ABB

ASEA BROWN BOVERI

April 15, 1992
LD-92-050

Docket No. 52-002

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Subject: System 80+™ Combustible Gas Control in Containment

Reference: ABB-CE Letter, LD-92-038, CESSAR-DC Submittal Schedule Update, dated March 25, 1992

Dear Sirs:

Enclosed with this letter is updated Section 6.2.5. The discussion on layout of hydrogen mitigation system igniter locations fulfills the commitment of item 3 of the Reference.

The revised section was referenced in the response to RAI 730.7(b).

Should you have any questions on the enclosed material, please contact me or Mr. Stan Ritterbusch of my staff at (203) 285-5206.

Very truly yours,

COMBUSTION ENGINEERING, INC.

S. E. Ritterbusch for

C. B. Brinkman
Acting Director
Nuclear Systems Licensing

vs/lw
Enclosures: As Stated

cc: J. Trotter (EPRI)
T. Wambach (NRC)

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6.2.5 COMBUSTIBLE GAS CONTROL IN CONTAINMENT

Following a design basis Loss-of-Coolant Accident (LOCA), control of combustible gas concentration in containment is provided by the Containment Hydrogen Recombiner System (CHRS). Hydrogen may be released to the containment atmosphere following a LOCA by radiolysis of water, corrosion of containment materials by the containment spray, reaction of the zirconium cladding with steam and dissolved hydrogen coming out of solution from the reactor coolant and pressurizer steam space. The CHRS prevents the concentration of hydrogen from reaching the lower flammability limit of 4% by volume. The system is designed in accordance with the guidance provided by Regulatory Guide 1.7 and as required by 10 CFR 50.44, 10 CFR 50.46 and General Design Criteria 5, 41, 42 and 43. In addition, this system provides the capability for controlled purging to aid in post-accident containment atmosphere cleanup with filtration of the discharge provided by the annulus ventilation filter trains.

During a degraded core accident, hydrogen will be produced at a greater rate than that of the design basis LOCA. The Hydrogen Mitigation System (HMS) is designed to accommodate the hydrogen production from 100% fuel clad metal-water reaction and ~~meet an~~ average hydrogen concentration ~~limit of~~ 10% in accordance with 10 CFR 50.34(f) for a degraded core accident. These limits are imposed to preclude detonations in containment that might jeopardize containment integrity or damage essential equipment. The HMS consists of a system of igniters installed in containment to promote the combustion of hydrogen in a controlled manner such that containment integrity is maintained.

6.2.5.1 Design Bases

6.2.5.1.1 Containment Hydrogen Recombiner System (CHRS)

A. The CHRS is an Engineered Safety Features (ESF) System designed to maintain the hydrogen concentration within the containment atmosphere below its lower flammability limit of 4% in accordance with Regulatory Guide 1.7. The system is designed to be manually initiated prior to hydrogen concentration reaching 3.5% by volume. I

B. Two independent, full capacity, parallel loops make the system fully redundant and enable it to withstand a single active failure and still perform its design function.

C. The CHRS is designed to provide sufficient suction points inside containment to eliminate stagnant pockets of air where hydrogen could accumulate.

D. Recombiner inlet connections from the In-containment Refueling Water Storage Tank (IRWST) are provided to remove hydrogen produced by sump radiolysis in the IRWST.

E. Components of the CHRS are designed to sustain normal and Seismic Category I loads as well as temperature and pressure transients from a LOCA.

F. The hydrogen recombiners are protected from damage by missiles or jet impingement from pipe ruptures.

G. Components of the CHRS located in containment will be designed to meet the appropriate environmental requirements specified in Appendix 3.11A.

H. System equipment located outside of containment will be arranged to preclude failure of the CHRS due to failure of other non-Category I systems.

I. CHRS components will be designed in accordance with ASME Boiler and Pressure Vessel Code, Section III, Class 2 requirements.

J. In the event of offsite power loss, power to the Containment Hydrogen Recombiner System will be automatically supplied by the Class 1E ~~Electrical~~ 480 VAC Auxiliary Power System which is supplied by the emergency diesel generators.

K. The system valves and components will be designed in accordance with ANS Safety Class 2 requirements.

L. Access and shielding are provided to the areas where the portable hydrogen recombiner and control panel skids are to be placed along with areas where coupling operations are required.

M. Capability will be provided for a controlled purge of the containment atmosphere to aid in post-accident containment cleanup. I

N. Redundant hydrogen analyzers provide hydrogen concentration measurement of the incoming gas from containment as well as the recombiner discharge for monitoring of recombiner performance. The hydrogen analyzers are independent of the hydrogen recombiners and are permanently installed to allow hydrogen concentration monitoring throughout the accident.

6.2.5.1.2 Hydrogen Mitigation System (HMS)

A. The HMS is designed to allow adiabatic, controlled burning of hydrogen at low concentrations to preclude hydrogen concentration build-up to detonable levels. The system is designed to prevent the average hydrogen concentration in containment from reaching 10% by volume during a degraded core accident with 100% fuel clad metal-water reaction in accordance with 10 CFR 50.34(f). The system is designed to be manually initiated from the Control Room.

B. The HMS igniters are divided into two redundant groups, A and B. Each group has independent and separate control, power, and igniter locations to ensure adequate coverage in the event of a circuit failure. In the event of an offsite power loss, the igniters have the capability of being powered from the (AC gas turbine) or emergency diesel generators. The igniters can also be powered from the Class 1E emergency batteries via DC-to-AC inverters.

alternate AC source

C. The hydrogen burning from the igniters will not jeopardize the survivability of critical plant equipment.

D. Although the containment is designed to promote mixing, the igniters will be positioned in areas where hydrogen is produced most rapidly or could accumulate. ~~Igniters are also placed at the IRWST safety valve outlets and the IRWST spillway outlet in the holdup volume.~~

E. HMS components in containment are designed to sustain normal and Seismic Category I loads.

F. HMS components are non-nuclear safety related since they are not required to prevent or mitigate the consequences of a design basis accident. However, the HMS is required to mitigate the consequences of a severe (degraded core) accident.

