1/18/82

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of ARIZONA PUBLIC SERVICE COMPANY, ET AL. (Palo Verde Nuclear Generating Station, Units 1, 2 and 3)	))))))))	Docket Nos. STN 50-528 STN 50-529 STN 50-530

AFFIDAVIT OF LUCIAN E. VORDERBRUEGGEN

Lucian E. Vorderbrueggen, being duly sworn according to law, deposes and says:

1. I am the Senior Resident Inspector/Construction for the Palo Verde Nuclear Generating Station, Units 1, 2 and 3. I am responsible for verifying that the construction of safety related structures, systems and components for Palo Verde is in accordance with design requirements and regulations of the NRC. A statement of my professional qualifications is attached to this affidavit.

2. The Intervenor in this proceeding has made allegations regarding falsification of concrete slump tests performed for the basemat concrete of Units 1 and 2. While she has withdrawn her contention in this area, the Licensing Board's "Order Concerning Sua Sponte Issue" dated December 11, 1981 directed the Staff to discuss in an affidavit the slump tests and other concrete strength tests performed for the Palo Verde units and suggested that the affidavit submitted in response to

the Order address five specified items. These items are discussed below, following a summary of the basic characteristics of concrete.

3. Concrete is composed of sand, gravel, crushed rock, or other aggregates held together by a hardened paste of hydraulic cement and water. The thoroughly mixed ingredients, when properly proportioned, make a plastic mass which can be molded into a predetermined size and shape. The development of concrete strength is a function of the compounds of the cement reacting and combining with water to form a slowly developing cementitious crystalline structure which adheres to the intermixed sand and stone particles. Upon hydration of the cement by the water, concrete becomes stonelike in strength and hardness and has utility for many purposes.

4. The concrete ingredients must be scientifically selected and proportioned such that the necessary placeability, consistency, strength and durability for the particular application will be obtained. For a given set of materials (mix design) and conditions (ambient temperature and humidity, mixing time, curing adequacy, etc.), concrete strength is determined by the net quantity of water used per unit quantity of cement, that is, the water/cement ratio. The lower the W/C ratio, the greater the strength.

5. There are several characteristics of concrete which are important to an understanding of the acceptability or non-acceptability of a concrete placement. First, placeability or workability is that property of concrete which determines its capacity to be placed and consolidated properly into a homogeneous mass and to be finished without harmful segregation. Second, consistency, loosely defined, is the

wetness of the concrete mixture. It relates to the character of the mix with respect to its state of fluidity and embraces the entire range from the wettest to the driest possible mixtures. Third, slump is the term used to describe the physical relaxation, or settlement, of a given mass of freshly mixed (fluid) concrete when the container (mold) confining it is carefully removed.

6. In its December 11, 1981 Order, the Licensing Board requested that the Staff discuss the procedures effected in making slump tests and other tests which measure the strength and acceptability of concrete in general and in the structure of the basemat in particular.

7. At the Palo Verde plant, all concrete is manufactured by Champion, Inc. in accordance with Bethtel Power Corporation (Bechtel) Specification No. 13-CM-101, "Technical Specification for Furnishing and Delivering Concrete." This contract includes supplying all ingredients for the concrete. The concrete for the Containment basemats is specified to be Class D-2 with pozzolan,* Mix P-601-Y, developing a strength of 5000 psi after 91 days, and having a nominal slump of 3-inches at the location of the placement. Specification 13-CM-101 establishes a tolerance of ± ½ inch on the slump value.

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* Pozzolan is a siliceous, or siliceous and aluminous, material which chemically reacts, in finely divided form and in the presence of moisture, with calcium hydroxide at ordinary temperatures to form compounds which possess cementitious properties. It is added to a concrete mixture to reduce heat generation and permeability, and to increase workability. Fly ash is a typical pozzolan used in the manufacture of concrete.

