activities. This included the attendance of the Senior Vice President for Nuclear Power at several meetings on the probabilistic risk assessment review and at all four ACRS meetings. The Chairman of the Board and at least three Vice Presidents attended the NRC Management Readiness meeting in September 1984. The Vice Presidents for Nuclear Power, Electric Production and Engineering and Research were directly involved in many of the decisions supporting resolution of technical issues during the rating period. The Senior VP for Nuclear Power and the VP for Engineering and Research have also been heavily involved in activities at the plant site during the rating period.

* * * *

The licensee's management consistently exercised firm control over the licensing activities performed by its contractors and maintained effective communications between its contractors, its own staff, the NRC staff and the NRC staff's contractors.

The success of the licensee's effort to assure quality is evident in that the many submittals made during this period have been virtually always submitted in a timely manner, have been complete and thorough (requiring very few revisions for correction of errors) and is reflective of a power plant design that is well controlled and verified by licensee personnel prior to submittal to NRC." (p. 31)

F. Quality Assurance and Quality Control

Q. Please describe the management of quality assurance and quality control.

A. Philadelphia Electric Company's experience in nuclear construction at Peach Bottom provided the basis upon which the Company established and implemented a quality assurance program for Limerick. The formal PECO nuclear plant quality program started with the construction of Peach Bottom and began evolving before the formalization of quality requirements contained in 10 CFR 50, Appendix B, which became law in 1970. The Company realized that the achievement of plant safety and reliability could be assured only through the imposition of high quality standards, both during the construction process and when the plant became operational.

An indication of PECO's commitment to quality is its development, for Limerick, of an expanded quality program. This expanded program applied to systems and components beyond those which were required by regulation to be covered. The expanded program covered Balance of Plant Systems such as radwaste and other nonsafety systems which could interact with safety systems. It was recognized that, in addition to assuring safe and reliable operations, such a quality assurance program was cost effective because the required quality measures were achieved through prevention rather than the more costly subsequent detection and rework. Further detail as to this program is presented by Mr. Clarey.

In addition to the design review program previously discussed, the Company developed a construction quality assurance/quality control program. This program embraced a "defense in depth" concept and was comprised of three levels. The first level, defined as the quality control inspection function, was performed by

Bechtel's Quality Control organization, which was independent from its construction forces. Quality Control was responsible for assuring that the final end product met the specified requirements. The second level, defined as the quality assurance surveillance function, included the auditing and/or surveillance performed by Bechtel's Quality Assurance organization, which was independent from the construction and Quality Control forces.

The third level, defined as the quality assurance auditing function, was performed by PECO's Quality Assurance organization, which was entirely independent from all Bechtel organizations. This organization was comprised of two groups. First, PECO's home office Quality Assurance group was responsible for the quality of work performed by both its own and the major contractors' home offices, and for audits of vendors which provided equipment or services for the Limerick Project. Second, the Company established a Quality Assurance group at the construction site which was responsible for work performed by PECO, Bechtel and General Electric site forces. Through these organizations, the Company performed quality assurance audits and surveillances to assure that the quality assurance programs of all Project groups were actually functioning as required. Moreover, PECO's Quality Assurance group reviewed specifications, site procedures and other required documents furnished by Bechtel to assure that the necessary quality requirements were incorporated into these documents.

From the program's beginning, PECO has, through the development of quality assurance procedures, ensured that quality personnel would have the power to require that technical requirements be met. In any quality assurance program, it is essential to verify that plant systems are constructed in accordance with the approved design. An effective work product acceptance program was thus developed at Limerick and resulted in the timely identification of nonconforming conditions which required corrective action. This avoided increased costs resulting from late, unnecessary rework and schedule slippage. In cases where the quality organizations considered an item to be a major problem, they had the authority to issue a "stop work order". Significantly, this action was taken at Limerick only in a relatively few number of limited situations, and it was never necessary to issue a general stop work order that applied to the total Project.

The results of our dedication to quality are exemplified by the fact that, unlike other nuclear plants, we have experienced no major work interruptions related to quality over the duration of the Project. All allegations of quality deficiencies brought forth by intervenors in public hearings associated with our operating license application have been considered by the NRC Atomic Safety and Licensing Board ("ASLB") and found to be without merit. As a result of this commitment, systems constructed at Limerick have generally performed as they were designed without failure, which in turn has resulted in a very short startup period, thus enabling the Company to achieve fuel load on schedule.

Q. How have independent third parties viewed the management of quality assurance at Limerick?

A. The Company's efforts in this area were generally found to be reasonable and appropriate. The NRC Region I Office of Inspection and Enforcement has consistently ranked the quality of construction at Limerick above average. Additional indications of satisfactory quality assurance are the Independent Design Verification Program findings of adequate design processes and a high appraisal of the quality program which consistently appears in the NRC's Limerick SALP Reports. For example, in evaluating the quality of the Company's piping system and pipe supports, the January 16, 1984 SALP report concluded:

> "Strong management attention was evident in the resolution of concerns identified by both the licensee and the NRC. The licensee's follow-up in handling of [NRC requirements] is a good example of management's attention and commitment to quality.
>
> * * *
>
> "Observation by the resident inspector and the Construction Inspection Team indicated that a strong construction QC program was in place. In addition to the A-E's well-staffed and trained QC organization, the licensee's QA organization is also staffed by well-trained and knowledgeable QA engineers. The resident inspectors have noticed that the licensee's QA engineers have performed more than the required amount of inspections and surveillances in this area." (pp. 12-13).

Similarly, this report further noted:

> "With other safety-related components, NRC inspections also indicated that the program was well-managed with adequate consideration of quality assurance. The installation of components were well-planned, installation requirements were properly implemented, and inspections were satisfactorily performed.
>
> The licensee has a strong training and qualification program. Welder qualification has been above Code requirements. Both engineering and craft personnel have a structured program to improve their skills. Additionally, licensee's senior management receive monthly training progress reports. In-process and final quality control inspections have been properly documented and [are] readily retrievable. A large and well-trained staff of QC engineers, technicians, and inspectors also indicated licensee's commitment to the assurance of quality.
>
> Overall, the licensee has demonstrated continued strong management attention, prompt identification and resolution of problems, ability to initiate and effectively implement long term corrective action and strong QA/QC coverage. Documentation of work has been complete and easily retrievable." (pp. 15-16)

Q. How have changing regulatory requirements impacted the quality program at Limerick?

A. Throughout the Project, the stringency of enforcement and interpretation of NRC quality assurance requirements increased dramatically, resulting in substantial increases in quality staffing levels, documentation requirements and the number and intensity of quality inspections. This escalation in quality requirements was primarily the result of operating and construction problems at other plants (i.e. TMI-2, Zimmer, etc), as well as the general proliferation of additional regulatory requirements. This increase is clearly demonstrated by Schedule 5, which provides a summary of increases in quality assurance and quality control staffing levels from 1975 to 1984. As indicated by this Schedule, PECo quality assurance staffing at the site increased by a factor of 5 during this period, while Bechtel quality assurance/quality control field forces more than quadrupled in size.

The increase in the number of NRC site audits and inspections is shown on Schedule 6. While these NRC audits did not add any significant manual labor costs to the Project, the number of audits reflect the increase in the number and intensity of required PECO and contractor-conducted quality inspections over that which was initially anticipated to satisfy NRC requirements. For example, as shown, the number of NRC site audits was 8 in 1974, varied between 16 and 23 from 1980 to 1983, and, finally, peaked at 74 in 1984. These audits and the efforts to meet the stricter quality assurance requirements substantially slowed the construction effort.

G. Cost and Schedule Control

Q. Please describe, to the extent you have not already done so, the major management control tools used to monitor and control cost and schedule.

A. Overall cost and schedule planning at Limerick was achieved through the Project Forecasts and Trend Reports. As a general matter, Forecasts incorporated management's best judgement as to future cost, schedule and cash flow projections in order to provide an overall Project budget. Two important sources of Project data used to develop the Forecasts were the Limerick Resource Management System, a computerized database that maintained current estimates of quantities to be installed, and the Forecast and Control Updating System ("FOCUS"), which developed forecasted manhours and unit rates for each commodity. These Project databases and their use in developing Forecasts are more fully described by Mr. Clarey.

Information from the Project Forecasts was used in the various cost and schedule control systems as the standard against which actual performance was measured and evaluated. Variations from the Forecasts and other changes in the Project that had a potential cost or schedule impact were identified through the Trend Program. This program was an early warning system through which Project management identified changes at an early stage, prepared order of magnitude estimates of any potential cost or schedule impact, and highlighted these changes for corrective action. These trends were then incorporated into the Forecasts and, where significant even prior to incorporation into the Forecasts, reflected throughout the functional control systems. All Forecasts and Trend Reports were carefully reviewed by PECO's site team and the Limerick Project Manager, and a detailed report of their review was provided to me for further action.

A system was also established to control cash flow expenditures on a regular basis. Long-term cash flow projections were developed as part of the forecasting process. These projections were then incorporated into a monthly expenditure report prepared by the System Planning Division which compared actual monthly expenditures to budgeted amounts. Significant deviations were brought to the attention of the Project Manager for corrective action. Review of the major aspects of Bechtel's billing, submitted on a monthly basis, was conducted by on-site representatives of the Plant Accounting and Internal Auditing Divisions. The Project Manager reviewed and approved all billing which was submitted by vendors of equipment which PECO itself had purchased -- most notably the General Electric nuclear steam supply system -- and by consultants directly engaged by PECO. As previously mentioned, the Purchasing Department also reviewed Bechtel recommendations for procurement of equipment, for award of subcontracts and for the issuance of subcontract amendments. Detailed review of all Bechtel and vendor billings was performed by the site management team and by PECO's internal auditors.

