UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter	)	
	)	
TEXAS UTILITIES GENERATING COMPANY, ET AL.	)	Docket Nos. 50-445 50-446
	)	
(Comanche Peak Steam Electric Station, Units 1 and 2)	)	

AFFIDAVIT OF ROBERT L. PALLA

Q.1. By whom are you employed, and what is the nature of your work?

A.1. I am employed by the U.S. Nuclear Regulatory Commission ("NRC") as a Containment Systems Engineer in the Containment Systems Branch of the Division of Systems Integration, Office of Nuclear Reactor Regulation. My duties in this position include reviewing and evaluating the functional capability, integrity, and operation of containment structures, systems, and components during normal, transient, and accident conditions; and performing independent calculations and analyses of technical issues within the branch's area of review. These independent technical reviews and analyses include the degraded core/hydrogen control issue; monitoring ongoing government and industry sponsored research programs concerning hydrogen generation, transport, and combustion phenomena, and containment response and equipment survivability due to hydrogen burning; evaluating computer codes for predicting containment response to postulated degraded core accidents; and following NRC rulemaking proceedings that deal with severe accidents. A statement of my professional qualifications is attached to my affidavit.

Q.2. Would you describe the subject matter of your affidavit?

A.2. My affidavit addresses Board Question 1, which states:

> Describe in detail the planned method of handling any hydrogen gas in the CPSES containment structure.

In particular, I will discuss the current status of Item II.B.8, "Rulemaking Proceeding on Degraded Core Accidents", NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident," as it relates to post-accident hydrogen control for large dry containments like the CPSES. I will also address why it is acceptable to license the Comanche Peak Steam Electric Station ("CPSES") for operation prior to the issuance of the final rule on this matter.

Q.3. What is the potential source of hydrogen gas in the CPSES containment structure?

A.3. Following a loss-of-coolant accident ("LOCA") in a light-water reactor ("LWR") plant, combustible gases, principally hydrogen, may accumulate inside the primary reactor containment. These gases are generated by: (1) metal-water reaction involving the fuel element cladding; (2) radiolytic decomposition of the water in the reactor core and the containment sump; (3) corrosion of certain construction materials by the spray solution; and (4) synergistic chemical, thermal, and radiolytic effects of post-accident environmental conditions on containment protective coating systems and electric cable insulation.

Q.4. What method has been used to control hydrogen generated inside the containment?

A.4. Hydrogen generated as a result of radiolytic decomposition of water, corrosion of metals inside containment, and environmental effects on coatings and insulation, historically has been controlled by conventional hydrogen control systems such as hydrogen recombiners. On the other hand, the design capability (or margin) to control hydrogen generated by a metal-water reaction involving the fuel cladding has historically been provided by the net free volume inside the containment structure. That is, the containment volume was large enough and the assumed extent of metal-water reaction was small enough such that hydrogen generated and released from the cladding reaction would not reach a uniform concentration approaching the lower limit of flammability.

The rate of hydrogen release as a result of a cladding reaction is assumed to be rapid following a postulated accident that is, on the order of minutes. This release rate is well beyond the capability of conventional hydrogen control systems. However, the containment net free volume and atmosphere mixing mechanisms were found to be sufficient for diluting the hydrogen released below the lower limit of flammability. Conventional hydrogen control systems would then be actuated to control hydrogen accumulation from the other sources and gradually reduce the hydrogen concentration inside containment. Therefore, the Staff believed that it was acceptable to rely on containment net free volume to handle the hydrogen generated as a result of the fuel cladding-water reaction.

Q.5. What are the present regulatory requirements for the design of combustible gas control systems as they relate to the hydrogen generated by a metal-water reaction involving the fuel cladding?

A.5. Because of the potential for hydrogen generation, Title 10 of the Code of Federal Regulations (10 C.F.R.) Section 50.44, "Standards for Combustible Gas Control Systems in Light Water Cooled Power Reactors," and General Design Criterion 41, "Containment Atmosphere Cleanup," of Appendix A to 10 C.F.R. Part 50, require that systems be provided to control hydrogen concentrations in the containment atmosphere following a postulated accident to ensure that containment integrity is maintained. 10 C.F.R. Section 50.44 requires that the combustible gas control system provided be capable of handling the hydrogen generated as a result of degradation of the emergency core cooling system ("ECCS") such that the hydrogen release is five times the amount calculated in demonstrating compliance with 10 C.F.R. Section 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light Water Nuclear Power Reactors," or the amount of hydrogen generated from reaction of all of the metal in the outside of the cladding cylinders surrounding the fuel (excluding the cladding surrounding the plenum volume) to a depth of 0.00023 inch, whichever amount is greater.