G. HMS components in containment will be designed to ~~meet the~~ withstand severe accident environmental conditions. I

6.2.5.1.3 Design Basis LOCA Hydrogen Production

The design basis LOCA hydrogen production and accumulation analysis was performed using the NRC Regulatory Guide 1.7 model. This model assumes the fission product activity release specified in TID-14844 and the values for post-accident hydrogen generation specified in Regulatory Guide 1.7. Per Regulatory Guide 1.7, the effects of partial pressure of steam is considered in the

The corrosion rate of containment aluminum and zinc during a LOCA is dependent on containment spray pH and composition, alloy composition and temperature, with temperature being the primary governing parameter. The time-temperature curve (Figure 6.2.1-16) used in determining aluminum and zinc corrosion rates is based on a conservative representation of the postulated post-accident ~~containment~~ transient. Since this temperature plot only extends to 11.57 days, the temperature at that time of 170°F is conservatively assumed from 11.57 to 30 days. The aluminum and zinc corrosion rates as a function of temperature are based on ANSI N-275, Draft 10 which provides conservative upper bound hydrogen generation rates. Aluminum and zinc inventories are listed in Table 6.2.5-4. No credit is taken for protective shield effects of insulation, oxide layer buildup or enclosures from the spray.

A. Aluminum

Aluminum corrosion rates are based on ANSI N-275, Draft 10 and are shown versus temperature in Figure 6.2.5-4 and as a function of time after the LOCA in Table 6.2.5-5. The aluminum inventory used is 1000 lbm which corresponds to a 285 ft^2 surface area with a thickness of 250 mils. Due to the conservative temperatures used in the later stages of the LOCA, the corrosion rate is above 200 mils/year for the entire period which is more conservative than the Regulatory Guide 1.7 requirements.

B. Zinc

Zinc in containment is in two forms, galvanized steel and zinc-based paint. These two forms are combined for a total inventory of 379,700 ft^2 surface area with a thickness of 6 mils. The zinc corrosion rates are based on ANSI N-275, Draft 10 and are shown versus temperature in Figure 6.2.5-5 and as a function of time after the LOCA in Table 6.2.5-6.

C. Corrosion of other containment materials is negligible.

6.2.5.1.3.4 Zirconium-Water Reaction

The zirconium-water reaction which occurs on the surface of the zirconium cladding during a LOCA is described by the chemical equation:

$$Zr + 2H_2O \rightarrow ZrO_2 + 2H_2 + Heat$$

Per Regulatory Guide 1.7, the hydrogen produced is assumed to be 5 times the maximum calculated reaction under 10 CFR 50.46. This corresponds to 5% of the zirconium cladding surrounding the active fuel. ~~71,760 lbm of Zircaloy-4 cladding reacting to form hydrogen.~~ Per Regulatory Guide 1.7, the hydrogen is assumed to be released into containment over a 2 minute period from the start of the transient.

6.2.5.1.3.5 Dissolved Hydrogen in Reactor Coolant

The maximum equilibrium quantity of hydrogen in the reactor coolant is 3890 scf. This quantity includes both the maximum allowable hydrogen concentration in the primary coolant water at 100 cc (STP) per kilogram of water and the equilibrium hydrogen in the pressurizer steam space at the maximum concentration of 2/10 of 1% by weight of steam. The entire 3890 scf of hydrogen is assumed to be released immediately into containment at the initiation of the LOCA.

6.2.5.1.4 Design Basis LOCA Hydrogen Accumulation

Besides containment, the IRWST is the only other enclosed compartment which could experience hydrogen pocketing. Hydrogen recombiner inlet connections are provided for the IRWST which account for one-half of the 100 cfm flow to each recombiner.

To account for single failure, only one of the 100 cfm recombiners is considered in the analysis. The flow split per recombiner is 50 cfm from containment and 50 cfm from the IRWST. Hydrogen concentration versus time is shown in Figure 6.2.5-2 for containment and Figure 6.2.5-3 for the IRWST. These figures show hydrogen concentration without recombiner flow and with a single recombiner started 72 hours after the LOCA.

6.2.5.2 <u>System Design</u>

6.2.5.2.1 Containment Hydrogen Recombiner System

The CHRS consists of two redundant loops. Within containment, each loop of the CHRS is comprised of a suction header (influent piping) with motor operated valves and a discharge header (effluent piping) with a check valve. Outside of containment, in the Nuclear Annex, each loop consists of influent piping, manual and motor operated isolation valves, sample piping, a hydrogen analyzer, a mobile recombiner and control panel skid, test and calibration connections, an isolated nitrogen supply connection, an isolated ~~service~~ instrument air connection, a safety valve, and effluent piping.

The recombiners and control panels are skid-mounted, self-contained units. Flanged piping connections are used for ease of installation. To place the recombiners in operation, the recombiners and control panels are placed in their specified locations and the following connections are made:

A. Instrumentation

B. Hydrogen Test Connection

C. Power Supply

D. Suction Piping

E. Discharge Piping

The safety valves protect the CHRS against inadvertent pressurization during testing or system purging. During normal system operation, the test and nitrogen connections are closed and the safety valve is isolated from the CHRS. The safety valve and its associated isolation valve provide two valve isolation between the CHRS and the atmosphere during a LOCA.

Instrumentation and controls are provided in a local control panel to allow operation and monitoring of each recombiner.

Inlet lines to the recombiners are provided from the IRWST and the upper portion of containment. Divisional separation is maintained in these individual inlet lines as well as the two recombiner inlet and outlet headers. Redundant inlet piping and an individual motor-operated valve in each suction line in containment allow suction from all areas of containment where hydrogen gas could accumulate while accounting for a single failure.

A ventilation survey of containment will be performed upon completion of containment construction and assembly of the enclosed equipment. This survey will be to verify that no stagnant air pockets exist in containment and the IRWST. If there are pockets of stagnant air where hydrogen could accumulate without local recombiner inlet connections, an inlet line from each of the recombiners will be placed in the high point of each of these stagnant pockets.

Table 6.2.5-1 lists component design parameters for the CHRS. The CHRS flow diagram is shown in Figure 6.2.5-1.

6.2.5 2.1.1 System Operation

The CHRS is started manually within 72 hours after a Loss-of Coolant Accident. By this time, two mobile recombiner skids are aligned and connected to the influent and effluent piping of the CHRS in the Nuclear Annex. The ~~recycle isolation valves are opened and the~~ recombiner units are manually started ~~in a recycle, preoperational, heatup mode by recirculating air. Once this heatup has been satisfactorily completed, the recycle isolation valves are closed~~, and the containment isolation valves and the motor operated valves in ~~of~~ the influent and effluent piping in containment are opened. The system is now in the operational mode and ready to perform its function.