Overall progress of Project activities was monitored and controlled through a comprehensive and integrated scheduling system. At the highest level, Project progress was controlled through a Milestone Summary Schedule which provided a summary overview of major events in engineering, construction and startup. In addition, numerous other schedules were employed within the specific functional areas of Project management. Project schedules and related control systems are more fully discussed by Mr. Clarey. Another important management tool for overall Project direction and control was the Project Status Review Meeting. This meeting was started in 1974 shortly after receipt of the construction permit, and was generally held at the construction site on a monthly basis. This monthly review was conducted under my direction and attendance customarily included the Engineering Division Heads, the Project Manager, the Resident Project Manager, the Project Manager for Construction, the Electrical Engineering Project Engineer, the Quality Assurance Manager, the Station Superintendent and appropriate representatives from Bechtel, General Electric and other contractors. The purpose of this meeting was to provide all management organizations with an update on the status of all key Project matters. Topics discussed typically included a Project Summary, Senior Management Attention Items, an Engineering Report, a Construction Report, a Procurement Report, a Quality Assurance Report and an Action Items Report (i.e. Action Items from the preceding meeting).

The specific functional reports were usually presented by Bechtel representatives, with appropriate responses, comments or direction provided by the PECO management personnel in attendance. Additional input was provided by PECO functional management groups through the submission of reports prior to the meeting. Action items or problems identified from discussion at these meetings were directed to the appropriate Project entities for resolution. Action items directed to PECo management groups were handled by the Project Manager through his Bi-weekly Meeting. The output of the Monthly Project Status Review Meeting was a comprehensive report which contained all the functional information discussed at the meeting. In addition, numerous other reports were prepared and meetings were held by all Project management organizations in order to further achieve control over the Project.

Q. Did Senior Management monitor the cost and schedule status of the Limerick Project?

A. Yes. In addition to monthly meetings at which a presentation was made to Senior Management covering the status and cost expenditures of all projects compared to budget, the Company's Board of Directors received complete reviews of the cost of the Limerick Project on at least two occasions each year. In May, a full presentation was made of major Company projects and their costs (including Limerick) for a five-year forecast period. In January, the projects' costs were updated and presented in written form to the Board. If significant project cost changes were recognized between budget periods, as, for example, when a Bechtel Forecast was revised, the Board of Directors was informed at this time.

Senior Management also participated in major control meetings and received frequent status reports on Project progress. For example, the Chairman of the Board, the President and the Senior Vice President - Nuclear Power periodically attended the Monthly Project Status Review Meeting at which detailed cost and schedule information was discussed. I personally provided a verbal report on cost and schedule progress and any other significant problems at the Chairman's weekly staff meeting. Finally, these senior officials received Project information through review of monthly progress and items of interest reports prepared by Bechtel and the Engineering and Research Department, respectively.

Through these meetings and reports, the Company's Senior Management was continually informed of the cost and schedule status of Limerick and actively participated in major decisions affecting the Project.

4. Explanation of Reasons for Cost and Schedule Growth.

Q. Please summarize the reasons for cost and schedule growth at Limerick.

A. The major reason for increased costs and schedule duration was changing regulatory requirements. Additional costs and schedule duration were incurred because of construction funding restrictions and labor unavailability. In addition, some increased costs were incurred as a result of design changes justified by improvements to plant safety, operability and reliability.

Q. How did changing regulatory requirements impact the Limerick Project?

A. During the 1970s and early 1980s, the number of NRC safety and environmental requirements and new interpretations of those requirements increased dramatically. These new regulatory standards imposed stricter design, manufacturing and construction requirements and greatly increased the Limerick Project work scope. In many instances, these new requirements were imposed after substantial construction and design had already been completed. This in turn resulted in extensive retrofitting and greatly increased the complexity of the Project and congestion in work areas, thus hindering construction performance. In addition, regulatory changes often imposed increased staffing and documentation requirements which further contributed to higher Project costs.

The overall result is that regulatory changes and changing regulatory interpretations were by far the single greatest reason for increased costs at the Limerick Project. Direct costs increased because of the additional engineering, equipment, materials, craft manhours and testing needed to meet the increased scope of the Project. Indirect costs resulted from less than optimal activity sequencing and reduced labor effectiveness caused by increased congestion, complexity and additional scope, and from the need to provide increased support services to the Project as the result of the regulatory imposed increased work scope.

Q. Please highlight the more significant regulatory changes that impacted the Limerick Project.

A. In 1970, Appendix B of 10CFR50 established eighteen broad criteria which applied to all safety-related items in all phases of nuclear projects from early site investigation to final decommissioning. To provide detail as to acceptable methods of compliance with Appendix B, the NRC issued a series of Quality

Assurance Documents in 1973-1974. It was not until the late 1970s and early 1980s, however, that the tremendous impact of these requirements upon design, procurement, fabrication and construction was recognized. Additional quality inspection and other requirements generated increased documentation requirements. The impact of documentation requirements was additional manhours to develop and process the documentation, additional manhours for training personnel to create the documents, additional hold points for inspections, and additional manhours to prepare already installed components for inspection against changed or more stringent applications of construction and installation criteria.

In 1971, the Advisory Committee on Reactor Safeguards ("ACRS") imposed a higher seismic criteria than anticipated at Limerick, in the form of a higher design ground acceleration and a modified frequency spectra of seismic events. This increase in seismic requirements resulted in additional engineering and construction manhours, equipment and component congestion and complexity.

In 1975, previously undefined hydrodynamic loads were identified which impacted wetwell structures as the result of Safety Relief Valve discharge and certain postulated Loss of Coolant Accident conditions in the Mark II containment. PECO took a lead role in addressing this problem. However, final resolution of the Mark II new loads was not achieved until 1981-1982, after an extended iterative process of analysis and testing. Although PECO successfully resolved this problem without impacting Project schedule, significant additional engineering manhours and costs were incurred in order to reach a resolution that was satisfactory to both the Company and the NRC.

Also in 1975, a fire at the Browns Ferry Nuclear Plant resulted in extensive damage to electric systems and control cables and ultimately led to increased fire protection requirements. Subsequent NRC regulatory changes such as Branch Technical Position 9.5-1 and Regulatory Guide 1.120 promulgated these requirements. The major modifications required to achieve a higher level of fire protection included increased electrical separation, penetration sealing, fire-proofing of exposed structural steel, additional detection and suppresion systems and encapsulation of safety-related electrical cable in certain plant areas.

Since many of these fire protection changes were identified toward the end of the project during the 1981-1984 time period, there was a substantial possibility that full compliance would impact the schedule. To avoid this schedule impact, PECO initiated several analyses to demonstrate that a safe plant shutdown could be achieved with reduced additional fire protection. The end result of these analyses was a substantial cost savings and minimized schedule impact. However, despite these efforts, substantial costs associated with additional engineering and construction activities were nevertheless incurred.

During the late 1970s and early 1980s, a number of additional regulatory changes had a substantial impact on the Project. The most significant of all regulatory changes occurred as a result of the accident at Three Mile Island ("TMI") Unit 2 in March 1979. In response to this accident, substantial new regulations were issued which greatly increased the scope of the Project by requiring significant engineering evaluations, hardware additions, related construction activities and other substantial changes. To further exacerbate the impact of TMI, many of these changes were imposed by the NRC late in the Project (i.e. as late as 1981-1982) and severely complicated the project's ability to meet schedule during the early 1980s. Moreover, the TMI accident substantially raised the level of safety consciousness of the NRC which resulted in increased enforcement and more stringent interpretations of numerous regulations unrelated to the accident. TMI requirements also substantially increased the staffing levels and training requirements for operations and startup personnel.

Regulatory requirements that impacted the later stages of the Project also included Anticipated Transients Without Scram modifications, further additions and changes to seismic requirements, changes in ASME Code requirements, highly disruptive control room panel modifications, increasingly stringent equipment qualification standards to satisfy hydrodynamic, seismic and environmental concerns, ALARA requirements, increased security, high energy line break concerns and others. Moreover, several significant and unanticipated engineering evaluations were required by the NRC as part of Project licensing. For example, in 1980, we were required to perform a Probabilistic Risk Assessment study to assure that the risk of a severe accident occurring and its probable effects were acceptably small. Indeed, this analysis, which had not previously been required by the NRC, established that "accident risks from Limerick are expected to be a small fraction of the risks the general public incurs from other sources." NUREG-0974, p. 5-126 (April 1984). Similarly, in 1984, we were required to perform an independent design verification program to demonstrate that the Limerick design as built complied with the licensing basis of the plant. This too was a new requirement.

Finally, disruption of the proper sequencing of work activities and a reduction in labor effectiveness were indirect impacts of regulatory change that resulted in additional costs and delay. A project which can plan its work activities based upon a firm and stable scope of work can complete its work in an economic and efficient manner. However, projects subjected to continuous increases in the scope of work because of regulatory change will find it impossible to complete work within estimated cost and schedule.

Increases in craft manpower represent a good example of the disruptive influence that regulatory change had on work sequencing at Limerick. When the Project plan called for a reduction in manpower at a certain point in time and an unexpected change created a need for additional manpower, it was often difficult to obtain sufficient, qualified personnel. Moreover, once additional manpower was obtained, a less efficient and more costly plan generally resulted. Construction manpower increases required to implement regulatory required design changes also increased construction congestion. Many of these design changes were located in areas that were already space limited, such as the Reactor and Control buildings, where the most critical schedule activities during the completion of the Project took place. These areas normally had high levels of construction manpower in order to minimize the duration of critical path activities. The design changes further increased the manpower congestion in these areas which resulted in lower than anticipated unit rates.