Q.6. What is the background for Item II.B.8, "Rulemaking Proceeding on Degraded Core Accidents", NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident", as it relates to post-accident hydrogen control for large dry containments like CPSES?

A.6. The accident at TMI-2 on March 28, 1979 resulted in a metal-water reaction which involved approximately 45% of the fuel cladding. This resulted in substantial hydrogen generation, well in excess of the amounts previously specified in 10 C.F.R. Section 50.44. As a result of the TMI accident, programmatic efforts were undertaken by the Staff to reduce the likelihood of degraded core accidents and to require measures for hydrogen control and mitigation.

Through numerous post-TMI actions by the Staff, including the Short Term Lessons Learned (NUREG-0578), the TMI Action Plan (NUREG-0660), and the TMI Near Term Operating License (NTOL) Requirements (NUREG-0694 and NUREG-0737), the NRC substantially enhanced its requirements in the areas of operator training, technical competence of the operations staff, and careful development and review of operating procedures for coping with emergencies and abnormal conditions. As a result the Staff believes that the likelihood of an event such as TMI-2 in which a degraded core condition existed for a sufficiently long time has been substantially reduced. Since the production of large quantities of hydrogen is dependent upon core degradation, i.e., zirconium cladding reaction with steam, once the probability of severely degraded core accidents has been reduced then the resultant risk associated with generation of large amounts of hydrogen have also been reduced.

In addition to these efforts to preclude or reduce the likelihood of sever core damage, it became apparent to the NRC that hydrogen control and mitigation measures for degraded core accidents would have to be considered for all nuclear power plants. This topic was first addressed in the Lessons Learned Report (NUREG-0578), and was subsequently included in the TMI Action Plan Item II.B.7, NUREG-0660. Based on these reports, the Commission determined that a rulemaking proceeding should be undertaken to define the manner and extent to which hydrogen generation and other effects of a degraded core must be taken into account in plant design. This "Rulemaking Proceeding on Degraded Core Accidents," Item II.B.8 in the TMI Action Plan, is a two-step process involving (1) the development and implementation of a set of interim actions (including the issuance of interim rules), and (2) completion of a longer-term rulemaking proceeding. With respect to the longer-term rulemaking proceeding, the Commission published in the

Federal Register an advance notice of rulemaking on October 2, 1980. 45 Fed. Reg. 65474. This rule, commonly referred to as the Severe Accident Rule, will prescribe the final NRC requirements for hydrogen control. Several years may elapse before the hydrogen control requirements for this final rule are developed and implemented. Furthermore, the applicability of this rule to currently operating plants is uncertain at this time.

Q.7. Describe the interim rulemaking proceedings for hydrogen generation and control.

A.7. Analyses conducted by the NRC, including that reported in SECY 80-107, as well as information developed by the industry, served as the bases for the development of the interim requirements on hydrogen control. These studies and subsequent Commission reviews indicated that the containment designs for all nuclear plants can generally be placed in three categories on the basis of their capability for accommodating large hydrogen releases and the subsequent burning of hydrogen without loss of containment integrity. These three categories are defined in terms of the relative containment volume as small (Mark I/BWR and Mark II/BWR), intermediate (Ice Condenser and Mark III/BWR), and large (large dry containments). A number of rule changes were proposed as a result of the TMI-2 accident to address large hydrogen releases for each of these containment categories. These rule changes cover current containment designs and apply to plants ranging from those already in operation to those for which applications for a construction permit are under Staff review. The rule changes include the following:

(1) "Interim Requirements Related to Hydrogen Control." This rule, published in the Federal Register, December 2, 1981 (46 Fed. Reg. 58484) as a final rule, deals with the requirement for inerting Mark I and II containments, among other requirements.

(2) "Interim Requirements Related to Hydrogen Control." This rule, published in the Federal Register, December 23, 1981 (46 Fed. Reg. 62281) as a proposed rule, provides the interim requirements for hydrogen control systems in Ice Condenser and Mark III containments and requires that hydrogen analyses be performed for large dry containments.

(3) "Licensing Requirements for Pending Construction Permits and Manufacturing License Application." This rule, published in the Federal Register, January 15, 1982 (47 Fed. Reg. 2286) as a final rule, specifies hydrogen licensing requirements for pending construction permit and manufacturing license applications.

Q.8. Which of the interim rulemaking proceedings apply to large dry containments similar to CPSES?

A.8. The "Interim Requirements Related to Hydrogen Control" published in the Federal Register on December 23, 1981 (46 Fed.

Reg. 62281) and modified in the Federal Register on February 25, 1982 (47 Fed. Reg. 8203).