The containment atmosphere is drawn into the recombiner package through the suction header. Hydrogen and oxygen are combined to form water vapor. The process gas is then piped back to containment completing the recombination cycle.

6.2.5.2.1.2 Hydrogen Analyzers

Two redundant hydrogen analyzers are provided. Each analyzer is independent of the recombiners and does not require connection of the recombiners to operate. Each of the analyzers can monitor either of the supply lines from containment. Within 30 minutes after a LOCA, both hydrogen analyzers are manually activated to monitor hydrogen levels and to alert the operators in the Control Room if hydrogen concentration exceeds 3.5%. A redundant analyzer is available should a malfunction occur in one of the analyzers.

After the recombiners are placed in operation, periodic operational checks of hydrogen recombiner performance can be performed. This is accomplished by opening the appropriate analyzer isolation valves and drawing a containment atmosphere sample through the hydrogen analyzer. The recombiner performance is determined by drawing recombiner influent and effluent through the hydrogen analyzer and comparing the hydrogen concentrations. Provisions are also made for periodic checks of hydrogen analyzer performance.

6.2.5.2.1.3 Containment Purging 1

The CHRS provides the capability for post-accident controlled purging of the containment atmosphere to aid in clean-up. The containment air can be routed from the suction header to the annulus via the recombiner bypass line. The air is filtered prior to discharge by the annulus ventilation filter trains. Make-up air to containment is initiated manually using the Containment Low Volume Purge Supply.

6.2.5.2.2 Hydrogen Mitigation System

The hydrogen igniters are placed so as to achieve controlled hydrogen burning. ~~Local areas of potential high hydrogen~~

~~concentrations will have two igniters, one from Group A and one from Group B.~~ Considerations for igniter positioning are as follows:

Replace With Insert 1

~~A. Local positioning at the In-Containment Refueling Water Storage Tank (IRWST) safety valve outlets and the IRWST spillway outlet in the holdup volume, due to hydrogen production from in-vessel oxidation.~~

~~B. Local positioning in the cavity area, due to dry cavity scenario where zirconium and steel are freely oxidized using steam from concrete as a water source.~~

~~C. Vulnerability to damage from a pipe rupture during a LOCA.~~

6.2.5.2.2.~~1~~ 2 Igniter Assembly

Each igniter is an AC powered glow plug powered directly from a step down transformer. Each igniter assembly consists of a 1/8" thick steel enclosure (8" H x 6" W x 8" D) which contains the transformer and all electrical connections and partially encloses the igniter. The enclosure meets National Electrical Manufacturers Association (NEMA) Type 4 specifications for watertight integrity under various environmental conditions, including exposure to water jets. The sealed enclosure incorporates a heat shield to minimize the temperature rise inside the igniter assembly, and a spray shield to reduce water impingement on the glow plug from above. The igniter assembly is designed to meet Seismic Category I requirements.

6.2.5.2.2.~~2~~ 3 Igniter Power Supply

The HMS igniters are equally divided into two redundant groups, having separate circuits and circuit breakers in each group. The number of igniters on each circuit ranges from 1 to 10. Each group has independent and separate control, power and igniter locations to ensure adequate coverage in the event of a single failure. The igniters are manually actuated from the Control Room. I

The igniters are powered from the Class 1E 120 VAC Vital Instrumentation and Control Power System (Section 8.3.2.1.2.1) that has normal and alternative power supplies from offsite sources. In the event of a loss of offsite power, the igniters will be powered from the emergency diesel generators. Group A igniters will be powered from the Division I diesel generator and group B igniters from the Division II diesel generator. On loss of offsite power and failure of the emergency diesel generators to start or run

A. Hydrogen released to the In-containment Refueling Water Storage Tank (IRWST) produced from in-vessel oxidation.

B. Ex-vessel hydrogen production.

C. Local positioning in the reactor cavity, due to dry cavity scenario where zirconium and steel are oxidized using steam from the concrete as a water source.

D. Potential areas of hydrogen pocketing.

E. Vulnerability to damage from a pipe rupture during a LOCA.

F. Accessibility for maintenance and testing.

6.2.5.2.2.1 Igniter Locations

The hydrogen igniters are positioned to burn hydrogen locally near the sources and globally in areas where hydrogen could accumulate. Each igniter location consists of two igniters, one from group A and one from group B. A total of forty-two igniters are distributed throughout the containment at the twenty-one locations listed in Table 6.2.5-8. These locations are approximate, based on equipment and piping proximity, as well as inspection and maintenance access.

(Station Blackout), the igniters can be powered from the alternate AC source gas turbine ~~generator~~ or the ~~station emergency~~ Class 1E batteries via DC-to-AC inverters.

6.2.5.2.2.~~3~~4 System Actuation

~~The~~ Station Severe Accident Management ~~Emergency~~ Procedures ~~(EPs)~~ for responding to severe accidents will include instructions for actuating the hydrogen igniters ~~. The Severe Accident Management Procedures~~ and will address actuating and securing the igniters in the later stages of the accident.

6.2.5.3 Design Evaluation

6.2.5.3.1 Containment Hydrogen Recombiner System

Since only one of the two completely separate recombiner loops is required, a single active failure will not prevent the recombiners from fulfilling their design function. The CHRS is in operation only during specified emergency conditions and not during normal plant operation. This system is, therefore, considered not subject to postulated passive failures. The system, as designed, can be periodically pressure tested to verify leak tightness. The effluent from this test can be vented to containment. IEEE Std. 279-1971, "Criteria for Protection Systems for Nuclear Power Plants" is applicable to automatically actuated protective systems. Since the hydrogen recombiner system is manually actuated and need only be placed in operation within 72 hours following a LOCA, the requirements of IEEE Std. 279-1971 are not applicable. However, the guidance of Section 4 was used in the system design as follows:

"4.2 Single Failure Criterion"

Any single active failure within the system will not prevent proper action at the system level when required.

"4.3 Quality of Components and Modules"

Quality levels shall be achieved through the specification of requirements known to promote high quality, such as requirements for design, rating of components, manufacturing, quality control, inspection, calibration, and testing.

"4.4 Equipment Qualifications"

Tests shall be conducted to verify the performance requirements determined to be necessary for achieving the system requirements. See Section 6.2.5.4.1.