Q. Have you directed that additional data respecting the effects of regulatory change upon the Limerick Project be prepared and presented for the record?

A. Yes, I have. This data, which is set forth as Section III of PECO Exhibit 2, has been prepared by and its details are supported by testimony from various Company engineering and construction personnel. My comments above are intended merely as a brief overview of this data.

Q. What has been the Project management philosophy for non-regulatory imposed design changes.

A. From the start of construction at Limerick, it has been a Project philosophy to minimize non-regulatory design changes. Only those changes that provided cost effective operability, maintainability, reliability and safety enhancements were implemented. All of these changes were justified based on either Peach Bottom or other industry experience. Indeed, our experience in operating the Peach Bottom units has proven extremely valuable in improving the Limerick design.

The Peach Bottom units were placed into commercial operation in 1974. However, it was not until 1977 that the number of modifications at Peach Bottom increased to a significant level. In October 1977, PECO management initiated a program to assure that Bechtel was made aware of operating and/or design improvements being made at Peach Bottom which should be considered in the design of Limerick. For Peach Bottom modifications in progress or completed, Bechtel was directed to review design material provided by PECO. For additional modifications planned at Peach Bottom, PECO engineers submitted information to the Limerick Project Manager who transmitted the information to Bechtel.

In this way, Bechtel engineers had the opportunity to review the Limerick design in light of changes being made at Peach Bottom and to make changes or modifications to the Limerick design when necessary. This timely identification of changes in the Limerick design process minimized the total cost and schedule of Limerick. Examples of non-regulatory design changes include condenser modifications, solid radwaste system changes, and improved reliability and diversity of emergency core cooling systems and supporting systems.

Q. Mr. Kemper, have you directed that there be prepared an analysis of the additional cost to the Project of the several reasons for cost and schedule growth which you describe above?

A. Yes, I have. This analysis, which is set forth as Section II of PECO Exhibit 2, was prepared by TB&A based upon Project cost documentation (i.e. primarily Project Forecasts and associated documents), with assistance from our and Bechtel's Project personnel. The analysis was reviewed by Dr. Roger J. Mattson, a former NRC official and a witness in this proceeding, to assure the correctness of its treatment of NRC regulations and licensing requirements. I and my staff have also reviewed the analysis and believe it to be accurate.

Q. Please describe the analysis which you had performed and its result.

A. The analysis compares our 1970 Capital Authorization cost estimate for the Project, which was used as the basis of our initial capital authorization, with a near final Project cost estimate reflecting a Limerick 1 commercial operation in February 1986. Based on the Project forecast documents, the analysis develops the increase in Project cost which is attributable to specific regulatory and non-regulatory causes. Further details respecting the manner of the analysis preparation are presented by TB&A.

As shown on Schedule 7, of a total direct cost increase of approximately $2.005 billion, fully $1.362 billion or 68%, is due to new or revised regulatory requirements, or to other externally-imposed factors such as new or increased taxes (excluding PURTA), cash constraint or labor unavailability. An additional $111.9 million or approximately 6% is due to plant design changes made to enhance operability and/or reliability. The great majority of the remainder of the Project's cost increases are due to increases in escalation and AFUDC.

Q. Mr. Kemper, what do you conclude from your review of this analysis?

A. In my opinion, this analysis provides a further demonstration of the reasonableness and prudence of our management of Limerick's construction and of the Project's final cost. As I and others have described, we could not prevent the effects of externally imposed forces such as regulatory changes or inadequate cash resources. When confronted with these forces, our only recourse was to react to them with an approach which would limit to the extent reasonably possible their adverse effect upon Project cost and schedule. As indicated in my testimony and that of other witnesses, I believe that we achieved that objective. Accordingly, Limerick 1 and Common Plant's Project management has been reasonable and prudent, and the entirety of its costs should be allowed in rate base.

Q. Does this conclude your testimony?

A. Yes, it does.

List of Professional Committees And Industry Organizations

American Nuclear Society - Member
  Standards Steering Com. - Member

ANSI N-45 Ad Hoc Com. on Packaging, Rec. Handling & Storage - Member

Association of Edison Illuminating Companies - Member
  Committee on Electric Power Apparatus - Member; Chairman

Atomic Industrial Forum
  Ad Hoc Review Group on 10 CFR Parts 2-50 - Member
  Nuclear Materials Safeguards Com. - Member
  Reactor Safety Steering Com. - Member

Concord Township Planning Commission - Member; Vice Chairman; Chairman

EEI-AEIC-NEMA Triple Joint Com. on Power Circuit Breakers - Member

EEI US/USSR Jt. Working Group on Electric Power Generation and Transmission - Member

Electric Power Research Institute - Member
  Nuclear Power Divisional Committee - Member

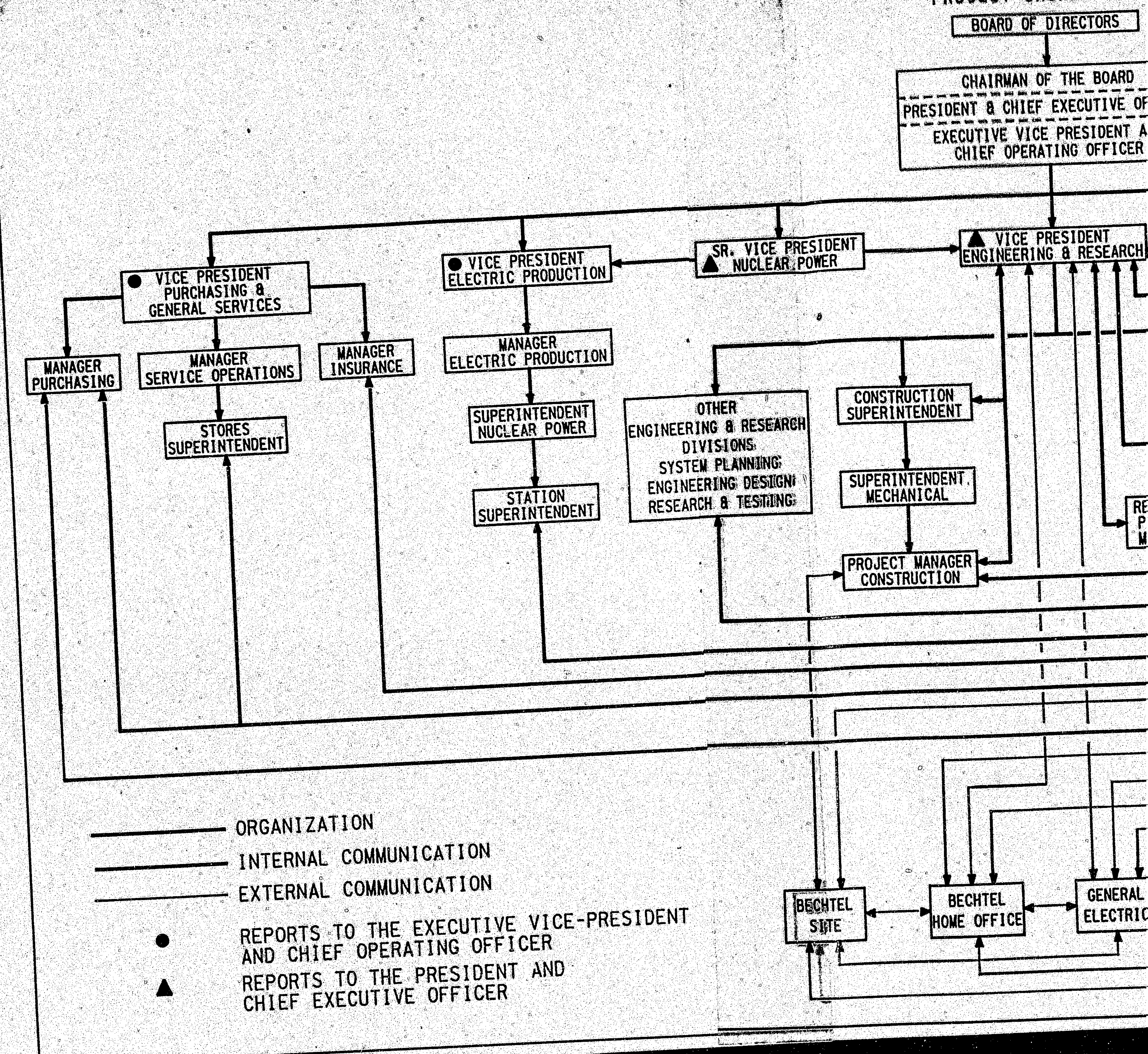
Engineers' Club of Philadelphia - Member

Institute of Electrical and Electronics Engineers - Member

Union League of Philadelphia - Member

University of Pennsylvania
  Mechanical Engineering and Applied Mechanics Advisory Council - Chairman
  Wharton Center for Risk and Decision Processes - Member