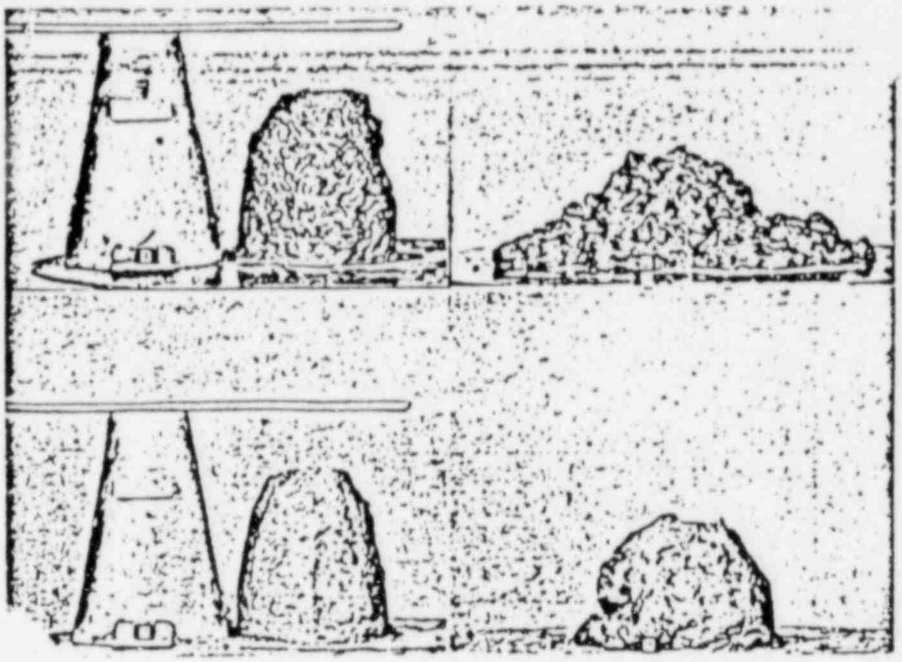
8. All concrete testing is performed by Engineers Testing Laboratories (ETL) in accordance with Bechtel Specification No. 13-CM-191, "Technical Specification For Testing Of Concrete Materials." For each class of concrete used in the containment building, this specification requires a slump test once for the first concrete batch placed each day, and once for each 50-cubic yards placed thereafter that day. The specified standard test method is ASTM C 143, "Standard Method of Test for Slump of Portland Cement Concrete."

9. Slump, as that term has previously been defined, is measured by filling a mold in the shape of a frustrum of a cone with the freshly mixed concrete. The cone is 12 inches high, base diameter 8 inches and top diameter 4 inches. When filled, the top is leveled off and the mold slowly and carefully lifted. The "slump" is the distance, in inches, that the mass settles as the mold is removed.

10. When the aggregates and cement content remain unchanged, the slump test gives a good measure of any changes in consistency. When the materials are being accurately measured, a change in the slump as the work proceeds indicates either a change in the grading of the aggregates, or a change in water or air content. The slump test under these conditions is a good basis for control and, obviously, an indicator of corresponding changes in workability. Similarly, an increased slump value might indicate an increase in water content, hence a larger W/C ratio and a resulting decrease in developed strength.

11. The figure below shows specimens from two different mixtures having the same slump. (Note the conical mold on the left.) In the two

views on the right, the specimens have been tapped with a tamping rod to demonstrate the relative workability of the concrete mixtures.



12. With regard to other tests which measure the strength and acceptability of concrete in general, Bechtel Specification 13-CM-101 required Champion, at the outset of the project, to demonstrate by ASTM testing methods that all ingredients going into the concrete would meet the many specified requirements. The specification further requires Champion to routinely perform those same tests periodically during the routine production of concrete. Then, using the materials selected from the aforementioned tests, ETL with the assistance of Bechtel concrete specialists and in conformance with Bechtel Specification 13-CM-191, designed the various concrete mixes that were to be used on the project.

The mix designs were established on the basis of trial batches to provide the following:

a. Conformance with concrete strength requirements,

b. Adequate workability and proper consistency to permit the concrete to be worked readily within the forms and around reinforcement, under the conditions of placement to be employed, without excessive segregation or bleeding.

13. The proportions of the ingredients which make up each design mix are carefully selected such that the consistency (slump) is of a value to enable satisfactory placement, that the desired content of entrained air is present to result in acceptable durability of the concrete, and that the water/cement ratio will result in the specified design strength. After the design mixes have been established, it is important that the measuring equipment at the batch plant is maintained in good condition and in calibration so that the intended proportioning of the ingredients is not violated. During concrete production, tests are performed by ETL for slump, air content, unit weight and temperature every 50-cubic yards of concrete produced, as a minimum, to verify proper proportioning of the ingredients. Slump and temperature measurements are also routinely made by ETL at the placement location, on the same batches tested at the batch plant, in order to monitor changes that occur in the concrete during transit. When compression test specimens are cast at the batch plant (every 100-cubic yards, 3-specimens, minimum) slump, air, unit weight and temperature are also measured. All test results are required to be recorded.

