DOCKETED

'82 [illegible] 26 [illegible]

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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

AFFIDAVIT OF FRED W. MADDEN, JR. REGARDING BOARD QUESTION ONE RELATED TO HYDROGEN GENERATION

I, Fred W. Madden, Jr., being first duly sworn, do depose and state as follows: I am employed by Texas Utilties Services, Inc. in the position of Lead Nuclear Engineer, Technical Support Group, Comanche Peak Steam Electric Station ("CPSES") Project. In this position I am responsible for performing engineering and technical evaluations of plant systems related to, *inter alia*, hydrogen generation and control. My professional qualifications are attached hereto (Attachment A).

This affidavit describes the method of handling hydrogen gas that may be generated in the CPSES containment. To facilitate review, the affidavit is divided into two sections. The first section describes the relevant hydrogen generation mechanisms at CPSES and summarizes two analyses set forth in the CPSES Final Safety Analysis Report ("FSAR") which calculate the quantity of hydrogen that the CPSES hydrogen control systems must be designed to handle. The second section decribes the systems designed to handle this amount of hydrogen. A more detailed discussion of this subject is set forth in Sections 6.2.5 and 6.2.5A of the CPSES FSAR (Applicant's Exhibit 3).

I. HYDROGEN GAS GENERATION

Significant quantities of hydrogen can be generated in the CPSES containment by only four methods: (1) a zirconium-water reaction, (2) release of the free hydrogen contained in the primary coolant system, (3) radiolysis of water and (4) corrosion of susceptible construction materials in containment. FSAR §6.2.5 at p. 6.2-79 and §6.2.5A at p. 6.2-103. In the FSAR, each of these hydrogen generation mechanisms is analyzed and combined using two independent methodologies to provide the total quantity and concentration of hydrogen as a function of time necessary to be considered in the design of the combustible gas control equipment at CPSES. The two methodologies used are a Westinghouse model (discussed in FSAR §6.2.5A) and an NRC model (discussed in Regulatory Guide 1.7, "Control of Combustible Gas Concentrations in Containment Following a Loss of Coolant Accident").

The results of the Westinghouse model analysis and the NRC model analysis are set forth in FSAR Figures 6.2.5A-6, 6.2.5A-7, 6.2.5A-8, and 6.2.5A-9. (Attachments B, C, D, and E). Based on the Westinghouse and NRC models (both assume no hydrogen control equipment), hydrogen concentrations of 8 volume percent (the concentration necessary to sustain a hydrogen deflagration throughout the containment 1/) would not be present until after approximately 100 2/ and 75 days, respectively, had elapsed since onset of a hypothetical design basis accident ("DBA"). The two analyses, extending only to 100 days after initiation of an assumed DBA, never reach the point at which hydrogen concentrations would be in the detonable range

---

1/ Deflagration is the propogation of a slow flame throughout a flammable mixture. In the temperature and pressure conditions relevant here, the lower deflagration limit (referred to as lower flammable limit) of hydrogen in air is 4.0% by volume for upward propogation. Ignition of such concentrations would result in a very thin and momentary upward flame traveling to the top of containment or to some intermediate point obstructing further upward movement. There is no detectable pressure rise associated with such a deflagration. Lower deflagration limits for horizontal and downward propogation are about 6.5 and 8 volume percent, respectively.

2/ The analysis was conducted for a model period of 100 days from the onset of a design basis accident. At the conclusion of this model period, the Westinghouse analysis indicated that there would be a concentration of hydrogen in containment of approximately 7.3 volume percent.

(18-59 volume percent). 3/ A description of the four hydrogen generation methods are set forth below.

A. Zirconium-Water Reaction (FSAR §§ 6.2.5.3.1, 6.2.5A.1, and 6.2.5A.2.1)

The production of hydrogen by the reaction of water and the zirconium cladding around the fuel is described by the following exothermic chemical equation:

$$Zr + 2H_2O \longrightarrow ZrO_2 + 2H_2 + \text{Heat}$$

This reaction, however, proceeds in significant quantities only in the presence of very high temperatures. Such temperature can only be achieved during a hypothetical loss of coolant accident coupled with loss of emergency cooling water from the emergency core cooling system ("ECCS"). 4/

3/ Hydrogen inside the CPSES containment is assumed to be uniformly distributed. This assumption is supported by the outstanding mixing characteristics of hydrogen and the configuration and systems in the CPSES containment. Specifically, hydrogen mixes readily with other gases, and once mixed will not separate in the containment environment. Mixing is promoted by convective currents created by temperature gradients in containment, containment sprays, subcompartment vents and drains, and jet-stream entrainment from the assumed break in the primary coolant system giving rise to hydrogen generation. See FSAR §6.2.5.3.2.