"4.5 Channel Integrity"

Both loops have been designed to maintain necessary functional capability under appropriate extreme conditions.

"4.6 Channel Independence"

Each recombiner loop is completely independent and physically separate.

"4.10 Capability for Test and Calibration"

Capability has been provided for testing and calibrating both loops during power operation. See Section 6.2.5.4.1.

The Containment Hydrogen Recombiner System is supplied power by a Class 1E electrical system which meets the requirements of IEEE 308-1972. Failure of one emergency diesel generator will not preclude the function of the other redundant CHRS train.

As stated in Regulatory Guide 1.7, the lower flammability limit for hydrogen in air saturated with water vapor at room temperature and atmospheric pressure is approximately four percent by volume. For these conditions, detonation does not occur until a much higher concentration is attained; the CHRS design limit of 4% by volume is far below the detonation point.

The portable recombiner skid and control panel skid will be situated in a shielded area such that the radiation level associated with post-LOCA conditions does not prevent personnel from manually operating the system, performing periodic inspection of the control panel skid, or sampling.

The CHRS failure modes and effects analysis is contained in Table 6.2.5-7.

Figures 6.2.5-2 and 6.2.5-3 indicate post-LOCA hydrogen concentration versus time both with and without a single recombiner in operation for containment and the IRWST. These figures show that a single 100 cfm recombiner, initiated 72 hours following a LOCA is capable of maintaining hydrogen concentration below the 4 percent by volume limit. I

~~6.2.5.2.1.1 Design Evaluation~~

The conservatism of the hydrogen production and accumulation analysis is assured by the following:

A. Limiting the amount of zinc and aluminum ~~materials~~ inside containment such that the resulting hydrogen generated is less than predicted.

B. Using conservative values for aluminum and zinc corrosion rates.

C. Using maximum value of fuel cladding zirconium-water reaction.

D. Using maximum hydrogen yield rates for radiolytic decay of fission products.

~~Uniform~~ Forced mixing of the containment atmosphere to prevent hydrogen pockets is not required since all potential stagnant air pockets are eliminated by venting them upward through open grating and vents as required. If any potential pockets are identified which cannot be vented upward they will be provided with suction lines to the recombiners.

Redundant hydrogen analyzers are provided for monitoring of the post-LOCA containment atmosphere. Each hydrogen analyzer is functionally independent of its associated hydrogen recombiner.

The portable portions of the CHRS are the hydrogen recombiner and control panel skids. Piping connections between portable and permanent portions of the system are equipped with flanges as shown in Figure 6.2.5-1. Blank flanges can be used when the recombiners are not in use to provide added isolation capability.

Electrical connections between portable and permanent portions of the system are equipped with quick disconnects. The portable skids are anticipated to be stored in place at each site with appropriate access to facilitate portability.

Suction points for the CHRS are provided in the upper portion of containment and the IRWST. Each recombiner's associated suction piping will be routed downward on opposite sides of containment. Suction piping is protected from dynamic effects such as missiles and pipe whip by maintaining physical separation. An analysis of postulated pipe breaks will be performed as described in Section 3.6 to further assure the adequacy of the routing.

The CHRS also provides the capability of hydrogen purging to allow cleanup of the post-accident containment atmosphere via the annulus ventilation filter trains.

6.2.5.3.2 Hydrogen Mitigation System

The HMS is non-safety related, but has the capability of being powered from the Class 1E gas turbine or alternate AC source emergency diesel generators or emergency batteries via inverters for reliability. HMS components in containment are designed to meet seismic Category I requirements.

The requirements of 10 CFR 50.34(f) are highly conservative in both the hydrogen concentration limit and the amount of fuel clad metal-water reaction ~~(MWR)~~ postulated. Steam present in containment and the open containment design provide additional design margin.

The igniters are positioned in areas of potential high hydrogen concentration, and each of these areas has at least two igniters with separate power supplies.

6.2.5.4 Testing and Inspections

6.2.5.4.1 Containment Hydrogen Recombiner System

Components of the CHRS can be inspected and, with the exception of the isolation valves inside containment, are accessible for maintenance during normal plant operation.

Instrumentation accuracy will be provided by instrumentation calibration as required under the facility maintenance procedures. Hydrogen analyzers will be calibrated against samples of known hydrogen concentrations to verify their accuracy.

The recombiner vendor will perform a full scale demonstration test as part of the process of obtaining NRC certification for the recombiner and control panel skid packages. The CHRS will incorporate recombiner and control panel skid packages which are equivalent to the one certified by the NRC.

Each recombiner unit will be functionally tested at the vendor's site prior to shipment. The operating conditions will be the maximum values from Table 6.2.5-1 of inlet temperature, pressure, external pressure drop, and hydrogen concentration. The test will include normal startup, operating steady state, and normal shutdown. The recombiner will meet the ~~minimum~~ flow rate ~~limit~~ specified in Table 6.2.5-1 for a minimum time interval of 15 minutes of steady state operation. I

Upon delivery of the recombiner and control panel skid packages and afterwards periodically, the following tests will be performed:

A. Safety valves will be tested in the context of a plantwide program for safety and relief valve testing.

B. At each scheduled refueling, but not less than once every two years, the following tests will be performed:

1. All valves with remote position indicators, which during power operation are inaccessible for direct observation shall be visually observed to confirm that remote valve indication accurately reflects valve operation.

2. The CHRS will be pressurized to test system integrity.

3. The CHRS will be brought into a recycle, preoperational heatup mode by the procedures given in Section 6.2.5.2.1.1 to check recombiner operation.

4. When the CHRS reaches operating conditions, hydrogen at a known rate and concentration will be added at the hydrogen test connection to verify recombiner operability with the hydrogen analyzer.

C. At least once every three months all valves will be exercised. The necessary valve stem or disk movement shall be established by exercising the valve while observing an appropriate indicator which signals the required change in position. The startup air and containment isolation check valves will be tested by connecting a pressurized air source with a flow indicator to the startup air line. The valves between the pressure source and the return line to containment will then be opened. A positive flow indicates that the check valves are opening properly.

6.2.5.4.2 Hydrogen Mitigation System

Preoperational testing, to be performed before startup, will verify that the electric current drawn by each group of igniters is within tolerance, and that the temperature of each igniter is at least 1700°F. The current measured in each circuit during preoperational tests provides the baseline for future surveillance tests.

