UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

October 17, 1978

MEMORANDUM FOR: Roger S. Boyd, Director, Division of Project Management

FROM: Roger J. Mattson, Director, Division of Systems Safety

SUBJECT: POST-LOCA HYDROGEN PRODUCTION FROM MATERIALS INSIDE CONTAINMENT

References: (1) Memorandum to D. B. Vassallo from C. O. Thomas, "Recommended Licensing Board Notification - Post-LOCA Hydrogen Generation from Materials Inside Containment dated August 24, 1978;

(2) Memorandum for Robert L. Tedesco from W. R. Butler, "Post-LOCA Hydrogen Generation from Zinc," dated September 20, 1978; and

(3) Memorandum for W. R. Butler from F. Eltawila through J. Kudrick, "Hydrogen Generation in Mark II Containment Due to Zinc Corrosion," dated September 20, 1978

In Reference (1) Mr. Thomas indicated that the post-LOCA hydrogen production due to corrosion of materials inside the primary containment, (such as aluminum and zinc) and the thermal, chemical, and radiolytic decomposition of organic components in protective coating systems may not have been adequately considered in the evaluation of combustible gas control systems and recommended notification of appropriate hearing boards. The effects of the matters discussed in Reference (1) have been conservatively evaluated to assess the potential for significant hydrogen generation due to the presence of the stated materials, i.e., conservative values were used for the hydrogen generation rates from galvanized steel and zinc-based coatings [provided by MTEB] in a post-LOCA environment and to evaluate the potential consequences on the design of hydrogen control systems in both BWR and PWR containments. A brief summary of the effects of these aspects as potentially additional contributors of hydrogen production follows:

DECOMPOSITION OF ORGANICS: A substantial amount of organic materials is used in protective coating systems, including those over zinc-based primer paints inside PWR and BWR containments. When exposed to the LOCA environment (high temperature, chemical, and radiation fields), these organic materials undergo a process of decomposition to form hydrogen and hydrocarbons. The Accident Analysis Branch (DSE) has estimated the resultant hydrogen and hydrocarbon concentrations resulting from the radiolytic decomposition of organics and the thermal and chemical reaction of organic coatings on concrete surfaces. Assuming a conservatively integrated radiation exposure of 10^8 rads, the Accident Analysis Branch (AAB) estimates the hydrogen concentration due to radiolytic decomposition of organic coatings to be less than 0.4% for PWR's and less than 0.2% for BWR's. For hydrogen generation due to thermal and chemical reaction of organic coatings on painted concrete surfaces the AAB estimates the resultant hydrogen concentration to be less than 0.3% for PWR's and less than .2% for BWR's. If we sum these hydrogen contributions from organic materials which were heretofore not included in our analyses, the additional hydrogen represents roughly a 10% increase in the hydrogen generated from all sources previously considered; i.e., zirconium water reaction, radiolysis of water, and oxidation of zinc with its organic topcoat during the post-LOCA period.

Since there will be a large amount of water, relative to the amount of organic materials, it can be concluded that the hydrogen gas generated from radiolysis of water should dominate that from decomposition of the organic materials.

CORROSION OF ZINC IN PRESSURE SUPPRESSION CONTAINMENTS: The hydrogen generation from galvanized steel and zinc-based primers is a strong function of the containment temperature history following a LOCA. For ice pressure suppression containments the post-LOCA temperature profiles have been found to be sufficiently low that the hydrogen generation from zinc-rich coatings does not jeopardize the capability of the hydrogen recombiner systems. Furthermore, for BWR containments, where the hydrogen concentration is predicted to peak within a few hours after accident initiation, there is not sufficient time for the hydrogen generation from the zinc-rich coatings to cause the hydrogen concentration to exceed the 4% flammable limit before recombiner actuation or shortly thereafter.

CORROSION OF ZINC IN DRY CONTAINMENTS: Because of the uncertainty in the hydrogen generation rates, calculations were performed to determine the impact of the uncertainty on the recombiner systems for several PWR plants (see Enclosure 3). The hydrogen generation rate curve for galvanized steel (provided by MTEB) was increased by a factor of 2.0 to bound the available experimental data for galvanized steel. This increase in the corrosion rate would only result in a very slight increase in the hydrogen concentration but would yield a H_2 concentration slightly in excess of 4% for Yellow Creek. In most cases, the recombiner systems had the capability of maintaining the hydrogen concentration below the 4% flammable limit by actuating earlier in the post-LOCA period.

In the analysis performed for the Yellow Creek plant, the hydrogen concentration would reach a peak value of about 4.13%; however, giving credit to the diluting effect of the steam in the containment atmosphere following a LOCA shows that the hydrogen concentration would not exceed the 4% flammable limit.

While it is our view that no safety concern is involved as a result of our using the updated hydrogen generation rates for zinc-rich coatings, we find that there is sufficient justification to warrant further staff effort toward examining the generation of hydrogen from zinc-rich paints and organic materials. A more refined knowledge of the behavior of these materials would increase our confidence in this area of review. We plan to prepare a User's Request to have RSR undertake studies in such areas as: 1) the impact of uncertainties in the hydrogen generation rates on the analyses of hydrogen accumulation in PWR dry containments including an assessment of the inherent conservatisms in such analyses (see Enclosure 3); and 2) the relative importance of the decomposition of organic materials as a source of hydrogen in containments.

In summary, we find that the effects evaluated regarding post-LOCA generation of hydrogen in both BWR and PWR pressure suppression type containments do not lead to new significant safety concerns not already being considered in our current safety reviews.

Since this matter was not explicitly considered in our reviews until recently, I agree that notification of appropriate licensing boards may be appropriate.

Roger J. Mattson, Director
Division of Systems Safety
Office of Nuclear Reactor Regulation

Enclosures:
As Stated

cc: See page 4

cc: H. Denton
R. Mattson
R. DeYoung
V. Stello
D. Eisenhut
B. Grimes
J. Knight
R. Tedesco
J. Glynn
D. Vassallo
W. Butler
C. Thomas
J. Kudrick
F. Eltawila
S. Pawlicki
W. Houston

Enclosure 1
(Reference 2)

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SEP 2 0 1978

MEMORANDUM FOR: Robert L. Tedesco, Assistant Director for Plant Systems. DSS

FROM: W. R. Butler, Chief, Containment Systems Branch, DSS

SUBJECT: POST LOCA HYDROGEN GENERATION FROM ZINC

Reference: Memo for R. Tedesco from S. Pawlicki, "Hydrogen Generation Rates after LOCA," March 15, 1978

We have received from the MTEB updated data, included in Attachment 1, on hydrogen generation resulting from the corrosion of zinc and zinc-based coatings. These data are in the form of hydrogen generation rates as a function of temperature. The purpose of this memorandum is to report the results of a study to determine the impact of using these revised MTEB hydrogen generation rates in our hydrogen control analyses.

Our hydrogen control analyses were performed using the COGAP 2 code for five selected plants to gauge the effect of the hydrogen generation rates. The plants selected and their pertinent input parameters are shown in Table 1. All of the plants included in the study are reported to have a substantial quantity of zinc inside containment. For example, San Onofre, which has the smallest reported mass of zinc, still has enough zinc to produce a 4% H_2 concentration, assuming all of the zinc reacts instantaneously to produce hydrogen. Therefore, it is important to accurately represent the rate at which the zinc reacts to produce hydrogen.

Figure 1 presents the calculated hydrogen concentration transients for the three dry containment plants (PWR) included in the study. For these analyses the recombiner actuation times, shown on Figure 1, were taken from the applicants' SAR, with the exception of the Yellow Creek plant, for which the recombiners were arbitrarily started one day after the postulated LOCA. As can be seen from Figure 1, all of the plants maintain the hydrogen concentration below the lower flammability limit.