4/ During the Three Mile Island accident a loss of coolant accident followed by operator interference with the ECCS resulted in an exposed core and excessive hydrogen production due to a zirconium-water reaction. Subsequent to this accident Commission directives required the development of procedures to assure that such premature operator interference with ECCS operation will not occur. To comply, procedures at CPSES will require that in the event of an ECCS initiation,

(Footnote continued on next page)

In such a situation, the core may be exposed and excessively high temperatures may be present.

The ECCS, a safety grade system with redundant trains and power sources, is designed to assure compliance with NRC regulations limiting zirconium-water reaction following a DBA to that associated with the reaction of 1% by weight of the total quantity of zirconium in the core. 10 CFR §50.46(b)(3). See also FSAR §6.2.5A.1. ECCS calculations, however, have shown that in the event of a DBA less than 0.3% of the zirconium will react. For the hydrogen generation analyses the Westinghouse and NRC models conservatively assume a 2% and 5%, respectively, zirconium reaction.

B. Release of Free Hydrogen in the Primary Coolant System (FSAR §§6.2.5.3.1, 6.2.5A.1, and 6.2.5A.2.2)

The hydrogen generation analyses set forth in the FSAR assume that the maximum equilibrium quantity of hydrogen in the reactor coolant system during normal operations is immediately released into containment following a LOCA. Such quantities include hydrogen dissolved in the primary coolant and hydrogen trapped in the pressurizer gas space.

(Footnote continued from previous page).

operators will not terminate ECCS operation absent positive indications that the core is completely covered. Core subcooling monitors will be installed to augment existing equipment and procedures, thus providing such positive indications. See FSAR Volume XIV, Response to the NRC Action Plan Developed as a Result of the TMI-2 Accident, §II.F.2. In addition, operators receive significant class room and simulator training in this area. Id. §§I.A.2, II.B.4 and II.F.2.

C. Water Radiolysis (FSAR §§6.2.5.3.1, 6.2.5A.1, 6.2.5A.2.4, and 6.2.5A.3)

Water radiolysis is a complex process in which water, in the presence of radiation, is broken down into hydrogen and oxygen in accordance with the following equation.

$$H_2O \rightleftarrows H_2 + 1/2\ O_2$$

The FSAR analyses consider the only two major sources of water for radiolysis that would be present following a DBA, i.e., the reactor coolant inventory in the reactor coolant system and the reactor containment sump water. Significantly, the radiolysis process is relatively slow, and is retarded by increasing concentrations of hydrogen which force a reverse reaction (i.e., combining hydrogen and oxygen to produce water). While the Westinghouse model takes credit for reduced yield of hydrogen due to such reverse reactions, the NRC model does not.

D. Corrosion of Susceptible Construction Materials (FSAR §§6.2.5.3.1, 6.2.5A.1, and 6.2.5A.2.3)

Oxidation of metals in aqueous solutions results in the generation of hydrogen gas as one of the corrosion products. Extensive corrosion testing has been conducted to determine the behavior of the various metals used in the containment during accident conditions. Metals tested include zircaloy, inconel, aluminum alloys, cupronickel alloys, carbon steel, galvanized carbon steel, and copper. The results of the corrosion tests have shown that only aluminum and zinc will corrode at a rate that will significantly add to the hydrogen accumulation in the containment atmosphere.

The corrosion of aluminum and zinc is described by the following two equations:

$$2\ Al + 3\ H_2O \longrightarrow Al_2O_3 + 3\ H_2$$

$$Zn + 2H_2O \rightleftarrows Zn(OH)_2 + H_2$$

Based on the corrosion rates and the aluminum and zinc inventory in the containment, the contribution of aluminum and zinc corrosion to hydrogen accumulation in the containment following the design basis accident was calculated and factored into the FSAR hydrogen generation analyses. To be conservative, no credit was taken for protective shielding effects of insulation or enclosures from the spray, and complete and continuous immersion was assumed.