14. The most common and significant measure by which the quality if concrete is judged is its compressive strength. The principal factors governing concrete compressive strength are the characteristics and quantity of the cement, quantity of the mixing water, time of mixing, characteristics of the aggregates, amount of air entrained, age of the concrete, curing conditions, and conditions of the test. Specification 13-CM-191 requires ETL to mold and cure test specimens in accordance with ASTM C 31, "Standard Method of Making and Curing Concrete Compressive and Flexural Test Specimens in the Field." For the Containment Building concrete, the specification requires one set of three test specimens for each 100 cubic yards of concrete placed, or a minimum of one set of specimens per day for each class of concrete placed. Compressive strength is determined from test specimens molded into 6-inch diameter by 12-inches high cylinders made from samples taken at the point of discharge from the concrete mixer. After curing under carefully controlled conditions, the cylindrical specimens are crushed in a compression machine after aging for 7-, 28-, and 91-days, as specified by the American Society for Testing and Materials, Standard C39, entitled "Method of Test for Compressive Strength of Molded Concrete Cylinders." As stated above, the concrete must develop a strength capable of withstanding 5000 psi after 91 days. Compression test data for both Containment Building basemats is provided in the table below.

15. The building industry has established 28-days as the time criterion at which standard Portland Cement concrete must attain the specified design strength. Early strength development is delayed, however, when pozzolan is added to the concrete mixture, and the industry has

standardized on 91-days as the age criterion for attained design strength. The 7-day test is basically for early information as to how strength is developing and provides a level of confidence regarding the hardening concrete. Over many years, the building industry has accumulated considerable data comparing concrete age and developed strength. This data has demonstrated that, in 7-days, acceptable concrete reaches 65 to 75-percent of the 28-day design strength. Consequently, if a compression test specimen at an age of 7-days shows a strength of 65 to 75-percent of the specified design strength, the concrete it represents should be acceptable.

16. The ingredient proportions for two typical mix designs used at Palo Verde are shown for information purposes:

	Water (lbs)	Cement (lbs)	Pozzolan (lbs)	Sand (lbs)	Coarse Agg. (lbs)	Slump (in)	Design Strength (psi)
*Mix K-104-Y Class B-1	390	520	0	1209	1750	4	3000 @ 28-days
**Mix P-603-Y Class D-2	395	517	91	1139	1690	3	5000 @ 91-days

* - The water/cement ratio is 0.75.

** - The water/cement + pozzolan ratio is 0.65.

<u>Note</u> - The quantities shown are for each cubic yard of concrete.

17. The Board's second request was that the Staff discuss the interpretation of the various test results and the manner and importance in which they are meaningful as a criterion for conformance to design

specifications. While some of the information is provided above in response to the Board's first request, the following additional information is provided.

18. The majority of the tests required by 13-CM-101 and 13-CM 191 are directed to the concrete ingredients. They address such factors as chemical composition and fineness of cement; mixing water purity; purity of pozzolans, air entraining agents and water reducing agents, when used; and numerous properties of the sand and large aggregates (soundness, gradation, clay lumps, organic impurities, friable particles, specific gravity, water absorption, abraision resistance, alkali reactivity, petrography, etc.). These tests establish limits outside of which the desired strength and durability properties of the concrete structures intended by the design specification would not be obtained. Consequently, failure of a test renders that particular source, lot, shipment, batch, etc., unacceptable for use. The mix design tests are important because they establish the ingredient proportions which provide the proper consistency for satisfactory placement and the development of the intended strength. The batch plant bulk batching scale certifications and calibrations are obviously important in obtaining proper mix proportions. The required accuracy of the cement and pozzolan scales is 1% by weight; the aggregate scale accuracy is 2% by weight. Air content of the fluid concrete mixture must be within 2 to 5% by volume to obtain satisfactory workability and durability without sacrificing attained strength. Temperature of the mixed concrete is held as close as practical to 50-degrees F., using flaked ice as needed, in order to avoid the need for additional mixing water and the possible

compromise of strength. (High temperatures also increase the rate of concrete hardening and shorten the length of time within which the concrete can be handles and finished.) Air content and temperature are measured each time a concrete batch is sampled for slump and compression specimen casting.