Contact:
C. Tinkler, CSB
492-7711

Figure 2 presents the calculated hydrogen concentration transient for the Watts Bar ice condenser containment plant. Even though this plant contains a large mass of zinc, in the form of galvanized metal, the hydrogen concentration is maintained well below the flammability limit. The effect of the large zinc mass is mitigated by the relatively low containment atmosphere temperature post-LOCA, which results in a slower hydrogen generation rate. This lower generation rate can be accommodated by the recombiners.

Figure 3 presents the calculated hydrogen concentration transient for the Hatch 2 plant (Mark I containment) using our estimates of zinc inside the containment since this information was not supplied by the applicant. Figure 3 also presents a comparison with a calculated hydrogen transient assuming no zinc was present. Figure 4 shows the post-LOCA temperature transient used to determine the zinc corrosion rates. It is apparent from the analyses performed that the effect of zinc, at least in the manner considered, was minimal for the Hatch 2 plant. This is probably due to the small surface area of zinc assumed to exist in the drywell and the relatively low post-accident temperature transient throughout the containment.

Attachment 2 provides the results of analyses performed for the Susquehanna plant (Mark II containment), which considered zinc corrosion and subsequent hydrogen production. In summary, the conservative analyses performed for Susquehanna demonstrate that the hydrogen concentration remains below the flammability limit. An evaluation of the design parameters for Mark III containments leads us to conclude similarly on the effect of zinc corrosion for these plants.

As a result of our analyses, we conclude that the effect of using the MTEB hydrogen generation rates to model the corrosion of zinc does not produce hydrogen concentrations above the flammability limit. In general, the effect of using the updated zinc corrosion rates on the plants considered would be limited to decreasing the required recombiner actuation time. However, there are uncertainties associated with these analyses, several of which are listed below:

1. The MTEB hydrogen generation rates for the corrosion of galvanized steel are portrayed as "realistic" (see Attachment 1) and as such do not represent conservative or bounding values.

2. There is little experimental evidence to determine the effect of the spray or sump water chemistry or pH upon zinc corrosion rates.

3. The actual quantities of zinc present in the BWR plants are not known.

4. The entire curve for hydrogen generation from zinc based paint is derived from one experimental data point with the slope of the line assumed to be equal to the slope of the curve for galvanized steel.

Although our findings with the updated corrosion rates for zinc do not appear to represent a safety hazard, it is our view that there is sufficient justification to warrant the continuation of staff efforts toward examining the generation of hydrogen from the reaction of materials inside containment.

Walter R. Butler

Walter R. Butler, Chief
Containment Systems Branch
Division of Systems Safety

Attachments:
As stated

cc: J. Shapaker
J. Kudrick
S. Brown
F. Eltawila
W. Milstead

Table 1

Plant	NSSS	Thermal Rating (Mwt)	Volume (ft^3)	Zirconium Mass Reacted	Mass and Surface Area of Zinc in Containment	
					Zinc Paint	Galvanized Metal
Yellow Creek	CE	4100.	3,580,000	3750 lb.	15,000 lb /360,000 ft^2	10,940 lb /140,000 ft^2
Erie	B&W	3876.	2,400,000	2600 lb.	20,875 lb /187,000 ft^2	7,000 lb /56,000 ft^2
San Onofre 2 & 3	CE	3560.	2,305,000	2500 lb.	850 lb /6,700 ft^2	15,600 lb /138,000 ft^2
Watts Bar	W	3565.	1,230,000	648 lb.	None	59,200 lb /336,000 ft^2
Hatch - 2	GE					
Drywell		2537.	146,266	560 lb.	6,710 lb /18,048 ft^2	None
Wetwell			109,712		22,980 lb /61,823 ft^2	None