Widener University School of Engineering Board of Advisors


BOARD OF DIRECTORS
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PRESIDENT & CHIEF EXECUTIVE OF
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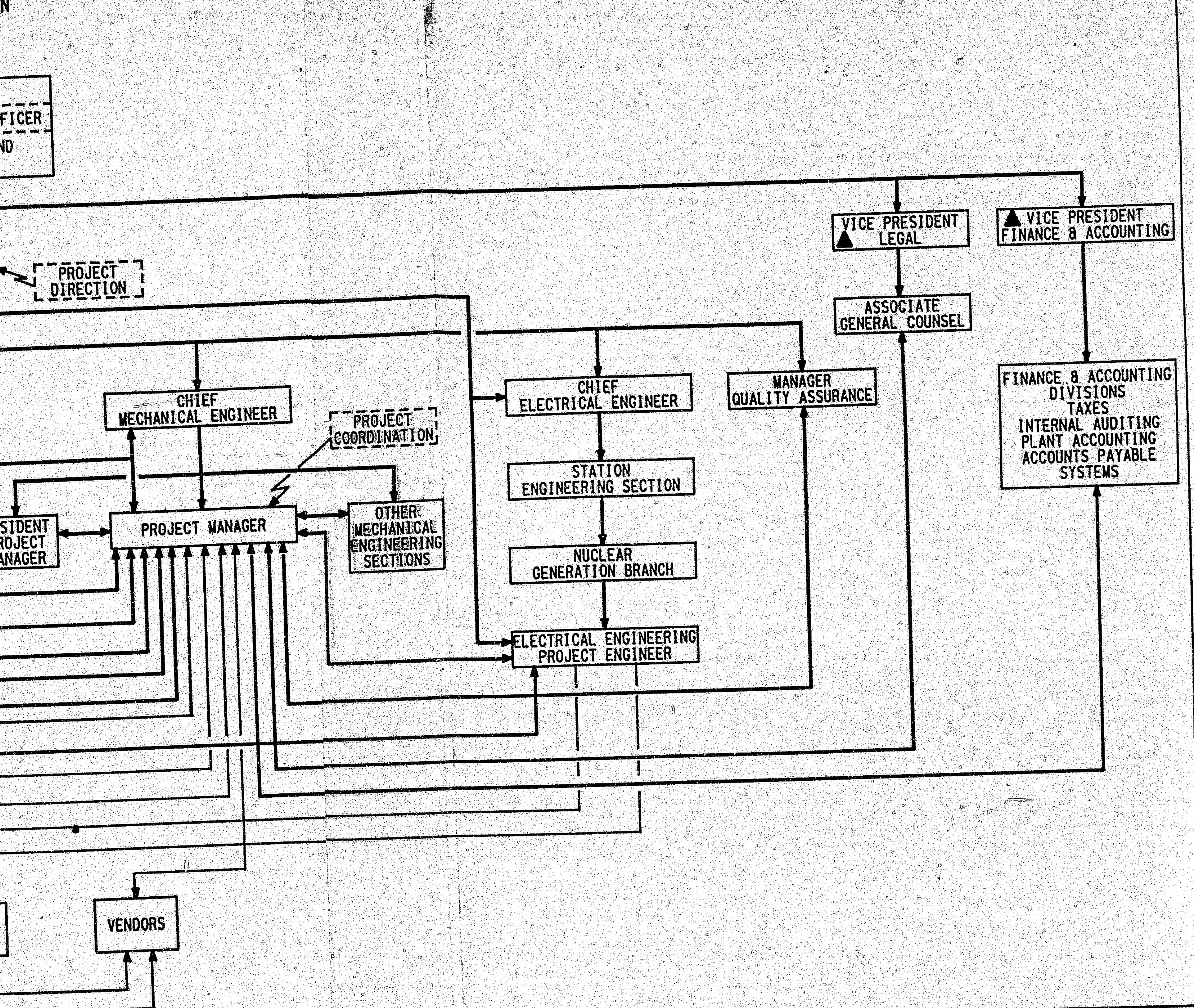
SUPERINTENDENT NUCLEAR POWER
STATION SUPERINTENDENT
SR. VICE PRESIDENT NUCLEAR POWER
OTHER ENGINEERING & RESEARCH DIVISIONS SYSTEM PLANNING ENGINEERING DESIGN RESEARCH & TESTING
VICE PRESIDENT ENGINEERING & RESEARCH
CONSTRUCTION SUPERINTENDENT
SUPERINTENDENT MECHANICAL
PROJECT MANAGER CONSTRUCTION
BECHTEL SITE
BECHTEL HOME OFFICE
GENERAL ELECTRIC
ORGANIZATION
INTERNAL COMMUNICATION
EXTERNAL COMMUNICATION
● REPORTS TO THE EXECUTIVE VICE-PRESIDENT AND CHIEF OPERATING OFFICER
▲ REPORTS TO THE PRESIDENT AND CHIEF EXECUTIVE OFFICER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FICER
ND
PROJECT DIRECTION
VICE PRESIDENT LEGAL
VICE PRESIDENT FINANCE & ACCOUNTING
ASSOCIATE GENERAL COUNSEL
CHIEF MECHANICAL ENGINEER
PROJECT COORDINATION
CHIEF ELECTRICAL ENGINEER
MANAGER QUALITY ASSURANCE
FINANCE & ACCOUNTING DIVISIONS
TAXES
INTERNAL AUDITING
PLANT ACCOUNTING
ACCOUNTS PAYABLE
SYSTEMS
STATION ENGINEERING SECTION
SIDENT
ROJECT
ANAGER
PROJECT MANAGER
OTHER MECHANICAL ENGINEERING SECTIONS
NUCLEAR GENERATION BRANCH
ELECTRICAL ENGINEERING PROJECT ENGINEER
VENDORS

Bechtel Documents Reviewed By PECO Engineering Personnel Under Design Review Program

1. Basic Design Drawings (But Not Construction)
2. Specifications
3. Procedures
4. Material Requirements
5. Selection of Subcontractors and Vendors
6. On-Site Administrative Controls
7. Material Controls
8. Examination Procedures
9. Inspection Plans
10. Design Calculations

Major Equipment Procurement
Administered Directly By PECO

I. Electrical Equipment

A. Transformers, Main Unit, 22-500 kV and 22-230 kV and associated lightning arresters

B. Transformers, Start-up, and associated lightning arresters

C. Transformers, Unit Auxiliary

D. Transformers, Safeguard and Plant Services

E. Switchgear, 4kV and above

F. Cable, 600 volt and above

G. Generator Isolated Phase Bus

H. Generator Surge Protection Equipment

I. Disconnect Switches, 230 and 500 kV

II. Mechanical Equipment

A. Air Compressors

B. Auxiliary Boilers

C. Condensers and Air Ejectors

D. Condenser Tubes

E. Diesel-Generators

F. Feedwater Heaters

G. Nuclear Steam Supply System and Auxiliaries

H. Pumps - Circulating Water, Condensate, Reactor Feed and Service Water.

I. Traveling Screens

J. Turbine-Generator and Auxiliaries

K. Turbine, Reactor Feed Pumps

L. Water Treatment - Make-up and Condensate Polishing

Increases In Quality Assurance/Quality Control Field Staffing Levels

Year	PECO QA	BECHTEL QA	BECHTEL QC
1975	5	5	
1976	5	5	66
1977	5	5	66
1989	6	6	67
1980	6	6	72
1981	7	8	117
1982	11	8	150
1983	16	9	210
1984	26 peak	15	265 peak

NRC Site Inspections of Limerick Generating Station

Year	No. of Inspections
1970	2
1971	3
1972	0
1973	5
1974	8
1975	13
1976	13
1977	15
1978	12
1979	15
1980	21
1981	17
1982	16
1983	23
1984	74
1985 (As of 7/15/85)	27
	264

Limerick Generating Station
Unit 1 & Common
Cost Reconciliation Summary

		($1,000s)
Original PECO Capital Authorization Value (Unit 1 & Common)		$344,100
Regulatory and Other Externally - Imposed Changes		
- TMI-2	$ 57,500	
- Plant Staffing, Startup and Training	181,600	
- Seismicity	119,600	
- Mark II	136,100	
- Fire Protection & Electrical Separation	65,800	
- Equipment Qualification	38,600	
- Anticipated Transients Without Scram	20,900	
- ALARA & OSHA	39,600	
- ASME Code Requirements	20,900	
- Security Requirements	43,500	
- IGSCC	10,200	
- Licensing Costs	62,900	
- Miscellaneous Other NRC Regulations	116,300	
- Non-NRC Requirements	63,800	
- Schedule Delays Due to Licensing Delays and Other Factors	385,100	
		1,362,400
Design Changes to Facilitate Operability and Reliability		111,900
Estimate Refinements and Other Causes		208,600
Unanticipated Escalation		322,100
Subtotal		$2,349,100
AFUDC		1,426,200
Overheads		5,800
Taxes (PURTA)		30,500
Contingency		7,500
RECONCILIATION TOTAL		$3,819,100

PECO STATEMENT NO. 7

Jat 12-18-85
Lbq

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SECRETARY'S OFFICE
Public Utility Commission

PENNSYLVANIA PUBLIC UTILITY
COMMISSION v. PHILADELPHIA ELECTRIC
COMPANY, Docket No. R-850152

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DIRECT TESTIMONY OF
CHARLES K. SOPPET

LIMERICK 1 AND COMMON PLANT
PROJECT ORGANIZATION, EXPERIENCE AND
PROCEDURES OF BECHTEL POWER CORPORATION;
EFFECTS OF NRC CHANGING DESIGN AND QUALITY
ASSURANCE REQUIREMENTS

September 27, 1985

TESTIMONY OF CHARLES K. SOPPET

Q. Please state your name and business address.

A. My name is Charles K. Soppet and my business address is 50 Beale Street, San Francisco, California, 94105.

Q. By whom and in what capacity are you employed?

A. I am employed by the Bechtel Power Corporation ("Bechtel") as a Project Manager, and am currently serving as Project Manager for the design and construction of the Limerick Generating Station in Limerick, Pennsylvania.

Q. Please describe your educational background and business experience.

A. These are set forth in detail in my curriculum vitae which is attached to this testimony as Schedule 1. The highlights of my professional career are as follows.

I graduated from the Michigan State University with a Bachelor of Science degree in mechanical engineering in 1950 and since that time I have been continuously employed in the nuclear energy field. Upon graduation, I joined the Argonne National Laboratory, a national center for nuclear research and development, where I was responsible for the design, fabrication and installation of nuclear reactor components, fuel and fuel handling equipment.