19. Champion and ETL are subcontractors to Bechtel, the construction contractor at Palo Verde. In this capacity, Bechtel installed the containment basemats and had responsibility for acceptance of the concrete furnished by Champion and tested by ETL. The specification governing the basemat concrete placement was Bechtel Specification No. 13-CM-365, "Installation Specification for Forming, Placing, Finishing and Curing of Concrete." This specification allows for a slump "inadvertancy margin" of up to 1-inch above the specified maximum (3½ - inches) for an individual batch (9 - cubic yards). Thus, a slump value of 4½ - inches is acceptable for an individual 9-yard batch. This "inadvertancy margin" is only permitted to be applied, however, when all subsequent batches or the last 10-batches tested, whichever is fewer, do not exceed the maximum limit (3½-inches). The placement specification permits the use of concrete having a slump lower than the specified minimum provided such concrete is properly placed and consolidated in the forms. At Palo Verde, it is normal for the mixed concrete to lose (drop) 1-inch of slump between the batch plant and the point of transit truck discharge, and another 1-inch between the truck discharge and the point of placement when a concrete pump is used. For both basemats, concrete pumps were used; consequently, slump measurements at the batch plant, where they are normally made, of 5½-inches were acceptable. If the

"inadvertency margin" were applied, some batch plant slump measurements up to 6½-inches were permissible.

20. The slump measurement records for the basemats show that none were outside the specified limits. Also, the records show that the "inadvertency margin" was not used for either placement. Statistics for the two installations are listed in the table below.

21. Slump values are of little meaning or importance in regard to the adequacy and/or acceptability of a concrete structure. Structural adequacy is solely based on the strength values demonstrated by the compression testing of the cured specimens that were molded at the time the concrete was manufactured at the batch plant.

22. The Staff was also requested to discuss the results of typical measurements on and near the days the alleged infractions occurred, including the inaccuracies, precisions and uncertainties in the results. Although the Board requested the Intervenor to supply to the Staff the dates of the alleged infractions and relevant test reports, the Staff has not received this information. However, measurement of slump and compressive strength pertaining to the placement of the basemats for Containment Buildings 1 and 2 are given in the following tabulation. The values also are typical for other safety related concrete structures. As shown, each of the several hundred slump tests performed fell within the acceptable range.

Placement Statistics

	Unit 1	Unit 2
Placement Number and Date	1C012 - 6/28-29/77 1C013 - 7/7 - 8/77	1C012/13 - 5/24-26/78
Placement Time (continuous hours)	1C012 - 38¼ 1C013 - 19¼	52
Quantity of Concrete (cu. yds.)	1C012 - 4486 1C013 - 2606	7216
Design Mix (class)	D2 with Pozzolan	D2 with Pozzolan
Number of Slump Tests	1C012 - 156 1C013 - 88	248
* Slump Measurement Range (inches)	2 - 5½	2½ - 5½
Design Strength (at 91 days)	5000	5000
Number of Strength Tests (cylinders tested at 91 days)	1C012 - 100 1C013 - 58	160
**Strength Measurement Range (psi)	1C012 - 5020 to 5915 1C013 - 5100 to 6130	5750 to 7260

* - Lower slump number was measured at point of placement. Higher slump number was measured at the Batch Plant. The range indicated for Unit 1 applies to both placements.

** - Each value is the average of 2 cylinders molded from the same batch.

23. The precision of slump measurement is probably within ± ¼-inch as the value is read from a graduated ruler and the height of the slumped mass is "eyeballed" during the placement of the ruler. The precision of the strength measurements is approximately ± 50 psi since the compression test machine is calibrated with a precision load cell to ± 1% of full scale. The values should be reasonably accurate because the measurements are made by the same individuals using the one testing machine and identical procedures (ASTM C 39). There is very little uncertainty in

the test results because of the degree of supervision over the test personnel and the nature of the controls exercised over the taking of specimens, and the casting, handling, and curing of the compression test cylinders. It should be pointed out that nothing can be done to obtain a greater strength test result from a test specimen than is representative of the mix from which it is taken; improper handling, curing, capping or errant placement in the compression test machine will only result in test results that are lower than would otherwise be obtained.