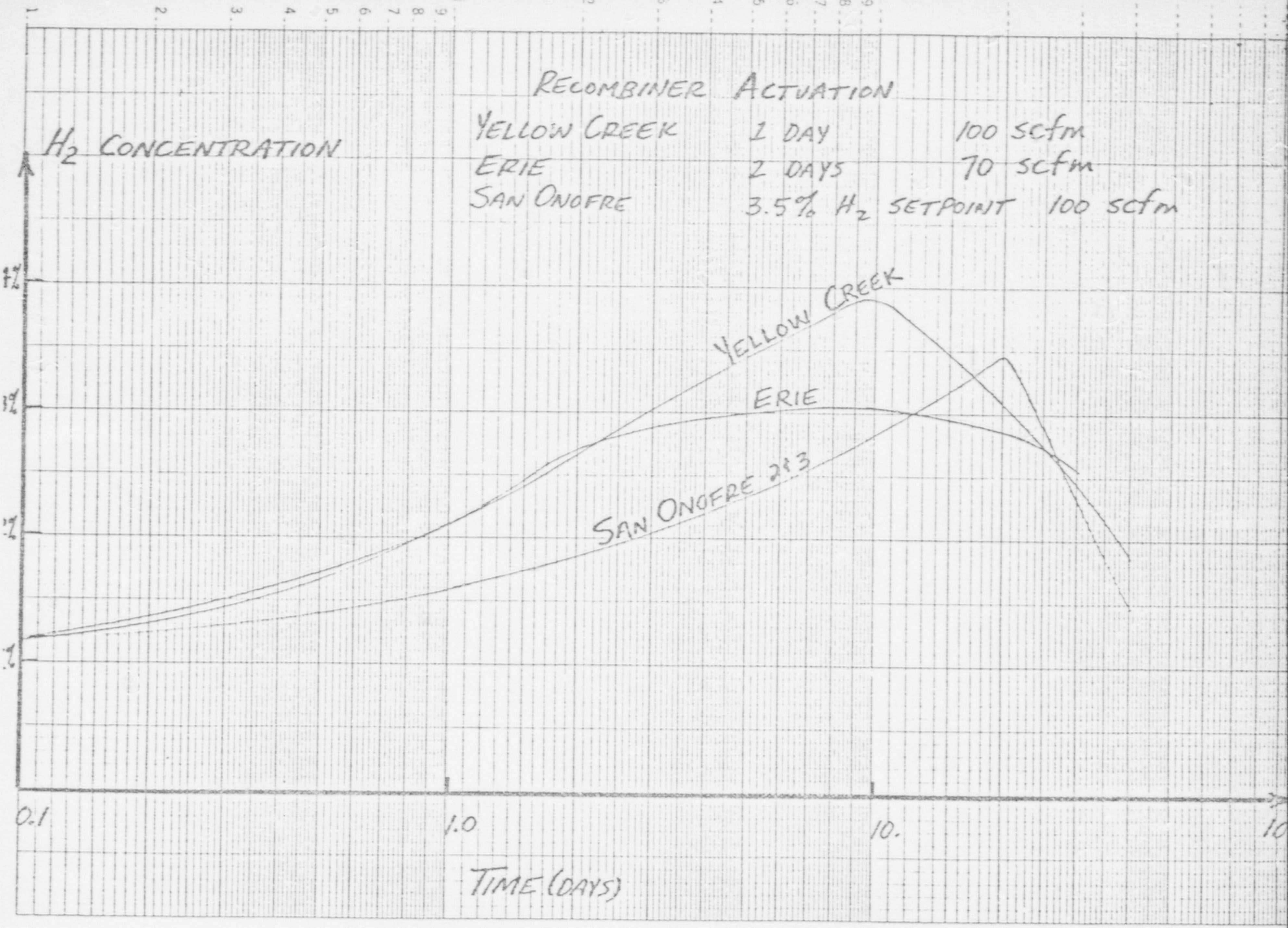


FIGURE 1 H_2 TRANSIENTS FOR PWR DRY CONTAINMENT

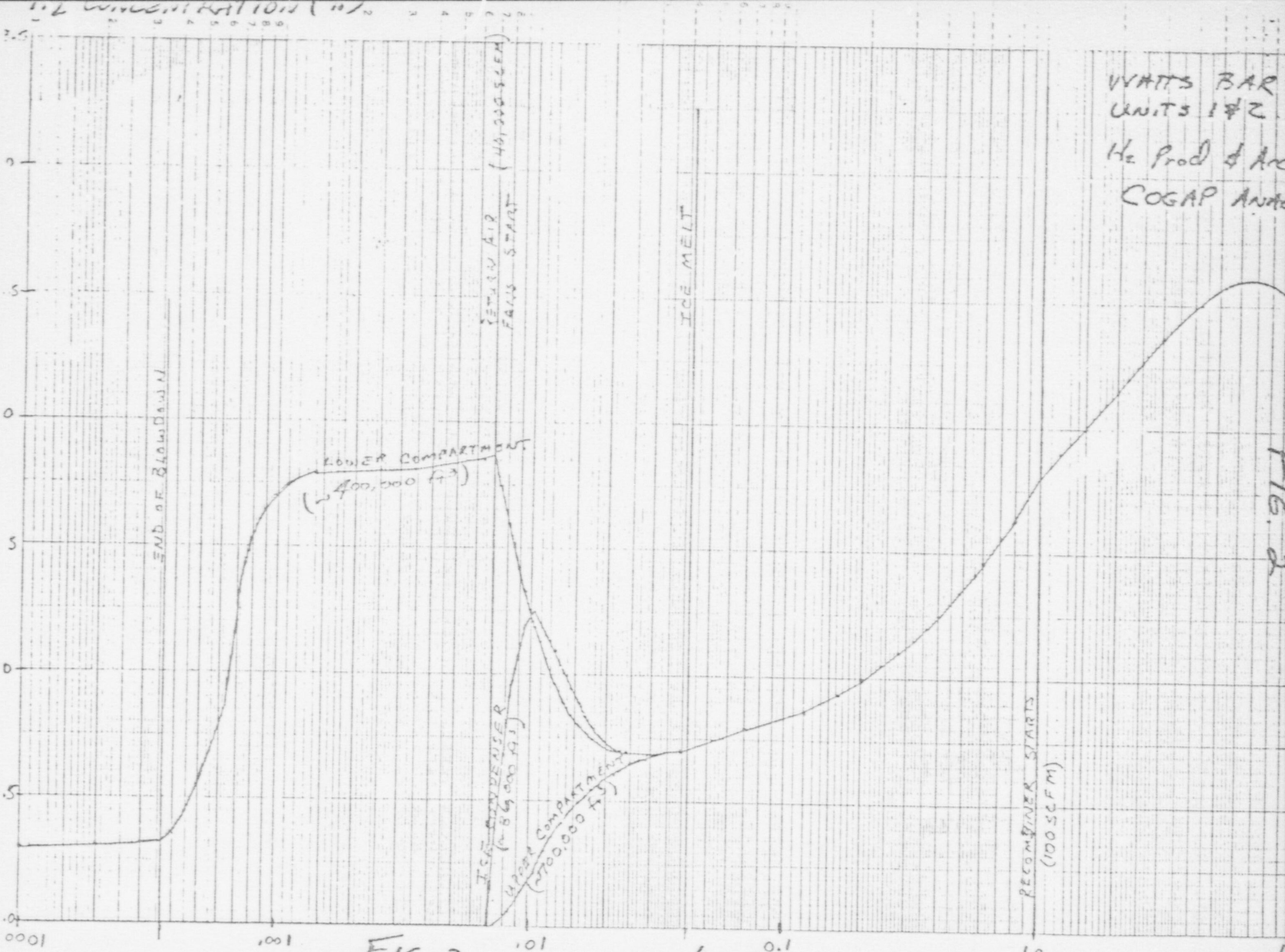

WATTS BAR
UNITS 1 & 2
H2 Prod & Acc
COGAP ANAL
H2 CONCENTRATION (%)
END OF BLOWDOWN
LOWER COMPARTMENT
(~400,000 ft3)
RETURN AIR FANS START (40,000 SCFM)
ICE MELT
ICE CONDENSER (~86,000 ft3)
UPPER COMPARTMENT (~700,000 ft3)
RECOMBINER STARTS (100 SCFM)
.0001
.001
.01
0.1
1.0
TIME (DAYS)