II. HYDROGEN GAS CONTROL

To safely handle the amount of hydrogen assumed to be generated by the four above referenced methods, redundant, electrical hydrogen recombiners and a backup hydrogen purge system are provided in accordance with NRC Regulatory Guides 1.7, 1.22, 1.26, and 1.29; General Design Criteria 41, 42, 43, and 50; and Branch Technical Positions CSB 6-2 and APCSB 9.2. FSAR §6.2.5 at p. 6.2-79. These systems are discussed below.

A. Electric Hydrogen Recombiners (FSAR §§6.2.5.1.2, 6.2.5.3.3, and 6.2.5.4.1)

Two redundant, electric hydrogen recombiners are provided in containment as the primary hydrogen control system. Each recombiner has sufficient capacity to assure that containment hydrogen concentration levels do not exceed 4 volume percent based on the conservative hydrogen release model set forth in Regulatory Guide 1.7. 5/ The recombiners are safety related and designed to sustain all normal loads as well as accident loads including a safe shutdown earthquake (SSE) and pressure-temperature transients from a design basis LOCA. Each recombiner is powered from a separate safeguards bus. There is no interdependency between this system and the other engineered safety features systems. In operation, hydrogen is removed from the containment atmosphere by heating in the recombiner to a temperature sufficient to cause recombination of hydrogen with the containment oxygen.

2. Hydrogen Purge System (FSAR §§6.2.5.1.3, 6.2.5.2.2, 6.2.5.3.4, and 6.2.5.4.2)

The hydrogen purge system, serving both CPSES containments, functions as a backup for the electric hydrogen

---

5/ FSAR Figure 6.2.5-3 (Attachment F) illustrates containment hydrogen concentration as a function of time assuming operation of one recombiner started 24 hours after initiation of a DBA. The Figure shows that even for the conservative NRC model, hydrogen concentration does not exceed approximately 2 volume percent, far below even the lower flammable limit for upward flame propogation.

recombiners. Like the recombiners, the purge system has the process capacity to maintain hydrogen concentration in the containment below 4 volume percent based on the conservative hydrogen generation model set forth in Regulatory Guide 1.7.

The hydrogen purge system for each containment consists of two 700 standard cubic feet per minute ("scfm") blowers for air supply, isolation valves, two atmospheric cleanup systems, and two exhaust fans. The blowers are capable of transporting 700 scfm of fresh, filtered air to the containment. The exhaust fan draws air from either containment, as required, and passes the air through high efficiency particulate and iodine filters before discharge through the plant discharge duct at levels that assure compliance with 10 CFR Part 100 guideline values. Two trains are provided for each containment, each capable of exhausting the design airflow of 700 scfm. The system components are designed for SSE loads and maximum termperature and pressure transients from a DBA.

Fred W. Madden, Jr.

Fred W. Madden, Jr.

STATE OF TEXAS
COUNTY OF SOMERVELL

Subscribed and sworn to before me this 19th day of APRIL, 1982.

Bill J. Hodges

Notary

MY COMMISSION EXPIRES
28 MARCH 1964

FRED W. MADDEN

STATEMENT OF EDUCATIONAL AND PROFESSIONAL QUALIFICATIONS

POSITION: Lead Nuclear Engineer, Technical Support

FORMAL EDUCATION: 1968-1972, B.S. Engineering Physics, Texas Tech University

1972-1974, M.S. Nuclear Engineering, Purdue University

EXPERIENCE:

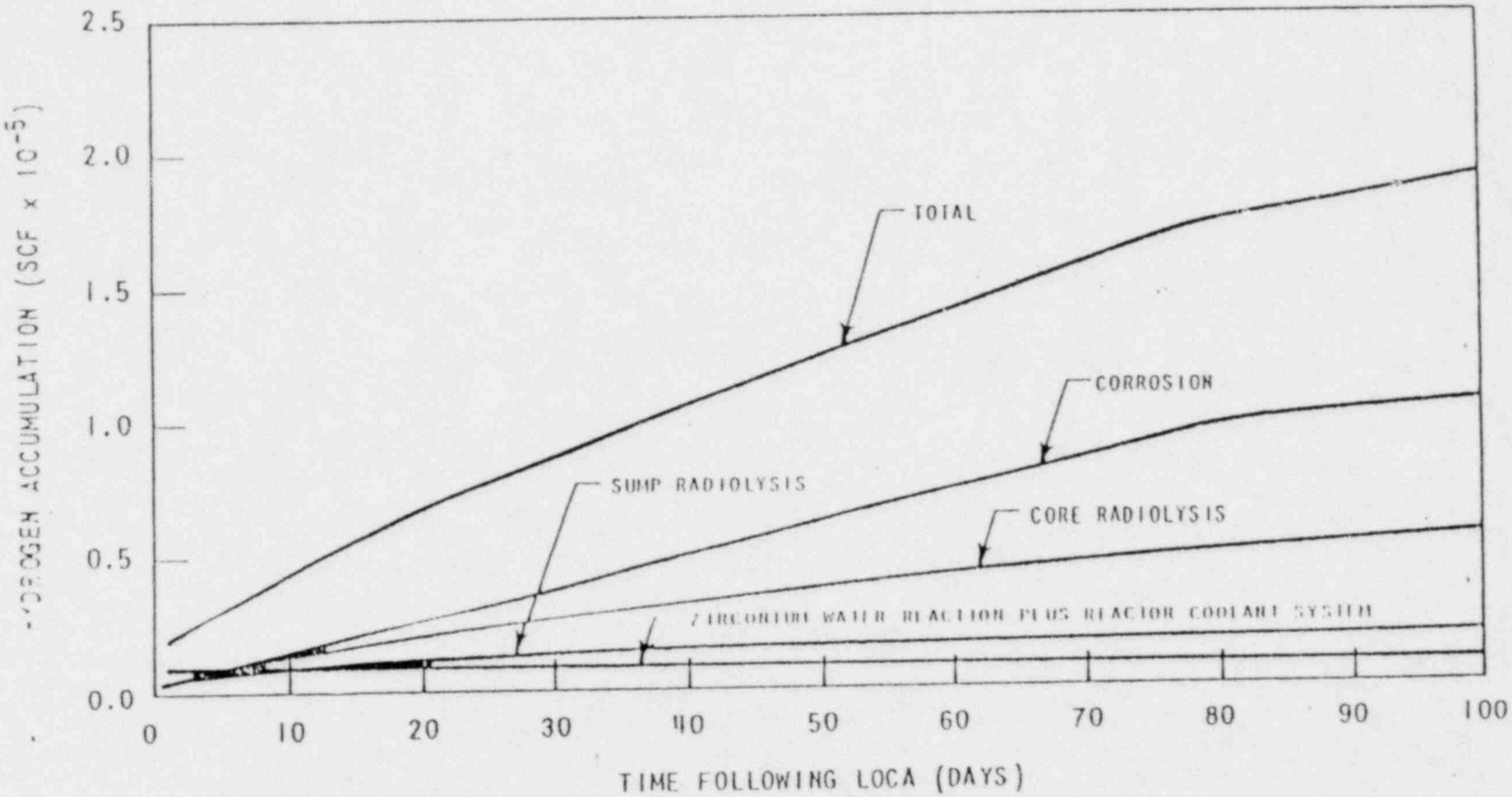
1981 - Present: Texas Utilities Services, Inc., Comanche Peak Steam Electric Station, Glen Rose, Texas, Lead Nuclear Engineer, Technical Support Group. Activities include design and engineering of TMI-related plant modifications; engineering resolution of licensing issues; and development of analytical capabilities.

1980 - 1981: Texas Utilities Services Inc., Dallas, Texas, Licensing Engineer. Activities included preparation of licensing information such as FSAR, responses to NRC questions, and interrogatories; and review and interpretation of regulatory criteria.

1976 - 1980: Brown & Root, Inc., Houston, Texas, Senior Licensing Engineer. Activities included preparation and coordination of licensing information such as SAR's, environmental reports and NRC questions; review and interpretation of regulatory criteria. Coordinator of project design review team following TMI accident.

1974 - 1976: Bechtel Power Corporation, Los Angeles, California, Engineer on Nuclear Analysis staff. Activities include accident analysis calculations; nuclear fuel cycle analyses; radiation dose calculations; and shielding design and analysis. Other project activities include system design; preparation of specifications and bid evaluation.

PROFESSIONAL: Registered Professional Engineer (Texas and California), American Nuclear Society, Tau Beta Pi, Phi Kappa Phi, Sigma Pi Sigma.