In 1958, I accepted a position with the General Nuclear Engineering Corporation to manage the design and construction of nuclear research reactors and experimental power station reactors. In this capacity, I was responsible for directing the design of systems, and managing all construction performed by subcontractors and fabrication of vendor-supplied equipment. My duties with General Nuclear were similar to my current responsibilities as Project Manager of Limerick, although the experimental projects were of a smaller scale.

In 1962, I joined the Aerojet General Corporation where I was involved in the "NERVA" project, a joint Atomic Energy Commission and National Aeronautic and Space Administration project, aimed at developing rocket vehicles powered by nuclear engines. At Aerojet, I initially served as Nuclear Operations Department Design Manager, and I managed the nuclear reactor design and reactor test program. Thereafter, I was appointed Manager of Engine Test Operations with responsibility for the engine test facility construction, operational modifications of that facility including any needed redesign, and the conduct of all test operations. I held this position until 1970 when I joined Bechtel as Project Manager.

As Project Manager at Bechtel, I was initially assigned responsibility for the design and construction of Limerick Generating Station Units 1 and 2, and I have retained responsibility for this project since that time. In addition, in 1973, I was appointed Senior Project Manager responsible for all PECO work performed by Bechtel in the nuclear energy field.

Q. Do you belong to any professional organizations or hold any professional registrations?

A. Yes, I am a member of the American Nuclear Society where I serve as Chairman of the Standards Committee, as Power Division Secretary and as an Executive Committee member. I am also a registered professional engineer in both nuclear engineering and quality assurance in the state of California.

Q. What is the purpose of your testimony?

A. The purpose of my testimony is to describe the management organization employed by Bechtel at the Limerick project and the management tools and processes implemented to monitor and control construction quality and project cost and schedule. In addition, I will briefly describe and illustrate the effects of NRC requirement changes and quality assurance requirements upon the project.

Q. Please describe Bechtel Power Corporation.

A. Bechtel Power Corporation, a subsidiary of the Bechtel Group Inc., is a leading company in the worldwide construction of power generating stations, including nuclear, fossil fuel and geothermal power plants, ancillary electrical transmission equipment and distribution facilities. Bechtel Power Corporation employs over 6,800 full-time employees in permanent offices in six states of the United States as well as Brazil, Spain, Indonesia, Saudi Arabia, England, Kuwait, Australia, Japan, Mexico, Canada and France. Bechtel's experience in the power industry includes management and performance of engineering and/or construction services for over 300 non-nuclear and 150 nuclear power plants. Of the latter, over 80 have been completed.

Bechtel has engineered and constructed fossil-fueled plants ranging in capacity from 8 to 800 mw, including the first computer-controlled turbine roll of a power plant and the first 1,500 ton per hour automatic coal handling system. In the nuclear generation of power, Bechtel pioneered the application of nuclear energy for the generation of electrical power with the construction, in 1949, of an experimental breeder reactor and the first nuclear reactor from which useful electrical power was produced. In addition, Bechtel constructed Dresden I, the first large-scale commercial nuclear plant in the United States, and San Onofre, one of the largest nuclear power generating stations in the United States today. We are also continuing work in the development of advanced fast breeder and fusion technologies.

Q. Please describe your position as Project Manager for Limerick.

A. As Project Manager, I have had and continue to have broad oversight responsibilities for managing, coordinating and administering the project from the conceptual stage through planning, engineering, procurement, contracting, construction, startup and closeout. I discharge these responsibilities subject to the overall direction and control of both my own management and of the Philadelphia Electric Company, our client. I supervised the preparation of project plans, budgets and schedules for submission to Philadelphia Electric personnel for review and approval. Moreover, I monitored project progress and took action to maintain schedules and obtain appropriate staffing to perform the work on budget and within schedule where possible.

Q. Please describe the project organization employed by Bechtel at Limerick.

A. The Bechtel project organization was divided generally into six discrete functional areas: Quality Assurance, Engineering, Construction, Technical Services, Administration and Procurement. Bechtel maintained an organization at both its home office in San Francisco and on-site to attain the objectives of cost effective quality design and construction. At the peak of the project's activity, Bechtel employed approximately 2,800 permanent engineering, clerical and supervisory personnel, with approximately 800 located in San Francisco and 2,000 on-site who were devoted full-time to both units of the Limerick Project. In addition, Bechtel employed slightly in excess of 2,600 manual craft workers on-site during the peak period.

The Bechtel home office Limerick project organization consisted of five functional groups: Engineering, Technical Services (Cost and Scheduling), Administration, Procurement and Quality Assurance ("QA"). The Project

Engineering group, which was organized into six areas of responsibility, including management, civil/architectural, mechanical, plant design, quality engineering and electrical/control systems, was responsible for the Limerick design and any needed engineering support of construction functions. The Technical Services group was responsible for planning, scheduling and cost estimating. This group, with input from each Bechtel project functional area, was also responsible for the preparation of project Forecasts and trends. The Administration group maintained all Limerick records and correspondence, and the Procurement group was responsible for bidding, purchasing and subcontracting. The Limerick Quality Assurance (QA) group, located in both the home office and on-site but functionally separated from the rest of the Bechtel Limerick organization, performed or monitored the performance of those functions necessary to comply with the NRC's QA regulatory requirements. Apart from these groups, there were approximately 75 additional off-project employees at the home office who, on a part-time basis, provided support services for the design and construction of Limerick.

The on-site Limerick organization was supervised by the Project Field Construction Manager, who had six functional groups reporting to him, including Field Engineering, Construction Superintendents, Services (including Contract Administration), Finance and Accounting, Field Procurement, and Cost and Scheduling. Field Engineering consisted of engineers whose design efforts directly supported construction at Limerick. The Construction Superintendents were in charge of labor relations and general craft labor supervision. The Cost and Scheduling group performed a service similar to that in the home office. Contract Administration managed subcontracts, while Finance and Accounting acted as a local financial agent. Field Procurement purchased field materials and managed the warehouse and stores. Finally, the Quality Control (QC) group was also located at the site but reported independently to the Bechtel Quality Control organization. This group was responsible for inspecting the safety-related systems at the plant.

Bechtel employed a matrix management organization which permitted each of the various project functional groups to receive technical direction and information, based on experience at other Bechtel projects, from the larger functional organizations within Bechtel, while receiving project direction with respect to budget, schedule and project objectives from my project operations organization. An organization chart which illustrates this matrix organization is set forth in Schedule 2.

Q. Please describe the project control system utilized at Limerick.

A. The project control system consisted of three parts: 1) a project plan communicated throughout the Bechtel and PECO project organizations, reflecting the planned scope, schedule and cost; 2) a monitoring system that measured progress and performance against an established baseline; and 3) a reporting system that identified deviations from the cost and schedule plan and provided analysis to facilitate decisions by the project team, as well as Bechtel and PECO management.

The project plan defined the technical scope of work and Bechtel's services and responsibilities. Based upon this technical and service scope of work, an estimate and schedule were developed which formed the basis for the project budgets. The monitoring and reporting of progress and performance were achieved through an integrated system of computerized and manual cost and schedule programs. Schedule 3 graphically displays the primary components of this cost and schedule control system.

Q. Would you please describe some of the more important cost and schedule control programs shown on Schedule 3.

A. Yes. The following description sets forth those control tools and systems which were the most significant to Bechtel's activities in controlling cost and schedule at Limerick.

Estimate and Milestone Summary Schedule

Estimates of the technical scope and services to be performed were prepared and budgeted in the framework of the approved project code of accounts. The code of accounts categorized and identified all labor, materials and services for the project.

The milestone summary schedule reflected the project plan in terms of significant schedule dates and established the master schedule for the total project. The more detailed intermediate engineering and construction schedules were developed within the constraints imposed by this schedule. The milestone summary schedule was intended to give a complete yet simple picture of the overall project schedule. It was used to status progress in a summary fashion for both Bechtel and PECO senior management.

Project Forecasts

Project forecasting was a technique used to systematically re-evaluate the project plan to avoid cost and schedule surprises, allow replanning of project activities and provide a basis for continuous project control. Forecasting consisted of the identification of actual "to date" costs and a comprehensive evaluation of project "to-go" costs at a detailed level for quantities of bulk materials, items of equipment, engineering, craft and field non-manual manhours, and a re-evaluation of the schedule in light of any changes in these variables. The forecasted costs of Limerick were divided into six basic categories: 1) engineering and other home office costs, 2) material and subcontract costs, 3) field installation costs, 4) PECO costs, 5) allowance for funds used during construction ("AFUDC"), and 6) overhead and tax costs. Taken together, these components determined the total cost of the project.

Estimates of engineering and other home office costs were obtained from a knowledge of the status of engineering design, necessary engineering support to construction activities, and other home office costs. These estimates were based upon Limerick experience to date and Bechtel's experience with similar projects.

Material quantities were estimated by reviewing project drawings. These estimates included quantities of pipe, conduit, concrete, reinforcing steel, structural steel, pumps, valves, wire, electrical switchgear, and other materials which had to be installed. Subcontract costs were derived from a review of the specifications controlling the work scope, and our current experience with the costs of similar work at Limerick and at other Bechtel projects. A comparison with other projects was especially necessary during the early stages of the project, because firm "project-unique" costs and experience were not yet available. This comparison with other projects continued throughout the life of the project, but diminished in importance as more Limerick-specific information, developed from on-going project experience, was compiled.

Similarly, field manual and non-manual construction costs were estimated from the quantities of material to be installed and the time required for installation, and were based in part on experience at other projects, our Limerick experience and our knowledge of labor conditions at the site. Projections of wage rates in the local construction area over the life of the project were applied to the estimates of construction hours to determine the field construction costs. These costs were added to the home office costs and material quantity costs (which were also adjusted for escalation over the life of the project) to derive Bechtel's "direct" costs. PECO costs, AFUDC, overhead and taxes were developed by PECO and added to Bechtel costs to obtain the total project cost forecast.