FIG. 2

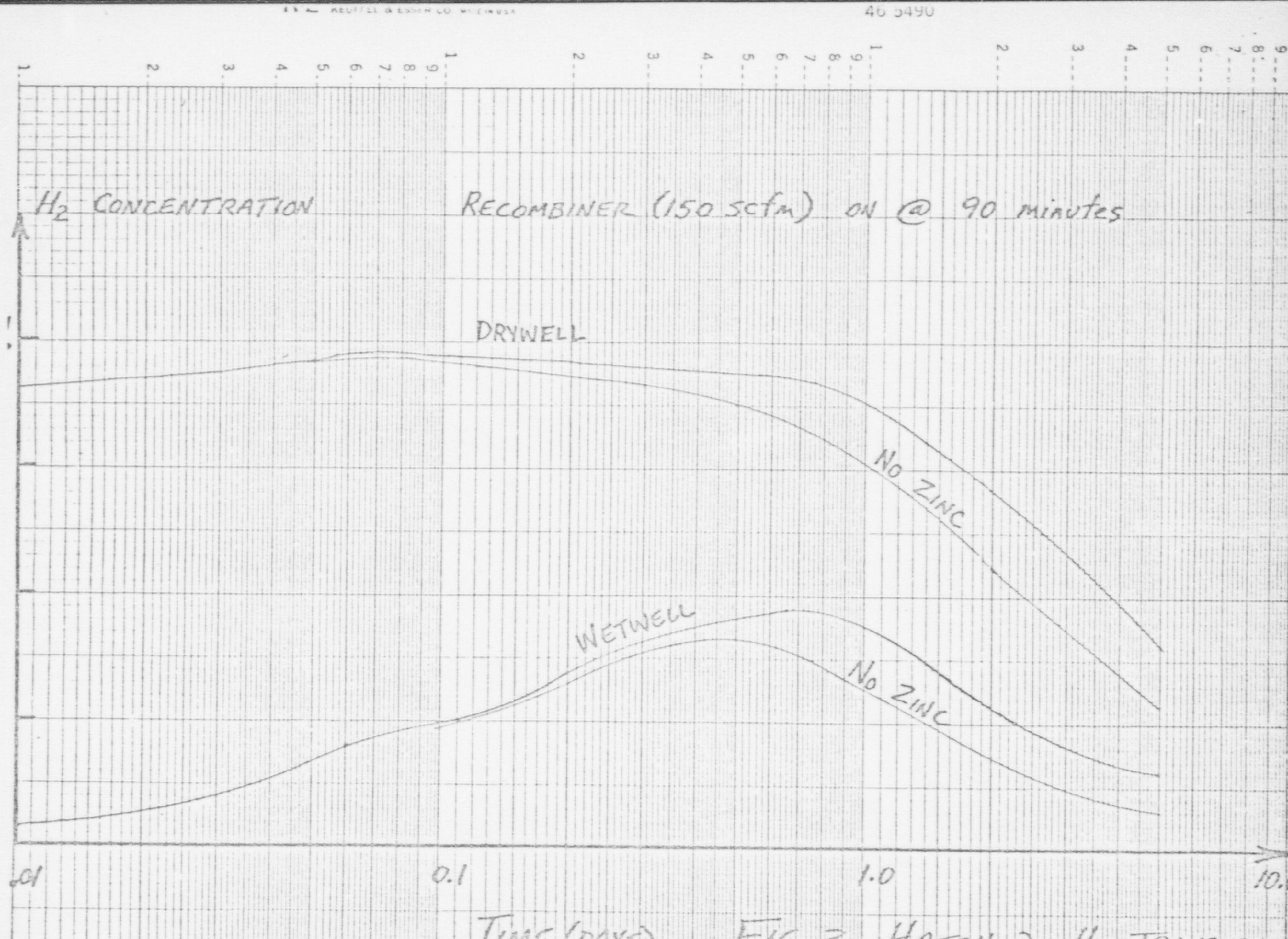


FIG. 3 HATCH-2 H_2 TRANSIENT

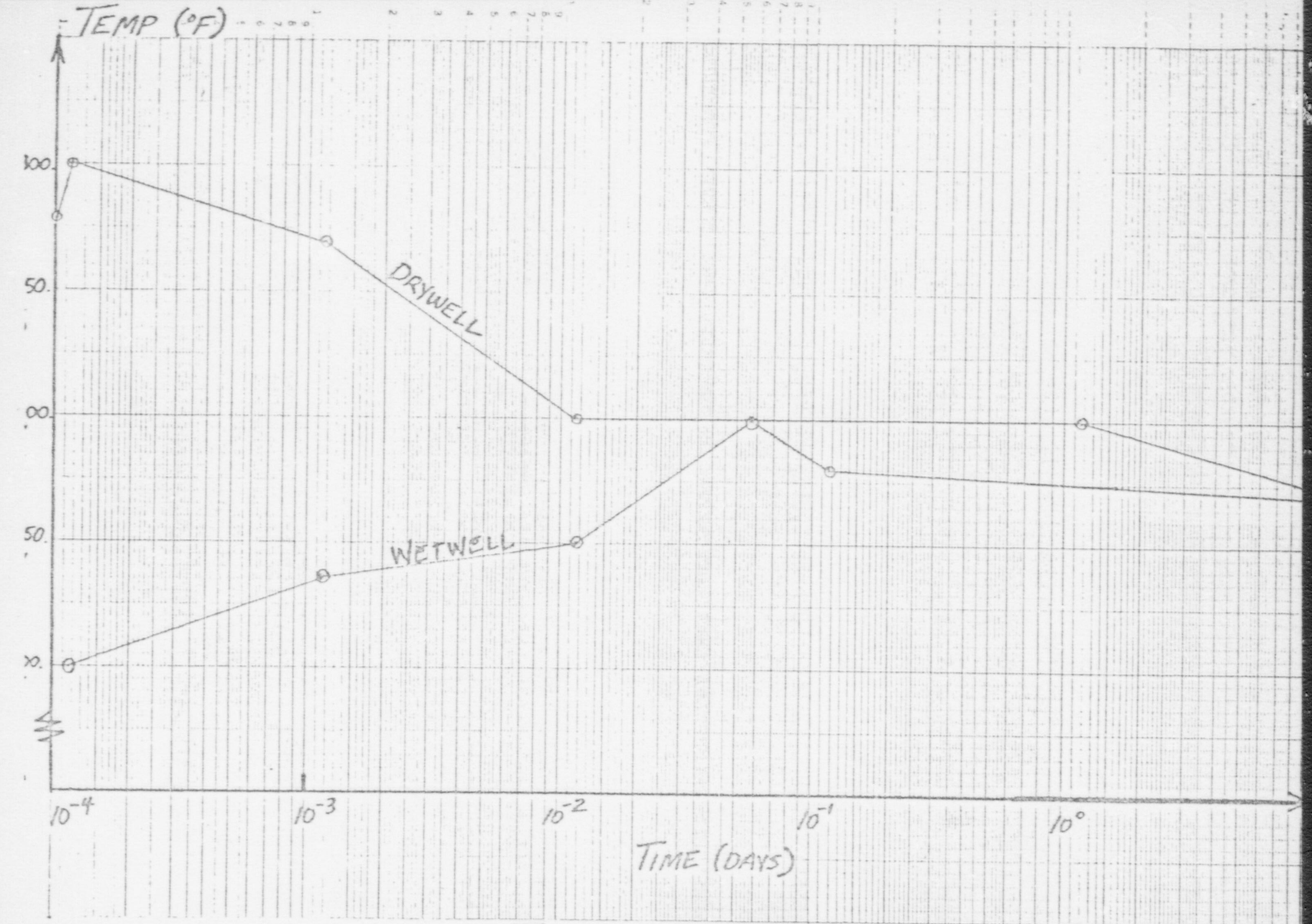


FIG. 4 Hatch-2 TEMP. TRANSIENT

ATTACHMENT I

BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

DATE: 8/2/78

TO: H.F. Conrad

FROM: D. van Rooyen

SUBJECT: H_2 Release From Zn Corrosion

We discussed today the questions of (1) amounts of H_2 - realistic curves vs. conservative curves, and (2) the effect of pH - neutral pure water vs. pH 9 with boron present.

1. Figure 11 of my report BNL-NUREG-24532 shows the best conservative curve for H_2 from Zn at various temperatures, and the text of that report gives the uncertainties associated with the evaluation of available data. The curve was arrived at by establishing the best slope for log H_2 vs. 1/temp (°K) plot, and drawing such a curve through the "Zittel" highest point for a zinc-rich paint. There is no other point quite as high as this Zittel result, and he also reported that the rate fell off to near zero after one day for the paint. However, he also reported an average value equivalent to 3.3×10^{-3} SCF.ft.$^{-2}$hr^{-1} for a 100 hour test at pH 9.3. Therefore, if I had to construct a curve for the most realistic curve, I would draw it as line A, Figure 1, attached. The curve is based on average rates at various temperatures in borated spray at pH 9.5, and is supported by NUS as well as Franklin Institute data, i.e. it is felt to be realistic since it contains several points of average values over periods of one day or more, and we have several sets of data that fit reasonably well. This curve falls below the Zittel point for average H_2 release of pH 9.3 for galvanizing in his 100 hour test, so that it seems difficult draw it any lower unless we obtain more data.

2. In discussion the pH effect, I assume that the presence of borate

does not make a significant difference, so that the conclusion will apply to BWR neutral water sprays at pH 7. In Figure 14 of BNL-NUREG-24532 it is shown that the rate of H_2 release from Zn increases by a factor of 1.3 to 1.4 for each pH unit below 9. Therefore, the values for pH 7 are proposed as line B in Figure 1 attached, which is 3.5 times line A, and parallel to it. I use 3.5 because the ph in the field will probably be a little below 7.

The two lines correspond to equations:

Line A (pH 9.5) $\text{Rate } H_2 = 1.3 \times 10^5 \exp\left(-\frac{14500}{RT}\right)$ $SCF.Ft.^{-2}hr^{-1}$

Line B (ph 7) $\text{Rate } H_2 = 4.6 \times 10^5 \exp\left(-\frac{14500}{RT}\right)$ $SCF.Ft.^{-2}hr^{-1}$

Note that line B is identical to Figure 11 of BNL-NUREG-24532.