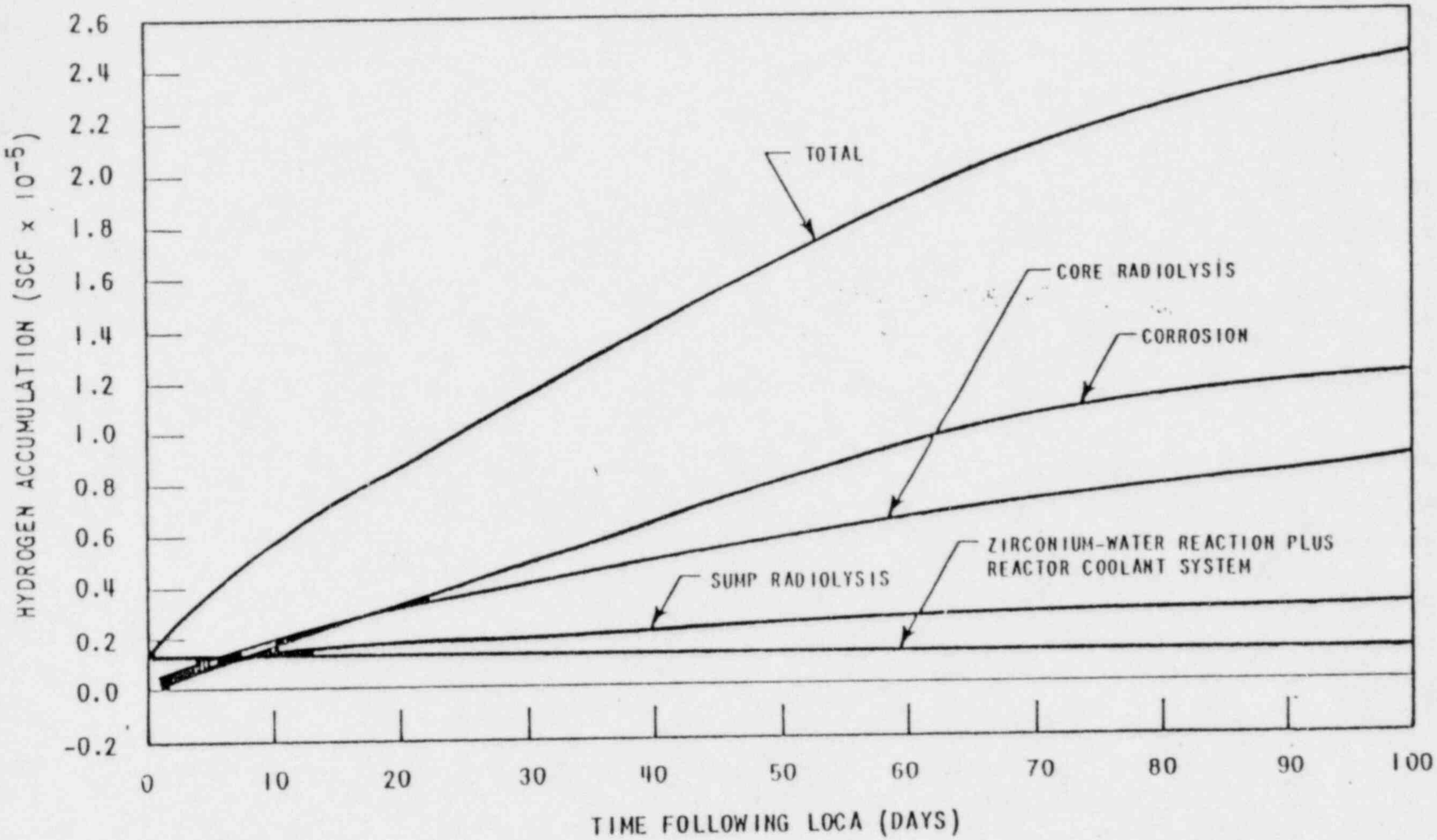


ATTACHMENT B

COMANCHE PEAK S.E.S.
FINAL SAFETY ANALYSIS REPORT
UNITS 1 and 2

HYDROGEN ACCUMULATION FROM ALL SOURCES - WESTINGHOUSE MODEL