Trend Program

An integral part of the project control system was the trend program which provided a mechanism for identifying changes in the scope of services to be provided (i.e. changes in design, material quantities, labor productivity, etc.) and the project schedule. The key activities of the trend program included establishing an initial control budget immediately after award of the Limerick contract, holding regularly scheduled project team trend meetings to discuss potential or actual deviations from the plan, documenting all potential or actual deviations through the participation of all project entities, and providing a periodic summary report of all trends. These activities enabled the project team to avoid cost and schedule surprises and minimize plant cost through a continuous review of the project's evolution and its causes. The trend program also continuously analyzed, reported and reviewed project status through the various control systems as design, procurement and construction progressed. Any significant deviation from the established budget was considered a trend and a rough estimate of the cost and schedule impact was determined, as well as any indicated corrective action to eliminate or minimize this impact.

Limerick Resource Management System

One of the most important components of our project control system was the Limerick Resource Management System ("LRMS"), a computerized system originally developed in the early 1970's and modified throughout the project to reflect changing project needs and technological advances. This system or data base utilizing those home office and field based computers identified discrete work activities (e.g. concrete placements, cable tray runs, etc.) and components (e.g. pumps, valves, equipment, etc.) by individual identifiers or tag numbers, and tracked the status of all necessary design, procurement, installation, and inspection activities associated with each individual activity or component. For example, data associated with a specific pump such as drawing number, purchase order number, installation status, area/elevation and startup system were available within LRMS by tag number. By simply querying LRMS, numerous status reports were generated on a regular basis for use by the various project groups. This system provided the primary source of project data used by all Bechtel and PECO management groups to develop forecasts and monitor and report the status of cost and schedule performance.

Quantity Tracking

Quantities were the "leading indicators" of the project's status. Quantity tracking was an integral part of the LRMS and was initiated when engineering design parameters were established. This aspect of the system was utilized to identify and quantify equipment and material needs and the progress of their installation, based on data obtained from the LRMS. The quantity estimates and takeoffs were the basis for the project reporting and control system.

Permanent plant equipment and uniquely identified bulk materials, such as pipe spools and reinforcing steel, were taken off drawings and tracked from project inception through design, procurement, receipt at the construction site and installation. Estimates of bulk quantities were initially developed in Bechtel's home office based upon historical information, from similar plants or systems, and replaced with actual quantities as the design, procurement and construction progressed. This "offsetting" of estimated quantities with actuals permitted a continuous review of the project's total scope, not just that designed at the time of the review. The major material items tracked were concrete bulks, mechanical equipment, piping, valves, pipe hangers, instruments, electrical equipment and electrical bulks.

Bulk commodities were the thread that tied the cost and schedule reporting systems together to provide the basis for progress measurement. Each entity of the project team i.e. Engineering, Procurement, Construction, Startup, etc., required that information be oriented in the manner in which its work was performed. For example, Startup was oriented by startup system, Construction by facility and module, Procurement by specification/purchase order, and Engineering by system and facility.

Engineering Budget and Schedule Control

Limerick's engineering control program provided the project team with specification/drawing status and engineering task information used to develop and update engineering schedules to support construction schedule requirements and to identify internal design restraints. All specification, task, and engineering drawing schedule release dates were derived from the engineering and construction schedules. Thus, engineering schedules were directly tied to the construction schedules and were responsive to construction/startup needs for materials, procedures, drawings and specifications.

As in the case of construction material and equipment, the number of specifications and drawings to be developed was estimated at the time of project award, using data from similar plants. This early identification of specifications, tasks, or drawings allowed engineering group supervisors to establish priorities within their groups. The use of standard numbering designations facilitated the early identification of specifications and drawings. The project team used the output from the various engineering control system reports to status the engineering schedule. The use of established control points for each type of drawing and specification enabled the team to accurately determine (using earned value techniques) the progress and performance of each engineering activity and identify deviations from the established plan in the cost and schedule trend program.

Procurement Controls

The procurement group initially utilized "heckle sheets" to track and control procurement and subcontract information. During the project's latter stages, these "heckle sheets" were superseded by the Procurement Status Report ("PSR") or "buck sheet" which gave an expanded picture of the procurement/engineering interface.

The heckle sheet and later buck sheets were issued monthly and were used by supervisors to monitor in detail the various processes required to purchase major equipment, including significant project/vendor milestones and completion data for each procurement package. After purchase orders were placed, fabrication and delivery status was reported on "buck sheets."

Field Cost/Schedule Control System

The Limerick field cost/schedule control system revolved around three main elements: 1) the project forecasts, 2) the LRMS data bases and 3) the Monthly Project Status Review Meeting. Each of these in turn had many interrelated sub-elements which combined to form an integrated project control system.

Each forecast contained key base-line data against which construction was managed. These data included the cost projection for each code account including craft hour estimates for the labor accounts. The basis for the cost projections was also provided and included a detailed listing of all bulk commodities and estimates of material pricing and wage rates. Along with the cost data, each forecast contained a summary level schedule describing key dates and installation rate targets for bulk commodity installations. Both the cost projections and schedule were used to develop forecasted cash flows.

The second main element of the control system was the LRMS. Early in the project and partially as a result of experience gained at the Peach Bottom plant, the LRMS was set up to identify and track all material used in constructing the plant. This system contained a series of computer files or data bases that provided a listing of each item of material along with important reference information (i.e. plant location, system designation, cost code, etc.) and current status (i.e. designed, fabricated, installed, etc.). The creation and maintenance of these data established the need for an organization to catalogue and manage all the information and a system to monitor and provide the status on each item as it progressed through the various steps from design to testing.

An organization was set up within project Technical Services in the home office and the Cost and Scheduling group in the field to maintain the accuracy of the files by reviewing revisions to project documents and changing the computer files as needed. A card system, utilizing a field engineer's "sign off" following inspection indicating completion of installation, was used to monitor completion status. As a result, the data base files contained the latest information from drawing inception through construction completion and generated reports displaying current status information at varying levels of detail and summarization up to and including total plant scope. This information was then used to measure schedule progress, control cost and provide forecast information.

The third main element of the field cost/schedule control system was the Monthly Project Status Review Meeting, and additional related meetings. At these meetings project progress was discussed and difficulties were resolved.

Q. Were there any other management tools used to control field activities?

A. Yes. A number of additional cost/schedule control tools were used to manage specific areas of the project from time to time. A brief description of each of the key scheduling tools that were employed during project construction are listed below:

1. The Management Scheduling and Control System ("MSCS") was a 3000 to 4000 activity computerized critical path model ("CPM") schedule used for long-range planning. MSCS provided the overall construction schedule logic for both critical path and non-critical path activities, early and late start dates, and activity float. This schedule provided the basis for the 12-month construction schedule described below.

2. The Intermediate Construction Schedule ("ICS") replaced the MSCS in 1978. This schedule consisted of 1500 activities organized by facility/elevation and displayed scheduled construction of major commodities. Starting in mid-1982,

commodities were grouped by startup system to facilitate the scheduling of completed system turnover to the startup organization. The ICS was similar in function to the MSCS but with the added ability to compare "earned" to "actual" manhours expended.

3. The construction 12-Month Schedule was a rolling schedule which provided detailed construction logic for the next 12-month period and was updated on a quarterly basis. At each update, the schedule was reviewed and approved by all affected project entities. This schedule was organized by facility/elevation with quantity and duration data shown for all commodities. In mid-1981, commodities were grouped by startup system and provided the basis for manpower histograms and commodity installation curves.

4. Commodity curves for installation of bulk commodities were also used to show scheduled and actual cumulative monthly installation rates.

Several types of construction detail schedules were also prepared. The 3-week rolling schedule, which was updated weekly, contained detailed planning of work activities for a 3-week period and was used primarily during the bulk commodity installation phase of the project. Work operations were scheduled by craft and components to be worked were identified by spool, valve, equipment/instrument number, etc. This schedule was used by superintendents for coordinating activities between crafts and as notification to field engineering to provide required construction support.

Special topic logic schedules were prepared for various items, such as facility/elevation completion, subcontracts, etc., which required more detailed planning than the 12-month schedule. These schedules generally covered durations of one month to two years and were updated as required. For example, a number of special schedules were prepared to facilitate planning of system completion and turnover to the startup organization. Facility and system turnover schedules were prepared and organized by system and facility to show interdiscipline logic and the pacing activities required to complete either or both systems and facilities for turnover. The intermediate startup schedule utilized both a bar chart and computer schedule to detail the individual milestones to be accomplished. The milestones included acceptance of each system by the startup group, preparation and acceptance of startup test procedures, completion of preoperational and acceptance tests, and review and approval of test results packages. Individual detailed schedules were also prepared for each preoperational test describing prerequisites, restraints and test logic. In addition, detailed special schedules were prepared for all major startup tests or plant operations which required coordination of activities between startup, construction and/or engineering activities. Examples include code hydrostatic testing, integrated leak rate testing, loss of air testing, and operational hydrostatic testing.

To manage field costs, a number of additional control tools were used. The Weekly Labor Cost Report ("WLCR") was a device used to monitor and control the expenditure of manual craft hours. Craft hours were collected daily through the field labor distribution system. On a weekly basis the hours were grouped by cost code and fed into the Forecast and Control Updating System ("FOCUS"). This program produced a series of productivity reports which compared the manhours expended, quantities installed, and the hours spent per unit of installation, to the original budget and the latest forecast. The reports were generated in cost code sequence and the cost code structure was set so that accounts were grouped to match the project organization structure. This system also produced a series of performance, trend projection, and percent complete calculations and reports. A weekly reporting cycle was observed and included a review of problem areas and assignment of corrective actions by site management to the implementing site organizations. As a result of this review cycle, trends or revised craft hour projections for specific accounts were included in the project trend program.