The igniter system will be subjected to surveillance testing on a quarterly basis. This testing will consist of energizing the HMS and taking current and voltage readings of the igniter circuits. If the power consumption is not comparable with that measured during preoperational testing, the igniters on the affected circuits will be individually inspected to ensure their operability. In addition to power consumption measurements, the temperature of each igniter will be measured ~~at least every 18 months~~ during each refueling outage to verify a minimum temperature of 1700°F.

6.2.5.5 Instrumentation Requirements

6.2.5.5.1 Containment Hydrogen Recombiner System

The recombiner skid package is capable of operating ~~provided with automatic control to enable it to operate~~ under varying containment atmosphere conditions. The unit gas flow is monitored and gas temperature is monitored at various points on the unit control panel. ~~The recombiner bed temperature is used to control gas feed.~~

The recombiner fan and heater are protected against high temperature by flow and temperature control instrumentation.

Instrumentation and control are provided for isolation of the CHRS through closure of the influent piping motor operated valves inside and outside of containment upon receipt of a Containment Isolation Actuation Signal (CIAS).

Hydrogen concentration is monitored in the Control Room from the hydrogen analyzers. An alarm is actuated in the Control Room if hydrogen concentration exceeds 3.5%.

6.2.5.5.2 Hydrogen Mitigation System

Indication and control for the HMS igniters are located in the Control Room. Temperature indication is provided for igniter operability testing.

6.2.5.6 Materials

Materials used in the CHRS and HMS are compatible with the containment atmosphere and the nuclear environment by the following means:

A. Components will be fabricated from austenitic stainless steel, type 316, 304, or equivalent.

B. None of the materials except elastomers and lubricants used are subject to decomposition by the radiation or thermal environment. The specifications require that the materials be unaffected when exposed to the equipment design temperature and the total integrated radiation dose.

C. Materials such as elastomers and lubricants that may reach their damage threshold by exposure to the specified environment will be replaced during routine maintenance.

D. Materials of the CHRS are compatible with the containment atmosphere composition and chemistry during normal operations and during design basis accident conditions.

TABLE 6.2.5-1

CONTAINMENT HYDROGEN RECOMBINER SYSTEM PARAMETERS

Parameter	Value	
Number of Recombiners	2	
Flow Rate per Recombiner, cfm	100	I
Design Pressure, psig	60	
Design Influent Temperature, °F	300	
Design Radiation Level, Rads	~~3.3×10^7~~	
Recombiner	1.0×10^7	
Recombiner Blower Motor	1.0×10^8	
Control Panel	3.0×10^6	
Hydrogen Concentration Limit, Percent by volume	4%	

TABLE 6.2.5-2

HYDROGEN PRODUCTION PARAMETERS

Parameter	Value
Reactor Power (Full power plus 2% uncertainty), MWt	3876
Reactor Operating Time, Months	18
Containment Net Free Volume (Minimum), ft^3	3.377×10^6
IRWST Freeboard Volume (Design basis LOCA), ft^3	1.032×10^5
Initial Temperature, °F	110
Initial Pressure, psia	15.1
Initial Relative Humidity	10%
Cladding Zirconium Mass (Surrounding active fuel), lbm	53,123
Dissolved Hydrogen in Reactor Coolant (Maximum), cc(STP) per kg of water	100
Dissolved Hydrogen in Pressurizer Steam Space (Maximum), by Weight	2/10 of 1%

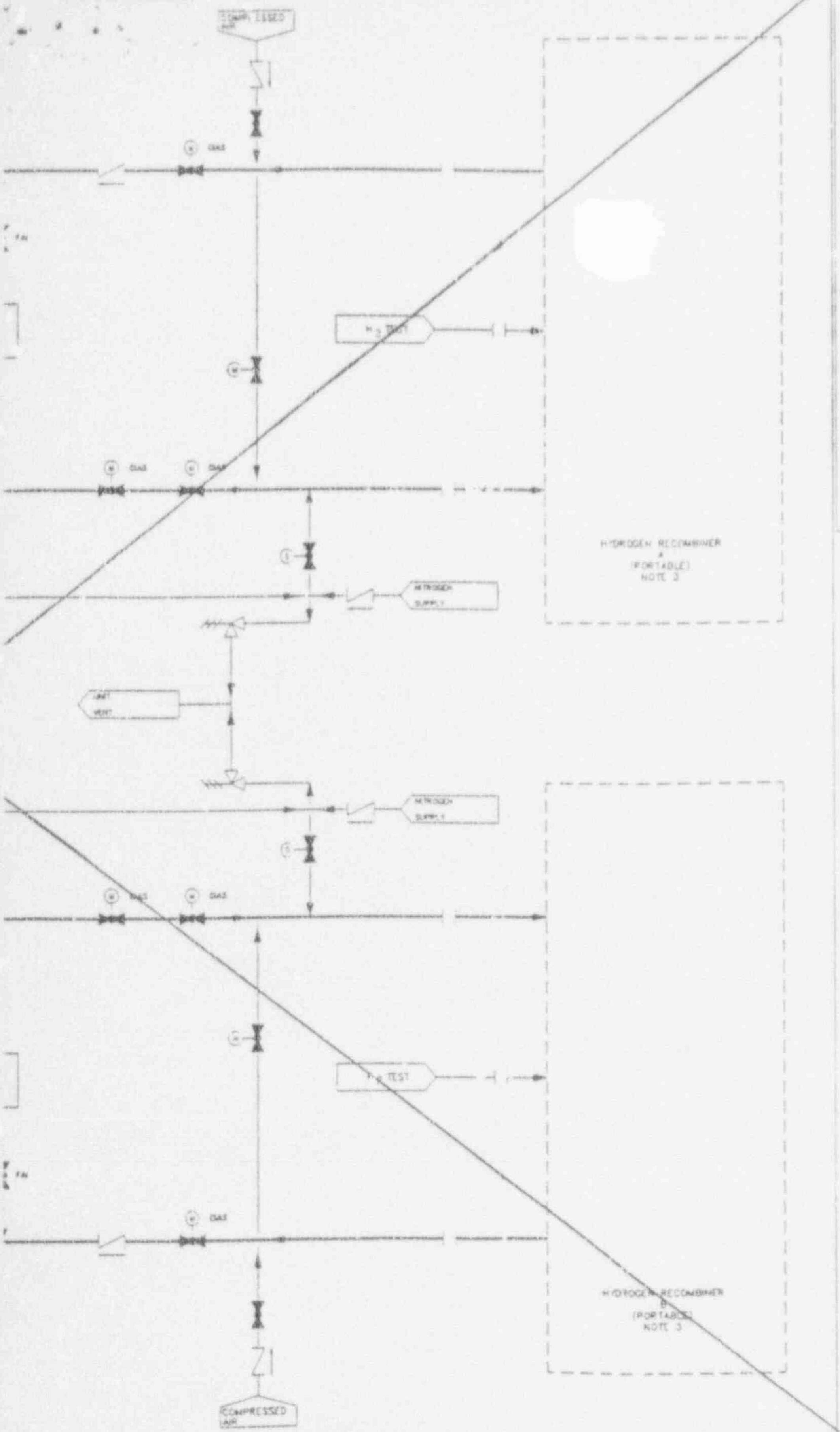
INSERT 2 CESSAR-DC, Table 6.2.5-8 (New)