FIGURE 6.2.5A-6

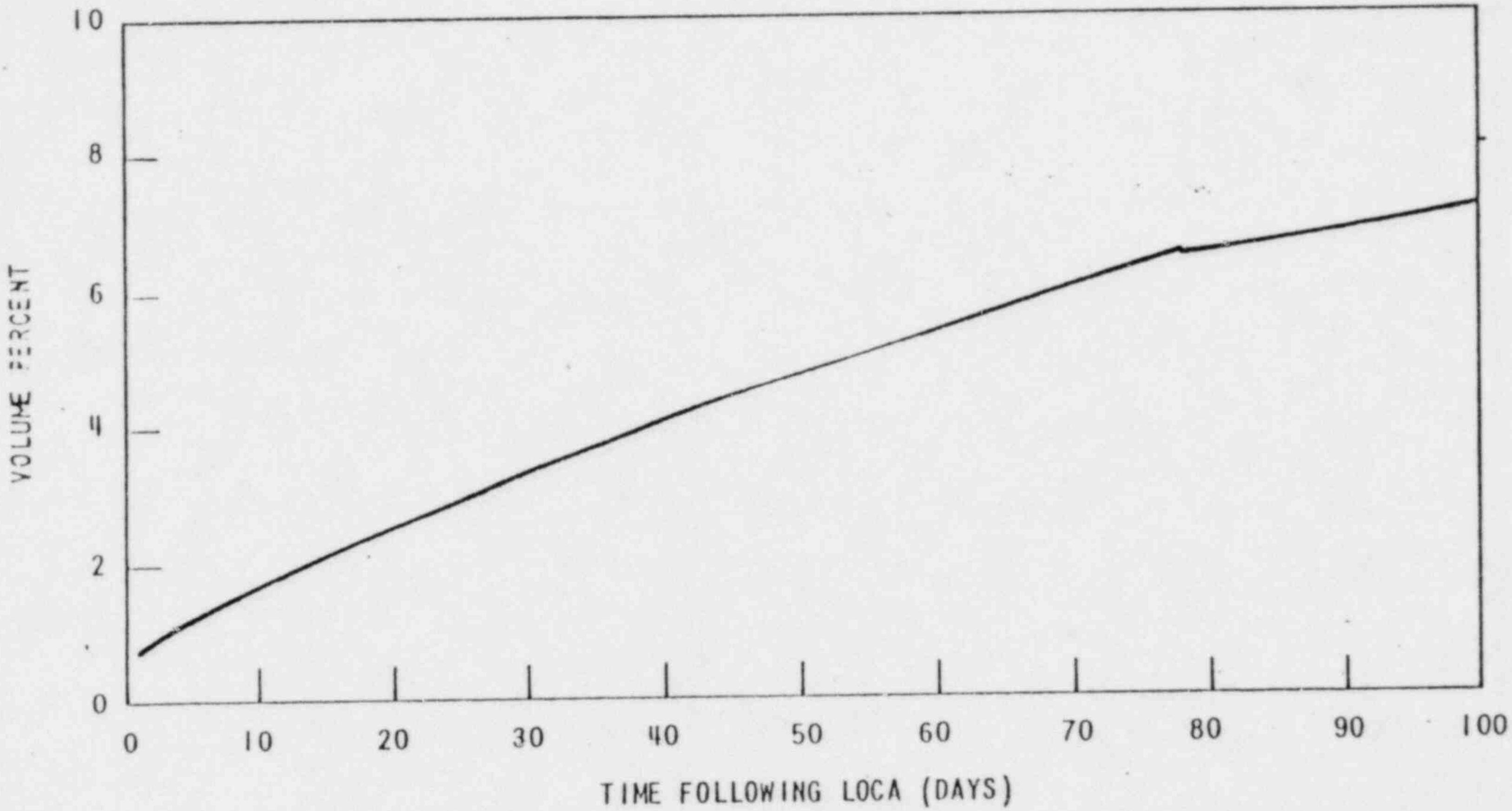


ATTACHMENT C

COMANCHE PEAK S.E.S.
FINAL SAFETY ANALYSIS REPORT
UNITS 1 and 2

HYDROGEN ACCUMULATION FROM