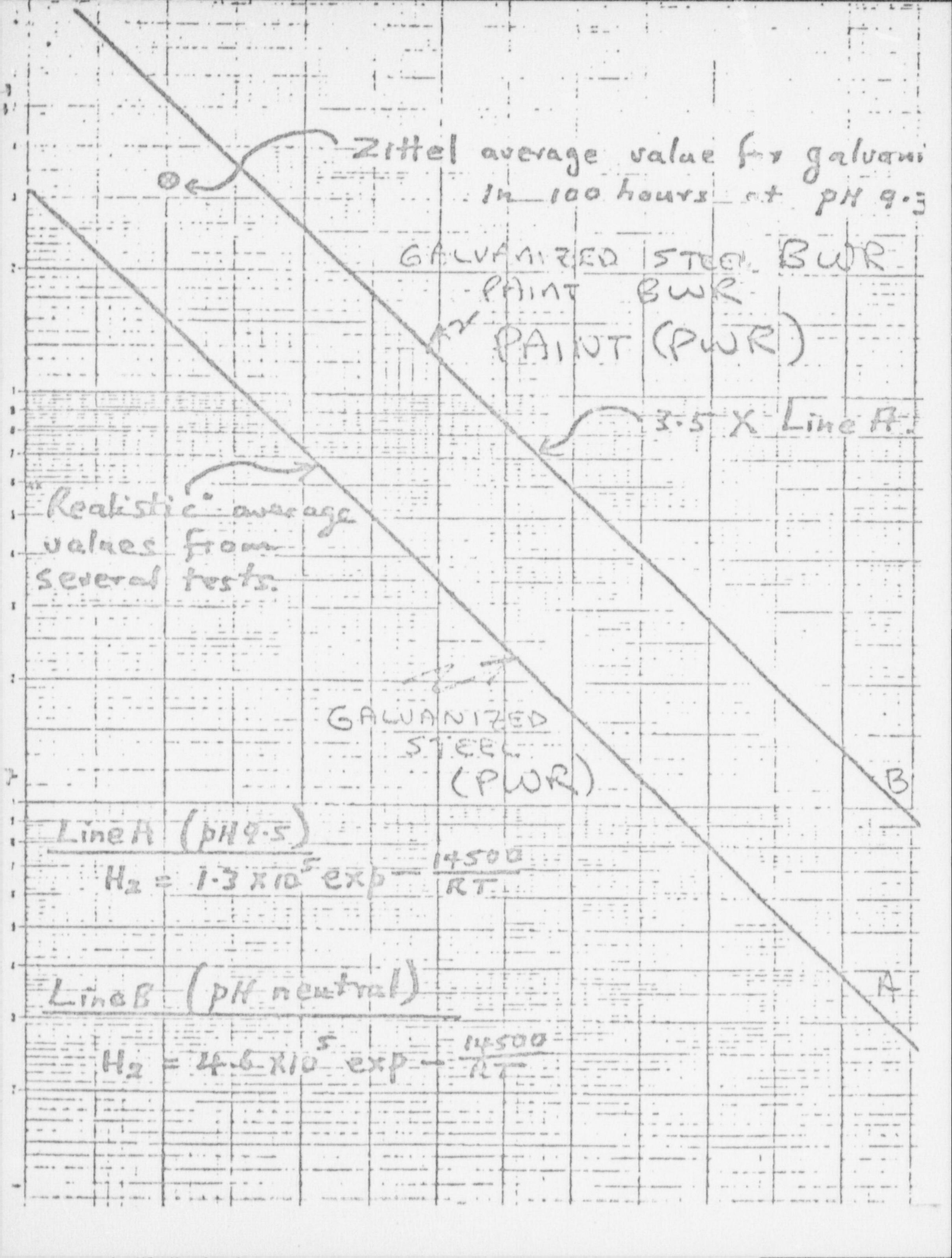
With more and better data we could construct curves with greater confidence, as mentioned in my report quoted above. Better knowledge of how the H_2 evolution is sustained over longer periods at the lower temperatures will also enable a more realistic evaluation of H_2 buildup over a cycle such as would be experienced during a LOCA.

$R = 1.986 \frac{cal}{gm \cdot K}$

$T = {}^{\circ}K$

DvR/bMc
mc.

cc:
D.S. Pawlicki
D. Turovlin
T.M. Almeter
W.Y. Kato
J.R. Weeks



Zittel average value for galvani
In 100 hours at pH 9.3
GALVANIZED STEEL BWR
PAINT BWR
PAINT (PWR)
3.5 X Line A.
"Realistic" average values from several tests.
GALVANIZED STEEL (PWR)
B
A
Line A (pH 9.5)
$H_2 = 1.3 \times 10^5 \exp - \frac{14500}{RT}$
Line B (pH neutral)
$H_2 = 4.6 \times 10^5 \exp - \frac{14500}{RT}$

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Note that line B is identical to Figure 11 of BNL-NUREG-24532.

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DvR/bMc
enc.

cc:

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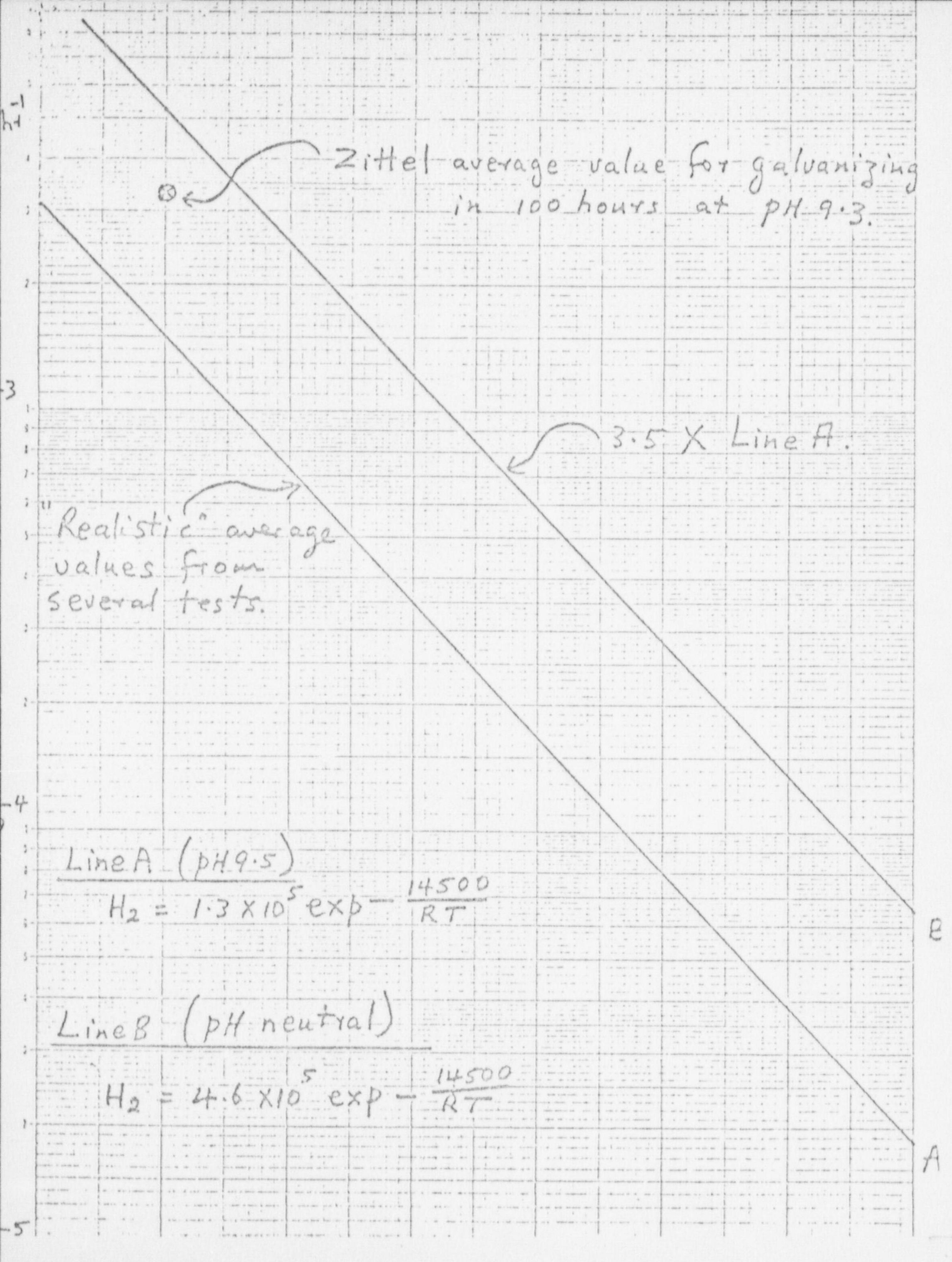
J.R. Weeks



h^{-1}
Zittel average value for galvanizing in 100 hours at pH 9.3.
-3
3.5 X Line A.
"Realistic" average values from several tests.
-4
Line A (pH 9.5)
$H_2 = 1.3 \times 10^5 \exp - \frac{14500}{RT}$
B
Line B (pH neutral)
$H_2 = 4.6 \times 10^5 \exp - \frac{14500}{RT}$
A
-5

UNITED STATES
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WASHINGTON, D. C. 20555

SEP 20 1978

MEMORANDUM FOR: W. R. Butler, Chief, Containment Systems Branch, DSS

FROM: F. Eltawila

THRU: J. Kudrick, Section Leader, Section A
Containment Systems Branch

SUBJECT: HYDROGEN GENERATION IN MARK II CONTAINMENT DUE TO ZINC CORROSION

Reference: Memorandum for W. R. Butler from S. Pawlicki dated August 9, 1978

Since the spray systems in BWR's use water without additives for the purpose of reducing pressure and temperature inside the containment, it was previously believed that the corrosion of zinc will contribute a negligible amount of hydrogen to the BWR containment atmosphere.