TABLE 6.2.5-8

HYDROGEN MITIGATION SYSTEM IGNITER LOCATIONS

REGION COVERED	ELEVATION	RADIAL LOCATION	AZIMUTH
Reactor Cavity	94 ft.	43 ft.	8°
91+9 Elevation	100 ft.	52 ft.	70°
91+9 Elevation	100 ft.	47 ft.	130°
91+9 Elevation	100 ft.	47 ft.	230°
91+9 Elevation	100 ft.	47 ft.	310°
HVAC Distribution Header	100 ft.	69 ft.	8°
HVAC Distribution Header	100 ft.	69 ft.	105°
HVAC Distribution Header	100 ft.	69 ft.	185°
HVAC Distribution Header	100 ft.	69 ft.	275°
Letdown HX Room	100 ft.	65 ft.	150°
Regenerative HX Room	100 ft.	60 ft.	200°
Outside Crane Wall	125 ft.	69 ft.	25°
Outside Crane Wall	125 ft.	69 ft.	142°
Outside Crane Wall	125 ft.	69 ft.	225°
Outside Crane Wall	125 ft.	69 ft.	310°
Dome	192 ft	46 ft.	90°
Dome	192 ft.	46 ft.	270°
Dome	252 ft.	24 ft.	0°
Dome	252 ft.	24 ft.	90°
Dome	252 ft.	24 ft.	180°
Dome	252 ft.	24 ft.	270°

Attachment ALWR-410



NOTES:

1. TYPICAL CONFIGURATION. THE EXACT NUMBER OF SUCTIONS DETERMINED BY CONTAINMENT GEOMETRY. ONE SUCTION LINE TO EACH RECOMBINER LOOP AT EACH REGION OF CONTAINMENT WHERE HYDROGEN COULD ACCUMULATE.
2. ANALYZER FOR EACH SENSOR LOCATED IN A SHIELDED AREA.
3. POWER AND INSTRUMENT CABLES FOR EACH RECOMBINER TO BE ROUTED TO A PORTABLE CONTROL PANEL IN A SHIELDED AREA.
4. VENT, DRAIN, AND TEST CONNECTION LOCATIONS CONTINGENT ON PIPE ROUTING.

See LD-92-048

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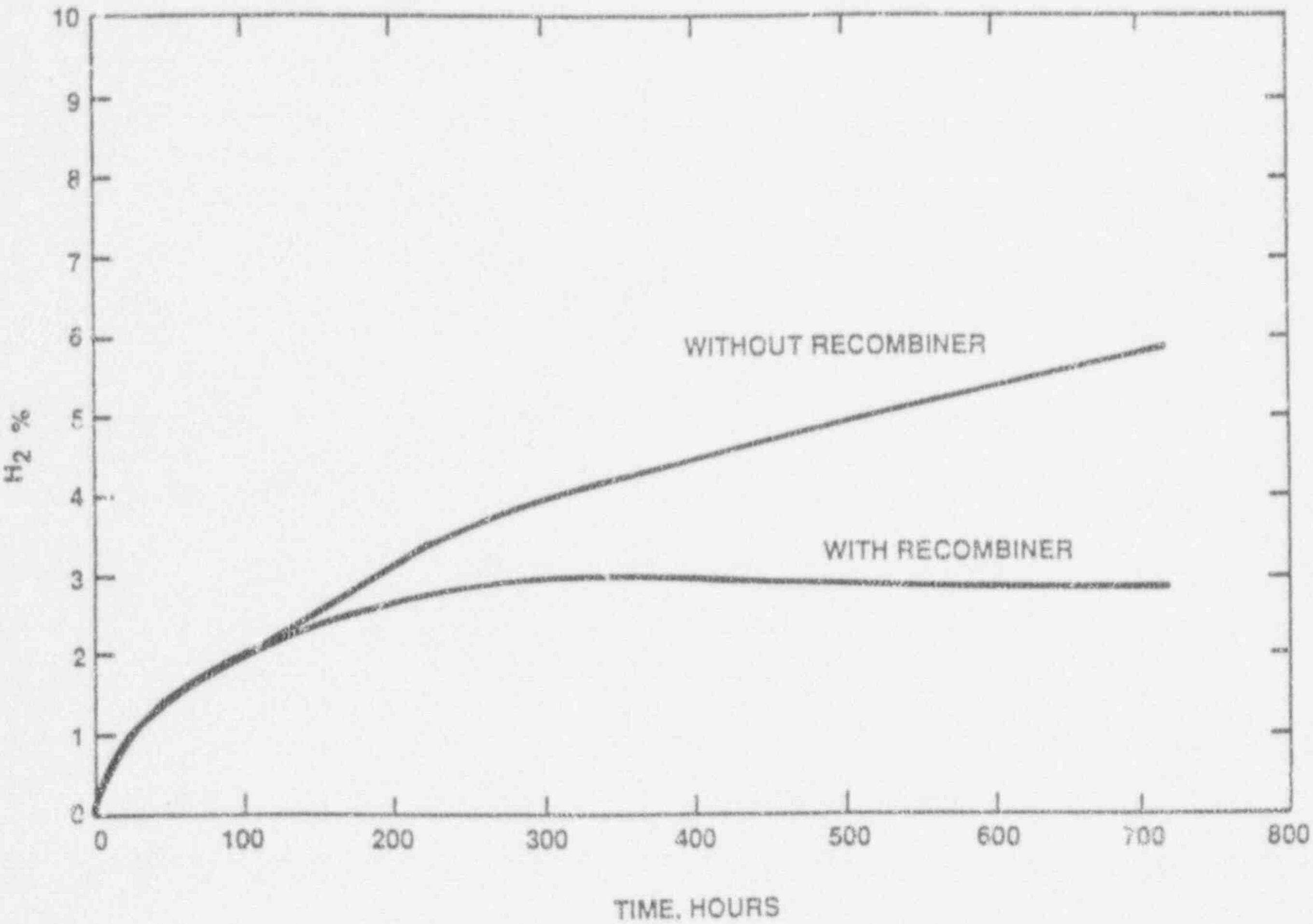
SYSTEM 80+™	CONTAINMENT HYDROGEN RECOMBINER SYSTEM (CHRS) FLOW DIAGRAM	Figure 6.2.5-1