ALL SOURCES, NRC MODEL-NO RECOMBINER

FIGURE 6.2.5A-7



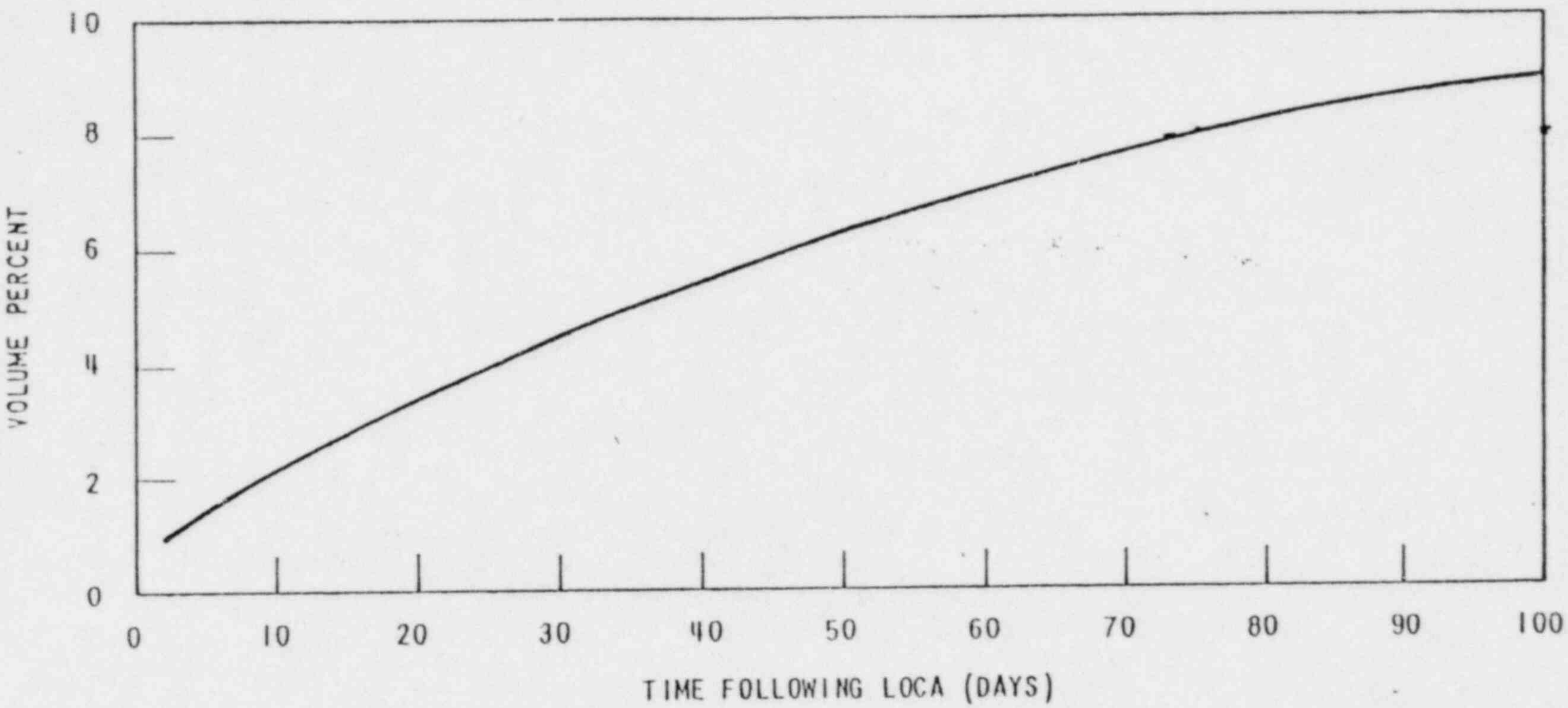
ATTACHMENT D

NOTE: Calculations assume no hydrogen recombiner capability.