However, during the course of our review of Susquehanna Steam Electric Station (SSES), a BWR Mark II containment, we noted that the applicant has considered zinc corrosion as a potential source of hydrogen following a postulated loss-of-coolant accident.

In order to determine the contribution of zinc corrosion to the total hydrogen accumulation in Mark II containment, an analysis was performed by the staff based on the following:

1. The masses and exposed areas of zinc paint and galvanized steel as reported in SSES' FSAR;

2. The containment temperature response to LOCA as reported in SSES' FSAR; and

3. Corrosion rates based on rate values recommended by the Materials Engineering Branch (see referenced memorandum).

The results of the analysis show that the 100 scfm flow rate provided by each of the two recombiners (Susquehanna utilizes two 100 percent redundant hydrogen recombiner systems, each system consisting of two hydrogen recombiners with one located in the drywell and one located in the wetwell) is sufficient to maintain the hydrogen concentration below 4 volume percent.

However, most Mark II containments utilize only one fully redundant hydrogen recombiner system with each system consisting of one hydrogen recombiner located outside the containment with the suction point located in the drywell and the discharge point located above the water level in the suppression pool. Therefore, a similar analysis was performed for LaSalle County Station (LSCS) to determine the contribution of zinc corrosion to the total hydrogen accumulation assuming that only one hydrogen recombiner serves both the drywell and the wetwell regions. The results of the analysis show that the 150 scfm flow rate provided by the recombiner to control the hydrogen concentration in both the drywell and wetwell is sufficient to maintain the hydrogen concentration below 4 volume percent if the recombiner is initiated when the hydrogen concentration reaches 3.5%.

On this basis, it is recommended that no design modification be required for the hydrogen control systems of the Mark II type containments. However, we will require the applicants to consider zinc corrosion in their analyses.

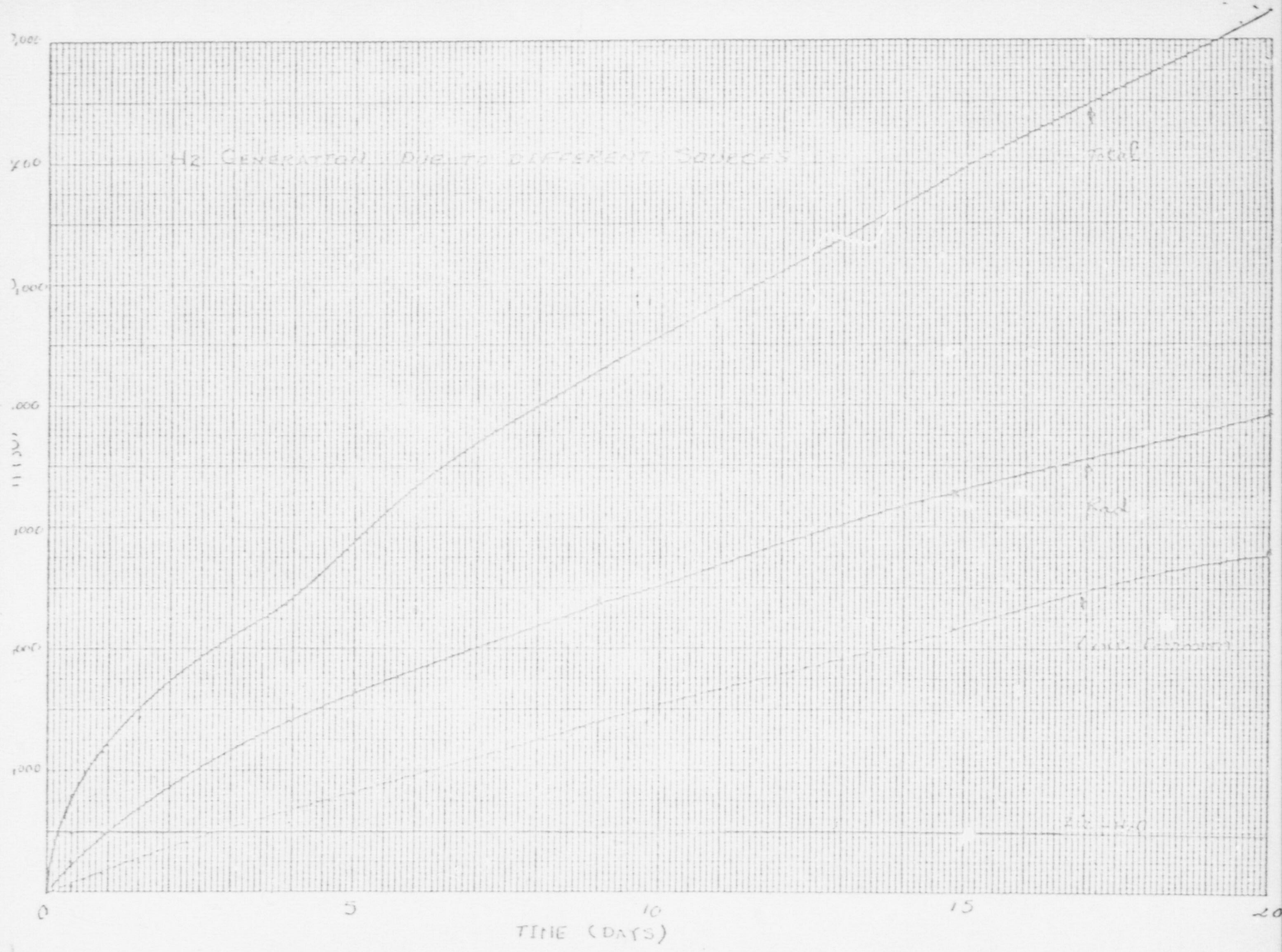
F. Eltawila
Containment Systems Branch
Division of Systems Safety

cc: R. Tedesco
S. Pawlicki
G. Lainas
J. Kudrick
C. Grimes
C. Anderson
T. Su
T. Huang
C. Tinkler
F. Eltawila
J. Glynn

Parameters Used For the Evaluation of Combustible Gases in the Containment After LOCA

Item	Value			
	SSES		LSCS	
	Drywell	Wetwell	Drywell	Wetwell
Mass of zinc as galvanized steel (lb.)	7498	2611	7498	2611
Area of zinc as galvanized steel (Sq. Ft.)	64,200	23,150	64,200	23,150
Mass of zinc as paint (lb.)	2480	—	2480	—
Area of zinc as paint (Sq. Ft.)	44,000	—	44,000	—
Mass of Zircalloy cladding surrounding the fuel (lb.)	78,700		75,324	
Zir-water Reaction Percent Volume (Cu. Ft.)	1.		1.*	
Reactor Power MWT	3439		3434	
Fission Product Distribution and Radiation Energy	R.G. 1.7		R.G. 1.7	
H_2 & O_2 Yield Rate	R.G. 1.7		R.G. 1.7	

* Metal water reaction for LSCS is .77%, the 1% metal water reaction used in this analysis is chosen to bound all Mark II Containments.