This Interim Rule applies to large dry containments such as CPSES and requires owners of plants with such containments to perform and submit by two years after the effective date of the rule or the date of issuance of a license authorizing operation above five percent of full power, whichever is later (i) analyses to assure that during degraded core accidents, containment structural intergrity will be maintained; and (ii) equipment survivability analyses to assure continued containment integrity and safe shutdown capability. These degraded core accidents will be assumed to produce hydrogen releases to the containment resulting from the reaction of up to and including 75% of the fuel cladding surrounding the active fuel region with water for a range of time periods consistent with the accident scenarios analyzed.

The analyses required by this Interim Rule serve two purposes. First, they would be used to support continued reliance on the interim requirements of this rule and, second, the results will be considered in the longer term rulemaking on degraded cores.

Q.9. What is the current status of the proposed rule, "Interim Requirements Related to Hydrogen Control".

A.9. Proposed rule "Interim Requirements Related to Hydrogen Control" was published in the Federal Register (46 Fed. Reg. 62281) on December 23, 1981. The comment period was originally to expire February 22, 1982 but was extended until April 8, 1982 by a further notice in the Federal Register (47 Fed. Reg. 8203). Approximately 15 comments were received.

The proposed rule is expected to be submitted to the NRC's Committee for Review of Generic Requirements in mid-1982, and the Commission and possibly ACRS in August-September. The rule, which specifies the interim hydrogen requirement, should be published in October-November 1982 and become effective approximately 60 days later.

Q.10. Does the proposed rule "Interim Requirements Related to Hydrogen Control" propose any requirements for assuring continued containment integrity and safe shutdown capability for large dry containments like CPSES in the event an accident leads to a hydrogen threat?

A.10. Yes, as stated in the response to Question 8, owners of all large dry containments would be required to perform and submit by two years after the effective date of the rule or the date of issuance of a license authorizing operation above five percent of full power, whichever is later (i) analyses to assure that during degraded core accidents containment structural integrity will be maintained and (ii) equipment survivability analyses to assure continued containment integrity and safe shutdown capability.

There is, however, no requirement in the proposed rule applicable to large dry containments for the installation of an additional hydrogen control system; e.g., igniters.

Q.11. Other than rulemaking, what other activities are occurring related to hydrogen generation and control?

A.11. Beginning early in 1980, a number of technical programs were initiated to investigate the control of large amounts of hydrogen in current containment designs. These industry-wide efforts include research by national laboratories (Sandia, Livermore), the Electric Power Research Institute (EPRI), the Industry Degraded Core Rulemaking (IDCOR) program, and owners groups such as the Ice Condenser Owners Group (ICOG) for ice condensers and the Hydrogen Control Owners Group (HCOG) for Mark III containments. These programs are directed toward resolving technical questions regarding: hydrogen source terms, hydrogen combustion phenomena, containment pressure and temperature environment due to hydrogen combustion, equipment survivability, containment mixing, and containment structural response. It is currently estimated that the parts of these programs necessary for the Staff to complete the final evaluations of the distributed ignition system proposed for the ice condenser containments will be completed by May 1982. The remainder should be completed by 1984.

The Office of Nuclear Reactor Regulation has been conducting an evaluation of the hydrogen control system proposed for the ice condenser plants since 1980 and the Mark III plants since 1981. However, these reviews have been conducted on an individual case basis as a part of the licensing efforts on those plants. In 1981 the Commission designated the hydrogen issue as an Unresolved Safety Issue, USI A-48, to: assure integration of the various plant-specific NRC efforts into a unified program with a generic resolution; and assure high NRC management attention leading to an accelerated resolution of the hydrogen issue.

Q.12. Has the NRC Staff studied the effects of hydrogen burns in large dry containments similar in design to CPSES and what conclusions did the NRC staff derive from these studies?

A.12. Yes. The large dry containments for PWR plants were found to have design pressures ranging from 45 to 60 psig and free volumes from about two to three million cubic feet. The design pressure of the CPSES containment is 50 psig. Structural analyses performed for the Zion and Indian Point plants (design pressures of 47 psig) show that for these containments the failure pressure is approximately 120 psig, or greater than twice the design pressures. Since these containment structures are similar in design and construction to that of CPSES, the Staff believes that the failure pressure of the CPSES containment would also be considerably in excess of the design pressure.

The CPSES containment has a net free volume of about three million cubic feet. Assuming a 50% metal-water reaction in the core, the resulting uniformly mixed concentration of hydrogen in the CPSES containment will be about 8%. This is well below the concentrations for detonation, and below the limits for combustion if there were more than 50% steam in the containment atmosphere. Even if the hydrogen were to burn, the resulting pressure inside containment is not likely to fail the containment. This was the experience at TMI-2 on March 28, 1979.

Calculations have also been performed by the Applicants and the Staff for CPSES, in order to determine the pressure in the CPSES containment resulting from the combustion of hydrogen corresponding to a 75% metal-water reaction. These calculations conducted over a range of preburn containment temperature, pressure and humidity, indicate a peak containment pressure that is well within the expected containment failure pressures.