COMANCHE PEAK S.E.S.
FINAL SAFETY ANALYSIS REPORT
UNITS 1 and 2

VOLUME PERCENT OF HYDROGEN IN CONTAINMENT
WESTINGHOUSE MODEL

FIGURE 6.2.5A-8



ATTACHMENT E

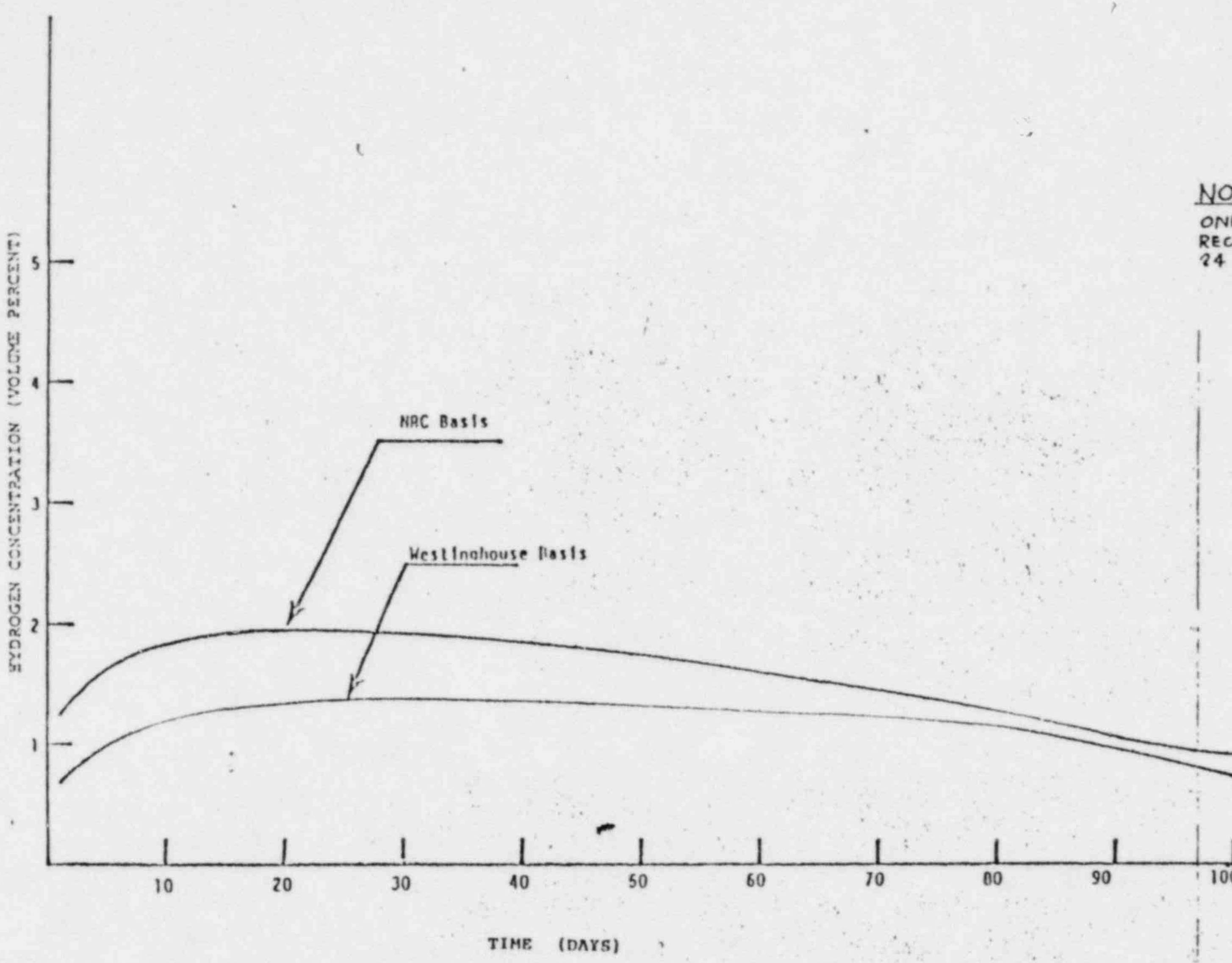
NOTE: Calculations assume no hydrogen recombiner capability.

COMANCHE PEAK S.E.S.
FINAL SAFETY ANALYSIS REPORT
UNITS 1 and 2

VOLUME PERCENT OF HYDROGEN IN CONTAINMENT
NRC MODEL

FIGURE 6.2.5A-9

ATTACHMENT F



NOTE:
ONE ELECTRIC HYDROGEN RECOMBINER STARTER 24 HRS. AFTER A LOCA

COMANCHE PEAK S.E.S. FINAL SAFETY ANALYSIS REPORT UNITS 1 and 2
CONTAINMENT HYDROGEN CONCENTRATION AFTER LOCA
FIGURE 6.2.5-3