The control of subcontract costs used an approach similar to that used to control manual craft hours. In addition to a "FOCUS" approach, each subcontract was reviewed for changes as part of the normal trending and forecasting process.

Nonmanual labor was not as directly related to the production measurement goals as was manual labor and, therefore, the cost control approach for these manhours was somewhat different. Each department prepared time oriented bar charts (i.e. "work plans") which displayed the tasks to be performed and the required staffing levels to achieve them. The actual manpower levels were monitored against these plans and deviations were identified and corrective action taken through the monthly meeting reporting process.

Finally, material costs were collected by cost code and controlled through the cost and commitment program. This program formed a part of the forecasting process and established a "forecast" or "budget" value for each account. Actual dollars committed and spent were collected on a monthly basis for each account and were compared to both the total forecast and cash flow forecast for each account. Deviations from either comparison were investigated as part of the monthly reporting and trending cycle and reported to management via the trend program.

Q. Mr. Soppet, please now explain how the implementation of NRC required design changes concurrent with plant construction affects cost and schedule?

A. In an ideal engineering and construction sequence, the design information needed for construction is provided early in the project. An ideal sequence permits construction to continue in a straightforward fashion unhampered by missing information or materials. Engineering performed over the last several years of the project following this ideal sequence consists of field support, as-built verification, and support of startup activities. The implementation of new design late in the project disrupts this ideal sequence and thereby adversely effects project cost and schedule.

The adverse effect on project cost and schedule is due to a variety of factors. Any change to a portion of a system requires that the performance of the entire system be re-evaluated, which may necessitate additional changes to other parts of the existing system. The addition of new systems, or changes to existing systems, late in the project frequently occurs in areas already congested with other systems and components. In these cases, the modifications typically impact the other systems and components in the area, requiring relocation of existing equipment and rework of existing piping, hangers, valves, conduits, etc. Because of the need to design around existing systems, pipe routing, cable routing, etc., design of the required new system cannot be achieved as efficiently as otherwise would be the case, which results in increased commodity levels and delay. In addition, new core bores through existing walls are frequently required. Electrical changes often necessitate modification of control room panels, which are highly congested. Changes to these panels typically necessitate rewiring of existing circuits to provide room for the added instrumentation and associated circuits. The time required for installation of items such as electrical tray, conduit, and cable is increased due to interferences and congestion in work areas, and the changes frequently disrupt startup activities, resulting in delays in the test program.

The implementation of the new requirements resulting from the Anticipated Transients Without Scram (ATWS) issue at Limerick 1 is an example of a regulatory-mandated design change that disrupted the ideal project sequence. An anticipated transient is an occurrence which is expected to occur once or more during the life of the reactor and to interrupt its normal operation. For some transients it is important that the control rods be rapidly inserted into the reactor core (a reactor scram) to shut down the chain reaction. If there is a potentially severe "anticipated transient" and the reactor shutdown system does not "scram" as desired, then an "anticipated transient without scram," or ATWS, has occurred.

The ATWS design features at Limerick, adopted as a conceptual design change in late 1980 in response to then still on-going NRC rule-making procedures, are as follows:

1. Redundant Reactivity Control System (RRCS)

The redundant reactivity control system (RRCS) determines that a transient is underway and exceeds expected operating parameters. The RRCS uses transient detection sensors for high vessel dome pressure and low vessel water level and the actuation logic to initiate the ATWS mitigation actions (ARI, RPT, SLC injection, and feedwater runback) discussed below.

The RRCS consists of two completely redundant divisions. Each division is initiated automatically by the ATWS detection sensors, which are independent of the reactor protection system (RPS) sensors, or manually by switches that require the same type of operator actions as manual scram. Installation of the RRCS required mounting new level and pressure sensors on instrument racks, installing new instrument cabinets in the already congested auxiliary equipment room, routing cables to maintain adequate separation and control room panel modifications. Also, an uninterruptable power supply had to be added to the average power range monitors (APRM) to ensure complete independence from the RPS.

2. Alternate Rod Insertion (ARI)

The ARI is designed to provide a parallel path for actuation of the scram valves, which results in control rod insertion. ARI consists of the redundant valves on the scram valve pilot air headers that are actuated by the RRCS logic. The RRCS logic is designed so that successful ARI performance will avoid subsequent ATWS mitigation action (feedwater runback and SLCS initiation). Installation of the ARI required mounting new solenoid valves in existing air lines and routing cables between the auxiliary equipment room and the CRD control area.

3. Recirculation Pump Trip (RPT)

The recirculation pump motors are tripped by the RRCS logic. The purpose of the RPT is to reduce core flow and create core voids to decrease power generation, thus reducing the steam discharge to the suppression pool. Installation of the RPT required finding space for additional switchgear cabinets and routing power cables from the motor generator sets to the switchgear, and from the switchgear to the recirculation pump motors.

4. Feedwater Runback

Upon receipt of a high-pressure signal from the RRCS and after a specified time delay, if core power is not reduced as evidenced by the Average Power Range Monitors (APRMs) reading downscale, feedwater flow would be automatically limited by the RRCS, thereby reducing power and steam discharge to the suppression pool. The system provides for manual operation to be returned to the operator after a time delay to allow an increase in feedwater flow if needed. Installation of the feedwater runback required routing cable from the RRCS cabinets to the feedwater control cabinets.

5. Standby Liquid Control System

The standby liquid control system (SLCS) is automatically actuated by the RRCS or manually initiated by an operator in the main control room upon indication of a failure to scram and in accordance with plant operating procedures. The system is designed to inject sodium pentaborate solution through a core spray sparger. Major modifications of the SLCS system were required to ensure that each pump in the system was as independent as possible. A third SLCS pump was also added, requiring additional power and control cables.

6. HPCI Flow Split Modification

The HPCI system has been modified to incorporate two injection paths to the reactor vessel. About one-half of the flow goes into the core spray sparger, and the remaining portion is routed to the feedwater sparger. Also, as mentioned above, the SLCS flow is injected via the core spray sparger. The flow split modification maintains proper natural circulation flow mixing within the reactor core during an ATWS event.

Installation of the above systems also required the addition of a third standby liquid control pump, valves, major piping and supports, new power supplies, switchgear, control cabinets and instrumentation. It also required modifications to existing piping (i.e., adding a tee and modifying pipe hangers), power supplies and panels. Possible locations within the plant had to be evaluated to accommodate the additional equipment and piping. Modifications to existing systems were evaluated to identify the options for adding the new ATWS equipment with the least impact to existing systems while complying with design requirements. The effects of potential hazards such as pipe break, fire, radiation and missiles associated with the addition of the new systems and the modification of existing systems were assessed and documented. New foundations for the additional equipment were designed. Routing for the new piping and electrical raceway for both ATWS and existing systems which were affected by the inclusion of ATWS modifications was selected and the design for these commodities was finalized.

The addition of this new ATWS equipment and associated commodities required that the delivery of the new equipment and access to facilities for its installation be factored into construction planning with consequent construction impact. Installation of the new piping, valves, and hangers also resulted in rework to systems already installed in the affected areas. In addition, the installation of those commodities which occurred late in the construction sequence, such as electrical tray, conduit, cable and terminations, was also adversely impacted in these locations. Greater time was required for such installations due to interferences and congestion in work areas. Moreover, craft manpower had to be obtained and brought back to the project unexpectedly. Delays occurred in fabrication of needed equipment and commodities. In sum, engineering, procurement and construction to satisfy these late imposed regulatory requirements substantially and adversely affected Project cost and schedule, particularly because such activities had to be performed out of the normal construction sequence. This rendered their performance more time consuming and costly, and disrupted the performance of other scheduled activities during the period in which they had to be performed.

In addition to the specifics just discussed, there were peripheral effects associated with the backfit. Various documents had to be revised to identify the new ATWS system, including the Final Safety Analysis Report, drawings and calculations. Also, revisions had to be made to the plant training manuals and startup test and operating procedures, plant operators had to be retrained and testing of the new ATWS system was required.

The implementation of new regulatory requirements was not limited to ATWS. Many more regulatory-imposed modifications of similar complexity or scope occurred over the life of the project. As backfits overlapped each other, negative synergistic effects started to appear, especially with respect to common plant support systems such as power supplies, heating and ventilation systems and cooling water systems. These multiple overlapping backfits complicated the design process resulting in the redesign of some already installed primary plant systems and their support systems up to and through the startup phase. The consequent disruption of construction and startup activities as a result of implementing these many new requirements imposed upon Limerick had a serious detrimental impact upon both project cost and schedule.

Q. Please describe the effects of changing NRC quality assurance requirements upon the Limerick project.

A. Of the NRC requirements imposed during the Limerick construction period, the most significant in terms of cost and schedule was the nuclear QA program. The imposition of 10 CFR 50 Appendix B, the NRC Quality Assurance rule, in 1970, had a profound effect upon all aspects of the nuclear power industry. Appendix B set forth the criteria which had to be met if acceptable nuclear power plant quality was to be demonstrated. Written in general rather than specific terms, the rule has been subject to increasingly more stringent NRC interpretation since its adoption.

Limerick was committed to conform to Appendix B, both in its engineering and construction by PECO's executive management, as early as 1971. The project was not only a proponent of quality workmanship, but a leader in complying with regulatory QA mandates. The project consistently received the highest ratings given by NRC inspection and compliance personnel. In short, it is a high quality plant designed and built by people who placed quality at the top of the list. This, however, was not achieved without cost. The escalation of quality-related requirements can be illustrated by a comparison to the earlier and quite acceptable Peach Bottom Project.