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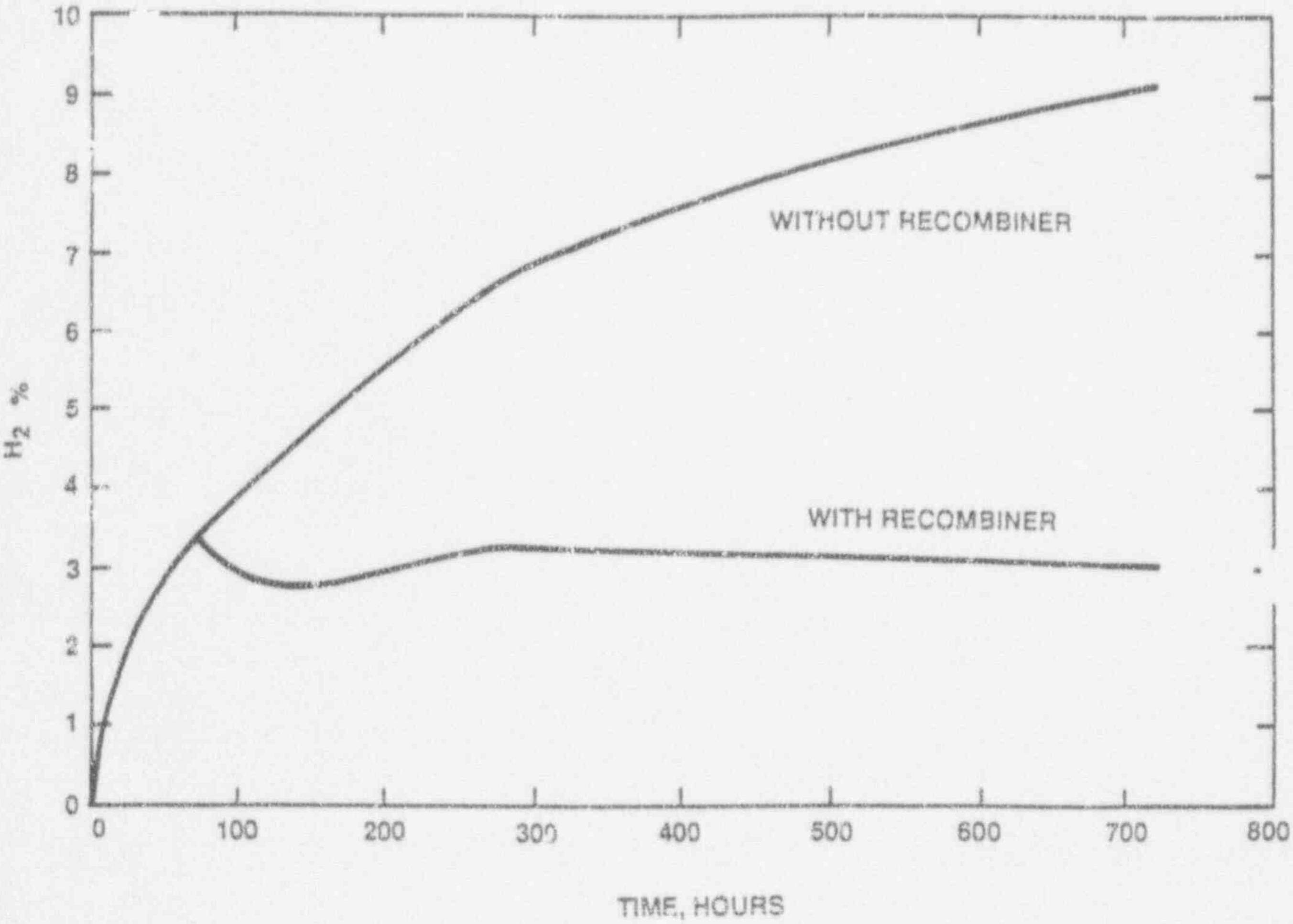
SYSTEM 80+™	CONTAINMENT HYDROGEN CONCENTRATION vs TIME AFTER LOCA (WITHOUT RECOMBINERS AND WITH A SINGLE RECOMBINER START TIME OF 72 HOURS)	Figure 6.2.5-2