24. The Staff has been requested to cite the industry standard (ASTM and/or other) method of testing and a description of the mode of calibration of the test equipment on which the accuracy is based. The pertinent ASTM testing standards have been cited previously. The various scales and other equipment used for batching the concrete and curing/testing compression test specimens are calibrated on a routine basis by an independent agency using equipment calibrated to NBS standards. Cones used for making slump measurements are not (cannot be) calibrated. They are only required to meet the dimension specified in the ASTM standard and be free of dents, gouges, etc. that might interfere with the slump measurement.

25. Finally, the Board requested the Staff to describe the quality assurance and quality control programs of the Joint Applicants, the architect engineer and contractor used in construction of the basemats.

26. Champion, the concrete manufacturer, assigns a quality control (QC) engineer to work closely with the batch plant operator. He verifies that the scales and other measuring equipment are in current calibration, materials are as specified and are being charged into the proper batching

bins, the operator has selected the proper quantities of the ingredients for input into the computer-controlled mixer as called for in the specified mix design, and assists the operator with any mix adjustments directed by Bechtel. Champion quality assurance (QA) personnel periodically audit the entire operation to verify that the program of controls is functioning in accordance with the contract commitments.

27. The QC activities of ETL are essentially under the direct supervision of Bethtel's QC Test Lab Coordinator. Prior to concrete batching for any placement, he establishes the testing program and the test frequency. He also verifies the qualifications of the ETL test technicians who perform the various tests. Bechtel QC inspectors are on continous duty at the batch plant and at the placement locations to assure that the specified measurements of concrete temperature, slump, air content and unit weight are properly and timely made, and that compression test specimens are properly cast and handled as specified. The ETL test technicians may also take and test samples of the concrete ingredients to independently verify that Champion's materials meet the requirements specified.

28. The Bechtel QC engineer at the batch plant verifies the concrete mix proportions for each batch and, after this verification, signs the batch delivery ticket which is automatically printed by the batching console. He indicates on the delivery ticket when a slump and temperature measurement is to be made at the point of placement for slump loss correlation information. He also is responsible to see that the ETL test technicians made the specified tests at the batch plant and at the proper frequency. As stated in the previous paragraph, Bechtel QC

inspectors are on duty at the point of placement to provide direction and surveillance of the ETL test technicians. Also, the Bechtel QC inspectors monitor the placement activities of the Bechtel personnel to assure that the requirements of the installation specification are satisfied. They have responsibility for issuing a Nonconformance Report (NCR) if any condition develops or occurs that does not conform to the requirements. The Bechtel Test Lab Coordinator is responsible to see that the compression test specimens are properly cured and compression tested by the ETL test technicians when the specified aging time has elapsed. At the time of the Units 1 and 2 containment basemat placements, Bechtel QA personnel performed essentially continuous audits of the batching, testing and placement activities to assure that the assigned individuals and organizations were following their respective procedures and satisfying the specified requirements.

29. Arizona Public Service Company, acting for the Joint Applicants, have overall responsibility for all aspects of the Palo Verde project. Their QA program exercises surveillance and audit of the activities of the various project participants in carrying out this responsibility. Their records show that they, in conjunction with Bechtel QA personnel, audited the QA programs of Champion and ETL to an appropriate degree prior to the Units 1 and 2 containment basemat placements, and no problems of any significance were identified during those audits. Also, at the time of the basemat placements, APS QA engineers devoted essentially continuous surveillance to the activities to Champion, ETL and Bechtel.

30. Given the extensive series of checks and balances inherent in these quality control programs, the falsification of slump tests and/or

test records is highly unlikely for two reasons. First, because of the large number of testing personnel involved in an around-the-clock operation, a collusion of large magnitude would have to be arranged. Second, the performance of the ETL testing personnel and their test results were continuously monitored by Bechtel engineers and quality control personnel throughout placement operations. Further, from a practical standpoint, regardless of whether the slump value is reported correctly or incorrectly, if the slump is too low, the mix will be too stiff. This would make placement and consolidation difficult, and the foreman or engineers would demand a wetter mix. Conversely, if the slump is too high, the mix will be too wet, segregation of the ingredients becomes probable, strength is possibly compromised, and the batch would be rejected by the Bechtel engineer or foreman.

31. In the final analysis, slump values are not important if the strength requirement discussed previously is met. This is the key point to remember. As set forth in the table of placement statistics in this affidavit, all of the concrete placements exceeded the 5000 psi 91-day requirement for each batch tested.

Lucian E. Vorderbrueggen

Subscribed and sworn to before me
this 18 day of January, 1982.