At Peach Bottom, Quality Control (QC) was the responsibility of field engineering. Five persons were devoted exclusively to QC activities and reported to the project field engineer. After Appendix B was issued, a QC group was established as a separate Peach Bottom entity and was expanded to 55 personnel. Its scope of work was increased to include receipt inspection and subcontractor surveillance as well as responsibility for final installation inspections and product acceptance. The inspections at that time were based on past construction practice and individual judgment and used a minimum of inspection tools. In certain areas, only a simple review of paperwork was required for acceptance.

During the time span covered by the construction of Limerick, the number of QA/QC functions and the degree of involvement by QA/QC organizations, in all aspects of the project from initial engineering through final acceptance, greatly increased. This impact was most clearly seen in the number of engineers required to staff and to support the QA and QC functions, the development of extensive training and qualification programs, and the millions of documents which were collected to demonstrate quality.

In this regard, the QC department at Limerick peaked at 270, compared to the 55-man peak staffing at Peach Bottom Unit 2. The collection and verification of documentation on all nuclear quality related components and construction at Limerick, estimated at three and one quarter million documents, added a workload for all field nonmanual personnel unprecedented at earlier generation plants. The increased level of QA/QC activity also resulted in increased staffing levels in both the design engineering and field engineering functions. To this latter point, the Limerick field engineering forces of approximately 700 contributed 20% of their time to the performance of redundant pre-QC inspections to ensure timely completion of the work under the existing QA rules.

From a project engineering standpoint, there were more than 10 times the number of calculations at Limerick than at Peach Bottom. In addition, the process of specification preparation underwent periodic redefinition of acceptance standards for the fabrication and installation of components as the NRC acceptance criteria changed. For example, commercial grade specifications on piping or steel fabrication and installation would typically include a statement that excluded weld splatter and arc strikes as a basis for finding workmanship unacceptable. The equivalent nuclear quality related specifications went through several sequential engineering evaluations, each of which defined more precisely and quantitatively the amount of weld splatter and arc strikes that could be accepted under then-current NRC inspection rules. The thoroughness of the field inspection of installed components was also significantly strengthened in order to demonstrate that the increased or more precisely defined acceptance criteria had been achieved.

The actual construction process was impacted by the increasing QA/QC level of activity in several ways. The acceptance standards that were imposed exceeded those in all other types of construction and previous nuclear construction experience. This increased the number of field craft hours required to complete a work item to these new standards. Also, the evolving nature of the acceptance criteria resulted in the application of new standards to previously completed work with a consequent expenditure of craft and nonmanual hours to bring previously constructed work into compliance with the latest acceptable criteria. This also caused work to be performed in a less than optimal sequence.

In response to these problems, extensive training programs were set up for both craft and nonmanual personnel to instruct them in the standards and to help them develop needed additional skills. The inefficiencies that resulted from this moving quality target significantly impacted the project's ability to maintain a motivated workforce and to achieve projected levels of productivity.

Compliance with mandated changes to design rules in the name of increased safety produced additional complications. For example, more stringent seismic requirements necessitated increased quantities of reinforcing steel in Seismic Category I structures. This quantity increase resulted in more complex designs and installation procedures for Limerick and in more quality control and quality assurance to ensure that the constructed plant reflected the design. As a second example, in 1979, as a part of the project's response to IE Bulletin 79-14, as-built drawings and analyses had to be reverified to be in close agreement with very tight installation tolerances. These tight tolerances also required a significant increase in quality control.

Q. Does this conclude your testimony?

A. Yes, it does.

PERSONAL RESUME OF CHARLES K. SOPPET

PROFESSIONAL LICENSES AND SOCIETIES

ANS - Power Division Treasurer, Executive Committee and Program Committee, Ch. Standards Steering Committee
Registered Professional Engineer - State of California

EDUCATION AND PERSONAL DEVELOPMENT PROGRAMS

B.S.M.E. Michigan State University, Mechanical Engineering 1950
Various graduate studies

OTHER SIGNIFICANT INFORMATION

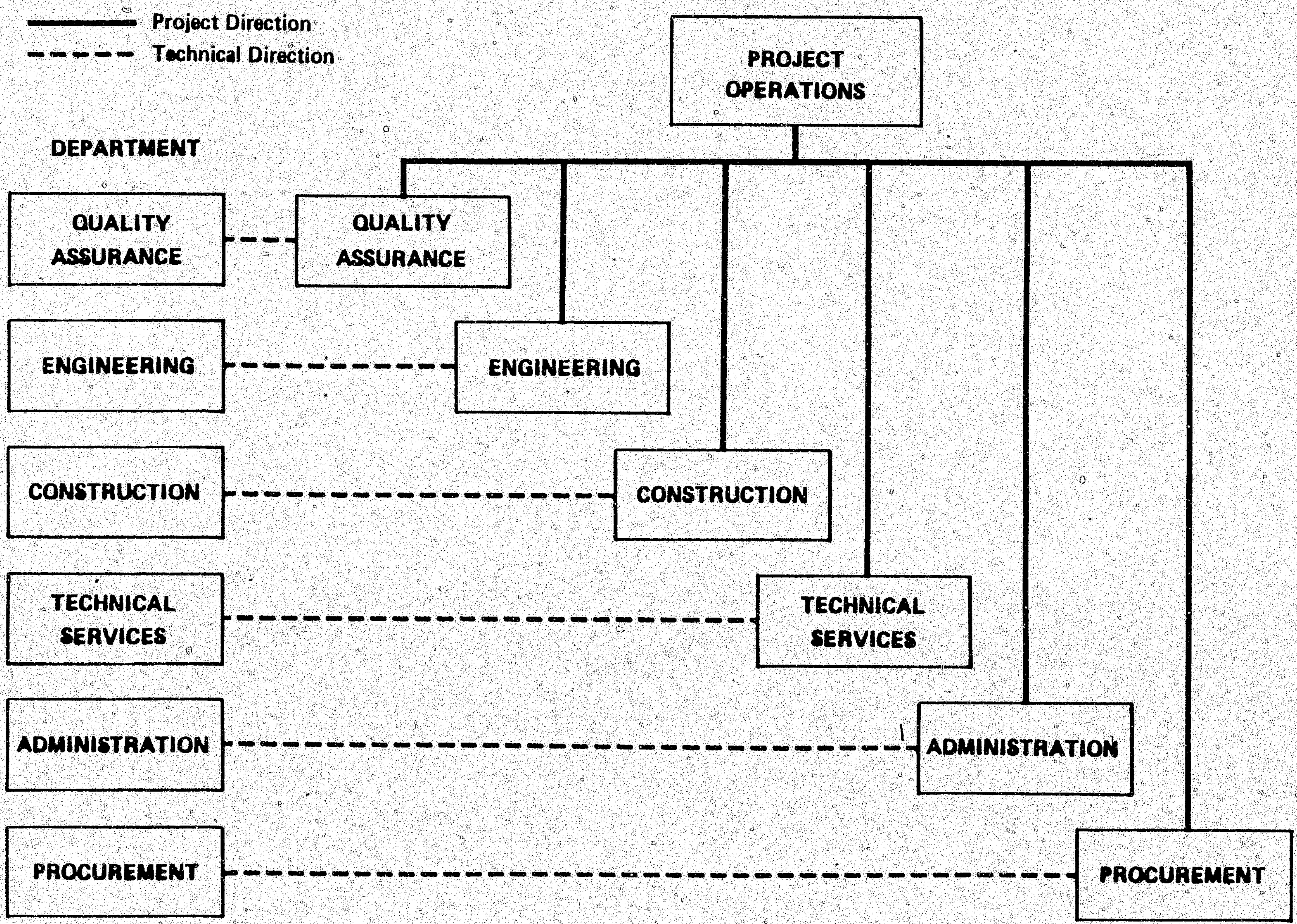
ACHIEVEMENTS: Three patents for nuclear fuel fabrication and design when with Argonne - assigned to Government; number of publications at Argonne and General Nuclear

WORK HISTORY

DATES FROM	DATES TO	COMPANY, DIVISION OR DEPARTMENT, LOCATION AND SUPERIOR	POSITION HELD, SUMMARY OF RESPONSIBILITIES AND SIGNIFICANT ACCOMPLISHMENTS
1950	1957	Argonne National Laboratory	Staff Engineer and Engineering Group Supervisor. Resp. for design and Fab. of reactor internals, control system & fuels
1957	1963	General Nuclear Engineering Corp.	Staff engineer and Project Manager - Directed and managed design and construction of nuclear research reactors and experimental central station nuclear power plants
1963	1970	Aerojet General	Manager Nuclear Operations Dept.; Manager Engine Test Operations; Mgr. New Product Development and Marketing. Directed and managed nuclear activities for both Aerospace and Civilian Commercial application.
3/70	5/70	Power & Industrial Bechtel Corp. - SF H.O. Reinsch	Project Manager
5/70	10/71	Bechtel Power Corp. S. F. Power Division San Francisco R. D. Allen F. A. Hollenbach	Project Manager - Limerick Project
10/71	8/84	Bechtel Power Corp. S.F. Power Division San Francisco, CA F. A. Hollenbach	Lead Project Manager - Peach Bottom and Limerick Projects
9/84	Present	Bechtel Power Corp. Western Power Division San Francisco, CA J. H. Battin	Same as above

LIMERICK GENERATING STATION
JOB 8031

PROJECT MATRIX ORGANIZATION



Schedule 2

LIMERICK COST & SCHEDULE CONTROL PROGRAM FLOW DIAGRAM