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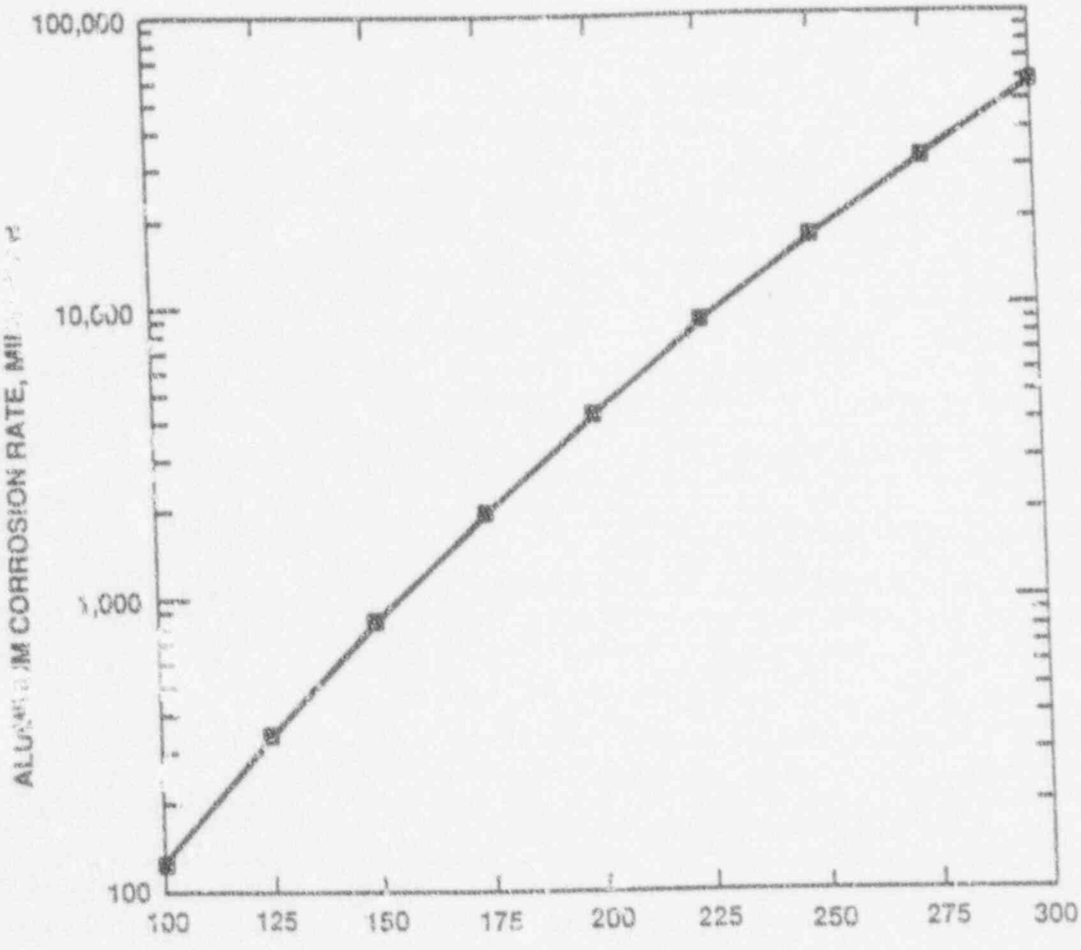
SYSTEM 80+™	IRWST HYDROGEN CONCENTRATION vs TIME AFTER LOCA (WITHOUT RECOMBINERS AND WITH A SINGLE RECOMBINER START TIME OF 72 HOURS)	Figure 6.2.5-3



ALUMINUM CORROSION RATES BASED ON ANSI N-275, DRAFT 10.

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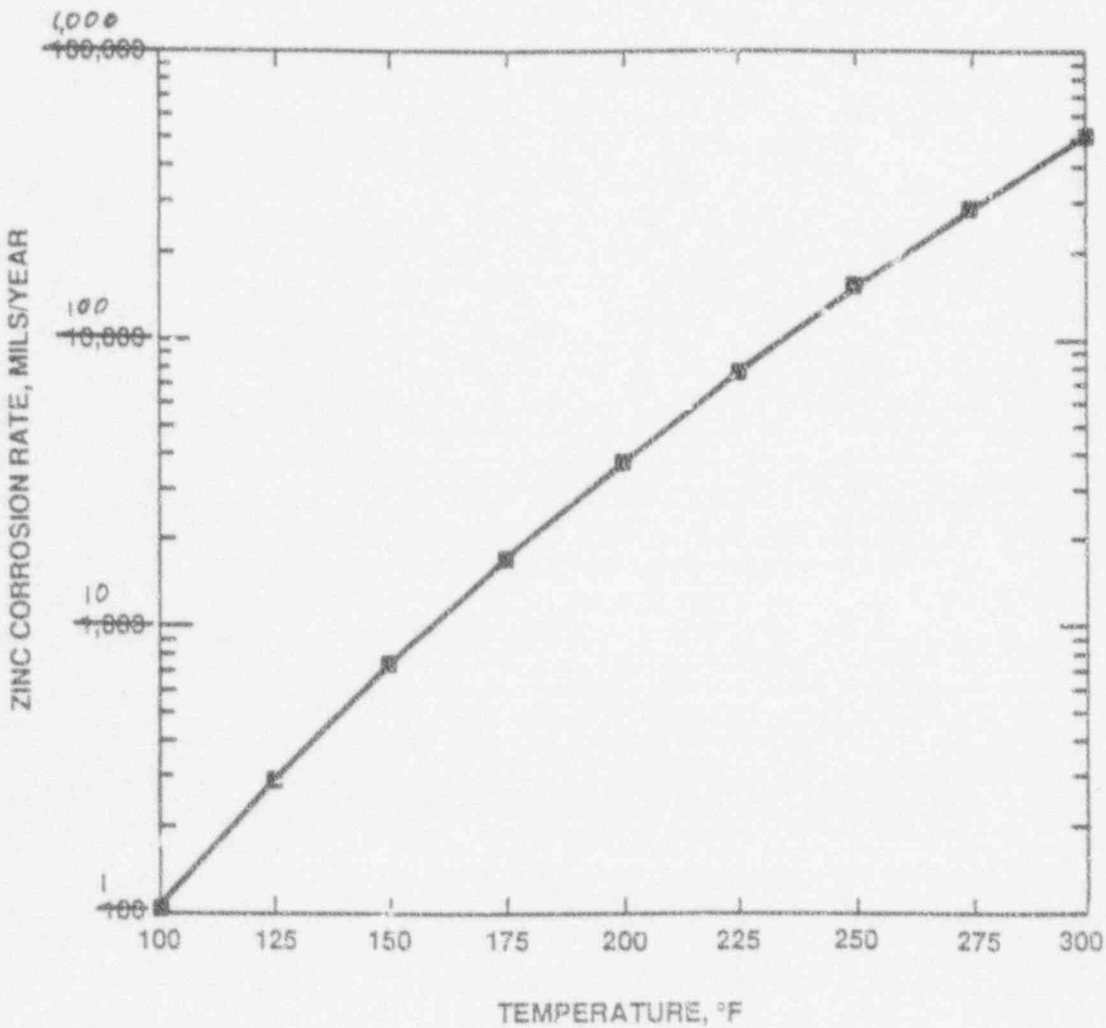
SYSTEM 80+™	ALUMINUM CORROSION RATE vs TEMPERATURE	Figure 6.2.5-4



ZINC CORROSION RATES BASED ON ANSI N-275, DRAFT 10