Notary Public

My commission expires: My Commission Expires May 28, 1982

STATEMENT OF PROFESSIONAL QUALIFICATIONS

Lucian E. Vorderbrueggen

My name is Lucian E. Vorderbrueggen. I am a Senior Reactor Inspector with the U.S. Nuclear Regulatory Commission, Reactor Construction and Engineering Support Branch, Office of Inspection and Enforcement, Region 5, Walnut Creek, California. The principal responsibility of this position is the inspection of nuclear power plants during the construction phase to ascertain the status of compliance with the approved plant design documents and with the rules and regulations of the Commission. My present assignment is Resident Inspector at the Palo Verde Nuclear Generating Station west of Phoenix, Arizona.

I was born in Proctor, West Virginia in 1924 and received my primary and secondary education in Moundsville and Wheeling, West Virginia.

From 1943 to 1946 I served in the U.S. Navy. Following commissioning in 1944, I served in the Executive Department at the U.S. Naval Academy for 6 months and later as an Engineering Officer aboard a light cruiser in the Pacific Theatre during World War II.

Following military service, I returned to the University of Louisville and graduated in 1947 with a Bachelor of Electrical Engineering degree.

From 1947 through 1948 I was employed by General Electric Company as a Test Engineer at their main plant in Schenectady, N. Y.

From 1948 to 1951, I worked for Weirton Steel Company in Weirton, W. Virginia, first as a Construction Electrician and later as an Electrical Draftsman/Designer.

From 1951 through 1956, I was employed by Columbia-Southern Chemical Company in Natrium, W. Virginia, beginning as an Electrical Designer and progressed to Electrical Engineer.

From 1957 through mid-1958, I worked for Hughes Aircraft Company in Culver City, California as an Electrical Facilities Engineer.

From mid-1958 to 1965, I worked for Atomics International in Canoga Park, California. My initial assignment was as a Senior Engineer in the Electrical Design Department designing the Emergency Power System for the Hallam Nuclear Power Plant. I was later assigned to the operations department at the Sodium Reactor Experiment where I functioned for 3 years as Shift Supervisor, and for 2 additional years in Operations Analysis and as Assistant Operations Supervisor.

From 1965 through 1969, I was employed by the United States Atomic Energy Commission as a Reactor Inspector with the Division of Compliance, Region III, Chicago Office. During that time my inspection assignments included Enrico Fermi I, Dresden I, Elk River and Plum Brook operating reactors, and the initial construction of the Donald C. Cook and Point Beach plants.

I joined Bechtel Corporation in January, 1970 as an Engineering Specialist in the Power and Industrial Division. My initial assignment was Supervisor of Quality Assurance for the Division. In that position, I assisted the Manager-Quality Assurance in the implementation and administration of the Division Quality Assurance Program on 12 nuclear power plant projects and in providing technical direction and administrative supervision over the Quality Assurance Group personnel. In April 1972, I was made Supervisor of Quality Engineering for the San Francisco Power Division. In this assignment I was responsible to the Division Manager of Engineering for the implementation of the quality assurance program in the Engineering Department. This included the preparation of Engineering Department Procedures for accomplishing quality related activities in the design process, providing administrative control over the Quality Engineering staff and Quality Engineers assigned to nuclear projects, and providing indoctrination and training programs for engineering department personnel to assure proper implementation of department quality program procedures.

In January 1975, I joined the Region 5 office of the Nuclear Regulatory Commission - Office of Inspection and Enforcement as a Reactor Inspector. Since that time I have participated in numerous inspections of nuclear plants in the construction or pre-CP phase, including Diablo Canyon 1 & 2, WNP-2, WNP-1 and 4, WNP-3 and 5, Sundesert, and Palo Verde.

During my employment with the Commission I have completed several training courses. They were:

* Boiling Water Reactor Fundamentals
  U. S. Nuclear Regulatory Commission, Bethesda, Md.

* Pressurized Water Reactor Fundamentals
  U. S. Nuclear Regulatory Commission, Bethesda, Md.

* Nuclear Reactor Safety
  Massachusetts Institute of Technology, Cambridge, Mass.

* Non-Destructive Examination
  General Dynamics - Convair Division, San Diego, Cal.

* Welding Technology and Codes
  Ohio State University, Columbus, Ohio

* Concrete Technology and Codes
  Portland Cement Association, Skokie, Ill.

* Structural Design Seminar
  U. S. Civil Service Commission, San Francisco, Cal.