H2 GENERATION DUE TO DIFFERENT SOURCES
Total
0
5
10
15
20
TIME (DAYS)

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

Enclosure 2
(Reference 3)

SEP 20 1978

MEMORANDUM FOR: W. R. Butler, Chief, Containment Systems Branch, DSS

FROM: F. Eltawila

THRU: J. Kudrick, Section Leader, Section A
Containment Systems Branch

SUBJECT: HYDROGEN GENERATION IN MARK II CONTAINMENT DUE TO ZINC CORROSION

Reference: Memorandum for W. R. Butler from S. Pawlicki dated August 9, 1978

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F. Eltawila
Containment Systems Branch
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cc: R. Tedesco
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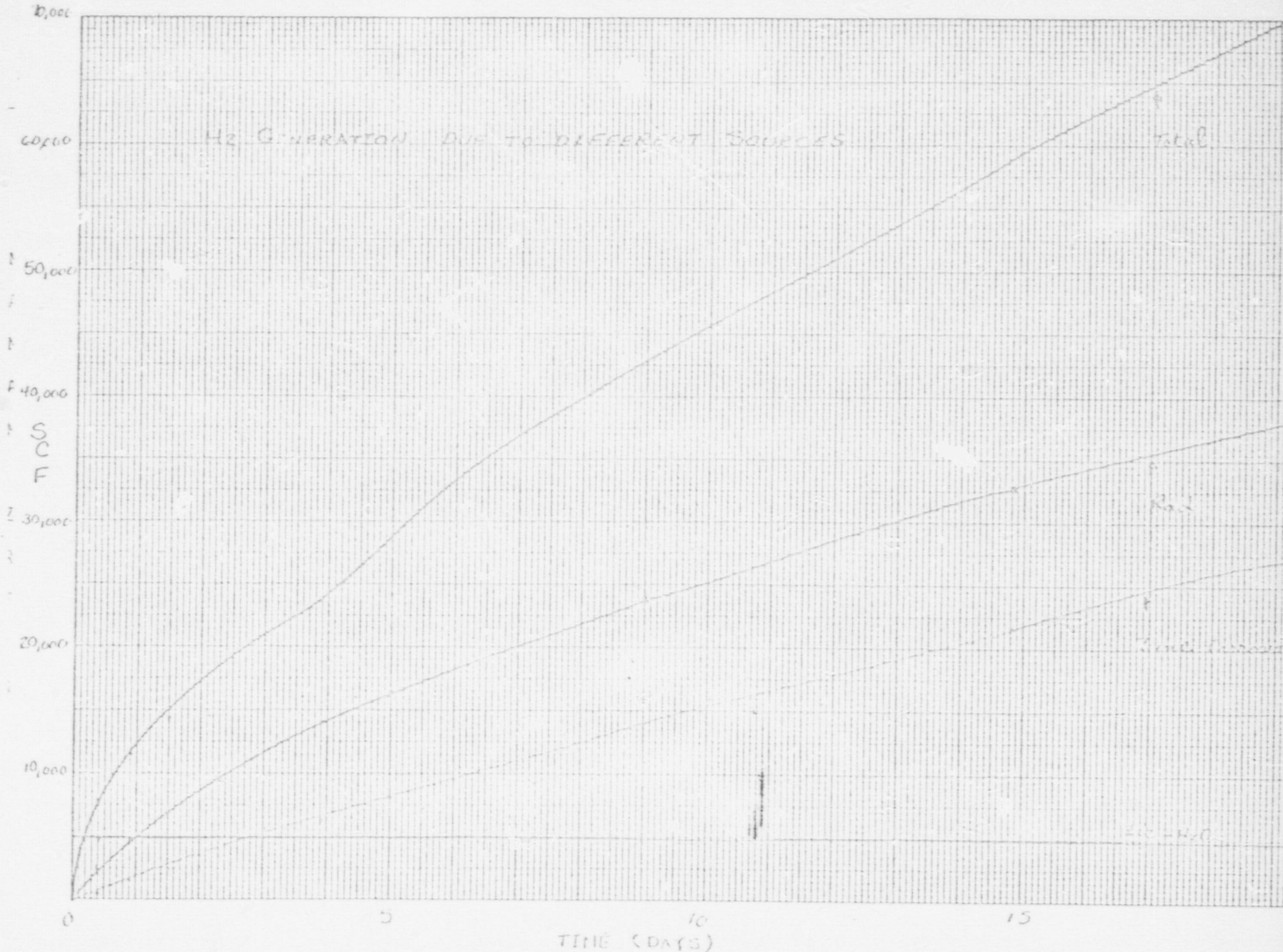
ass of zinc as paint (lb.)	2480	___	2480	___
rea of zinc as paint (Sq. Ft.)	44,000	___	44,000	___
ass of Zircalloy cladding surrounding the fuel (lb.)	78,700		75,324	
ir-water Reaction Percent Volume (Cu. Ft.)	1.		1.*	
eactor Power MWT	3439		3434	
ission Product Distribution and Radiation Energy	R.G. 1.7		R.G. 1.7	
2 & O_2 Yield Rate	R.G. 1.7		R.G. 1.7	

*Metal water reaction for LSCS is .77%, the 1% metal water reaction used in this analysis is chosen to bound all Mark II Containments.


H2 GENERATION DUE TO DIFFERENT SOURCES
Total
SCF
60,000
50,000
40,000
30,000
20,000
10,000
0
5
10
15
TIME (DAYS)

DISCUSSION OF UNCERTAINTIES AND CONSERVATISMS IN THE POST-LOCA HYDROGEN ACCUMULATION ANALYSIS

References:

1) Memorandum for Robert L. Tedesco from Walter R. Butler, "Post-LOCA Hydrogen Generation From Zinc," dated September 20, 1978.

2) Memorandum [illegible] W. R. Butler from F. Eltawila thru J. Kudrick, "Hydrogen Ge[illegible]eration in a Mark II Containment Due to Zinc Corrosion," [illegible]ted September 20, 1978.

The above referenced memoranda discuss the impact of using the MTEB hydrogen generation rates for galvanized steel and zinc-based paints on analyses of the post-LOCA accumulation of hydrogen in various containments. The containment types selected for the study include several PWR dry containments, a PWR ice condenser containment, a BWR Mark I containment and a BWR Mark II containment. The results of the study indicate that there is no apparent safety concern. However, because of uncertainties in the hydrogen generation rates for zinc-rich coatings, there is sufficient justification to warrant additional staff effort in obtaining more refined information regarding the behavior of materials inside cotainments following a LOCA.

The uncertainties associated with the hydrogen generation rates for zinc-rich coatings, as stated in Reference 1, are as follows:

1. The MTEB hydrogen generation rates for the corrosion of galvanized steel are portrayed as "realistic" and as such do not represent conservative or bounding values.

2. The entire curve for hydrogen generation from zinc-based paint is derived from Zittel's one experimental data point with the slope of the line assumed to be equal to the slope of the curve for galvanized steel.

Additional calculations have been made to assess the effects of these uncertainties on post-LOCA hydrogen accumulation analyses. With regard to Item 1, the analyses for the Yellow Creek, Erie and San Onofre plants were redone using the hydrogen generation rate for galvanized steel determined by Zittel. This essentially increases the hydrogen generation rate of galvanized steel by a factor of 2.0, which represents an upper bound of available data. For the Erie and San Onofre plants, the effect of increasing this rate was small. Both plants were reanalyzed assuming recombiner actuation at a hydrogen concentration of 3.5% decreased from 6 days to 5.5 days, and for the San Onofre plant, the time decreased from 21 days to 18 days. For both plants, when the recombiners were actuated the hydrogen concentrations leveled off and began to decrease.

The reevaluation of the post-LOCA hydrogen accumulation analysis for the Yellow Creek plant, using the higher hydrogen generation rates for galvanized steel, resulted in the hydrogen concentration exceeding 4%, and reaching a maximum value of about 4.13%. Hydrogen recombiner operation was assumed to be initiated one day after the accident. The results of the analysis are shown in Figure 1. Case A is the analysis that was presented in Reference 1; i.e., the analysis based on different hydrogen generation rates for zinc-based paint and galvanized steel. Case B is the analysis where the hydrogen generation rate for galvanized steel was taken from the same reference as the hydrogen generation rate for zinc-based paint. As mentioned previously, this represents an increase in the hydrogen generation rate for galvanized steel by a factor of 2.0, which bounds the known experimental data. The lower curve on Figure 1 shows the results of Case B with the effect of steam dilution. Hydrogen accumulation analyses conservatively neglect the effect of steam present in the containment atmosphere. The lower curve is only an estimate of the effect of steam dilution but it does demonstrate that the presence of the steam maintains the hydrogen concentration < 4%.