Industry and government sponsored test programs and analyses addressing equipment survivability have produced preliminary results indicating that essential safety-related equipment will continue to function during and after repeated hydrogen burns. Also, the recommendations of the "Short Term Lessons Learned" Report, which was developed from the TMI-2 accident experience, have been implemented at all operating plants and will be implemented at all other plants before issuance of operating licenses. The Applicants will be required to implement the recommendations of this Report before issuance of an operating license for CPSES. These actions will have the effect of reducing the likelihood of accidents that could lead to substantial amounts of metal-water reaction.

Based on the ability of large dry containments to accommodate the generation and combustion of large amounts of hydrogen, the likely survival of essential safety-related equipment, and the reduced likelihood of accidents, the Staff concludes that operation and licensing of nuclear plants with dry containments will not jeopardize the health and safety of the public.

Q.13. Have you read the Applicants' Response to Board Question 1 concerning the capability of the CPSES design to comply with 10 C.F.R. Section 50.44?

A.13. I have read the Applicants' Response to Board Question with regard to the capability of the CPSES design to provide continued containment integrity and safe shutdown capability. The Applicants response summarizes the hydrogen generation analyses and hydrogen control provisions required to establish compliance with 10 C.F.R. 50.44. These methods for handling hydrogen gas are described in detail in the CPSES FSAR and are considered acceptable by the Staff for design basis accidents.

Q.14. Do you believe that Board Question 1 raises a serious safety issue which would preclude the issuance of an operating license for CPSES?

A.14. No, Board Question 1 does not raise a serious safety issue which would prohibit the issuance of an operating license for CPSES.

Q.15. Is it acceptable to license CPSES for operation prior to resolution of Unresolved Safety Issue A-48 and implementation of the final rulemaking related to increased hydrogen control requirements?

A.15. Yes, for several reasons. As stated in response to Question 12, large dry containments, of which CPSES is representative, are capable of accommodating the generation and combustion of the hydrogen that may be produced during postulated degraded core accidents.

In addition, industry and government-sponsored test programs and analyses addressing equipment survivability have produced preliminary results indicating that essential safety-related equipement will continue to function during and after repeated hydrogen burns.

Finally, the recommendations of the "Short Term Lessons Learned" report have been implemented at all operating plants, and will be implemented at all other plants, including CPSES, before issuance of the operating licenses. This action will reduce the likelihood of accidents that could lead to substantial amounts of metal-water reaction.

Based on the capability of large dry containments to accommodate the generation and combustion of large amounts of hydrogen, the likely survival of essential safety-related equipment, and the reduced likelihood of degraded core accidents which may result in hydrogen generation, the licensing and operation of CPSES is justified and will not jeopardize the health and safety of the public.

The above statements and opinions are true and correct to the best of my personal knowledge and belief.

Robert L. Palla Jr.

ROBERT L. PALLA

Subscribed and sworn to me this 6th day of May, 1982.

Maxine Laiefsky

Notary Public

My Commission expires: 7/1/83

MAXINE B. LAIEFSKY
NOTARY PUBLIC
MONTGOMERY COUNTY, MD.

PROFESSIONAL QUALIFICATIONS
Robert L. Palla Jr.

I am a Containment Systems Engineer in the Containment Systems Branch of the Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission. In this position, which I have held since October 1981, I am responsible for reviewing and evaluating the functional capability, integrity, and operation of containment structures and systems and performing independent calculations and analyses of technical issues, most recently the degraded core/hydrogen control issue. These independent technical reviews and analyses include applying state-of-the-art containment codes; monitoring ongoing research programs concerning hydrogen generation, transport, and combustion phenomena, and containment response and equipment survivability due to hydrogen burning; and evaluting computer codes and code modifications for predicting containment response to postulated accidents.

From July 1976 to October 1981, I was employed as a Mechanical Engineer at the National Bureau of Standards, Washington, D.C. I was responsible for planning and conducting heat transfer studies involving analytical and finite difference solution techniques, developing appliance energy test procedures, evaluating energy/water conservation strategies, computer programming for complex engineering calculations and setting up and troubleshooting data acquisition systems.

From March 1976 to July 1976, I was employed as a Mechanical Engineer at the Naval Ship Engineering Center, Hyattsville, Md. I was responsible for review of contractors' work; written and oral communication with field units, shipbuilders and contractors; and review and modification of specifications and blueprints.

My formal training includes a Master of Science and a Bachelor of Science Degree in Mechanical Engineering from the University of Maryland in 1975 and 1981, and NRC sponsored PWR courses. I am a member of the American Society of Mechanical Engineers and hold a E. I. T. certificate from the State of Maryland.