The analysis described above for the Yellow Creek plant based the calculation of the hydrogen generation from zinc-rich coatings and the mass of steam present in the containment atmosphere on the temperature profile calculated for the accident.

We have also performed a bounding calculation which takes minimal credit for the presence of steam in the atmosphere. The mass of steam was minimized by assuming the temperature of the containment atmosphere to be a constant 120°F throughout the transient, which is the assumed initial containment temperature prior to the accident. Using this conservative assumption for the containment's steam inventory, we calculated a peak hydrogen concentration of 3.7% using the higher corrosion rates. A plot of the hydrogen concentration transient including steam dilution at 120°F is also shown in Figure 1.

The analysis for the Yellow Creek plant is considered to be a bounding analysis for PWR dry containments for the following reasons:

a) The zirconium cladding mass is the largest that has been specified for the NSSS vendor reactor cores;

b) A 5% core metal-water reaction was assumed; i.e., no Appendix K evaluation was performed to determine the extent of the cladding reaction;

c) The containment temperature profile is relatively high since the spray system provided for containment depressurization has a relatively low capability. Since the hydrogen generation rates from zinc-rich coatings are a strong function of temperature, the high containment temperature profile will enhance the impact of the coatings as a source of hydrogen on the overall hydrogen production analysis.

The hydrogen accumulation analyses for the BWR Mark I and Mark II containments and the PWR ice condenser containment were not re-evaluated since the hydrogen generation rates for galvanized steel and zinc-based paint were based on the conservative MTEB curve. Also, since the hydrogen concentration for BWRs peaks within a few hours after the accident, there will not be sufficient time for the zinc-rich coatings to contribute enough hydrogen to cause the concentration to exceed 4% before the time for recombiner actuation or shortly thereafter. Later in the accident, the recombiners are capable of controlling the hydrogen from this source. For the PWR ice condenser containment, the hydrogen concentration remains so low that increasing the hydrogen generation rate of the galvanized steel in the manner described above would not significantly affect the results. In general, the low temperature profiles in pressure suppression containments prevent the zinc-rich coatings from dominating the hydrogen production analysis.

There are other considerations which suggest that the post-LOCA hydrogen accumulation analyses over-predict the hydrogen concentration in PWR and BWR containments. For example, a factor of 5 is applied to the core zirconium-water reaction; and all zinc rich coatings within the containment are assumed to contribute equally to the generation of hydrogen. Although it is not possible to quantify the conservatism of this latter assumption, it is reasonable to assume that not all surfaces within a containment would behave in a uniform manner.

Item 2 identifies a concern about the hydrogen generation rate for paint since the curve is drawn through one data point. However, the data point chosen represents the highest generation rate obtained from the testing of several samples by Zittel at the Oak Ridge National Laboratory. To our knowledge, there are no data which suggest higher hydrogen generation rates for zinc-based paint. Therefore, although more data regarding the hydrogen generation rates for zinc-based paint would be desirable, the MTEB curve is considered to conservatively predict the hydrogen generation rates.

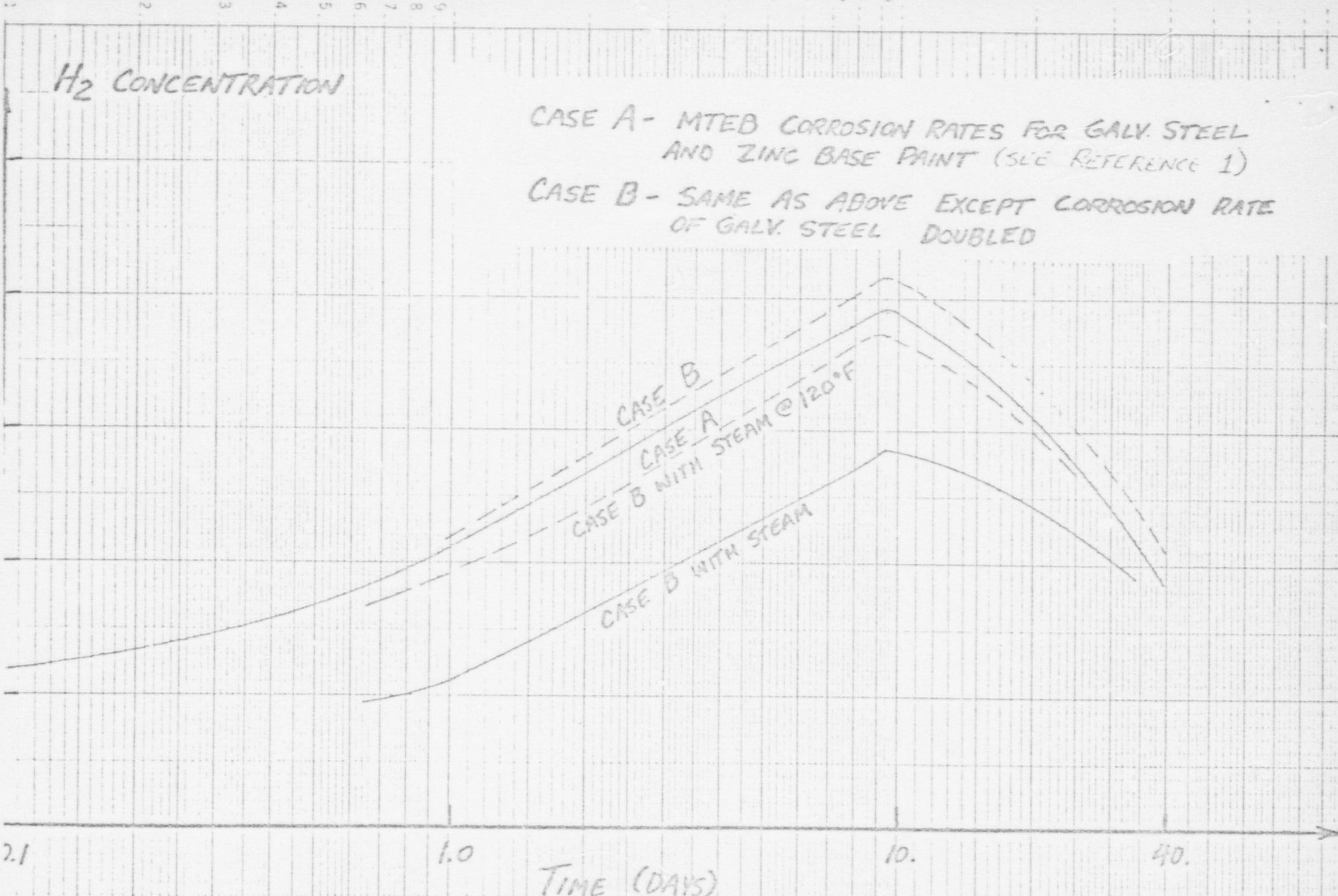


FIGURE 1. YELLOW CREEK H_2 TRANSIENTS

ENCLOSURE 1

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

AUG 24 1978

MEMORANDUM FOR: D. B. Vassallo, Assistant Director for Light Water Reactors, DPM

THRU: Steven A. Varga, Chief, LWR-4, DPM

FROM: Cecil O. Thomas, Jr., Project Manager, LWR-1, DPM

SUBJECT: RECOMMENDED LICENSING BOARD NOTIFICATION - POST-LOCA HYDROGEN GENERATION FROM MATERIALS INSIDE CONTAINMENT

In accordance with the provisions of NRR Office Letter No. 19, "Procedures for Notification of Licensing Boards of Relevant and Material New Information," I recommend that the appropriate Licensing Boards be notified of the following information which has been brought to my attention concerning post-LOCA hydrogen generation from materials inside containment. I believe that this information is relevant to and constitutes material new information concerning all boiling and pressurized water reactor nuclear power plants.

Following a LOCA in a light water reactor nuclear power plant, hydrogen may accumulate inside the primary containment as a result of (1) metal-water reaction involving the fuel rod cladding; (2) radiolytic decomposition of the water in the reactor core and containment sump; (3) corrosion of materials inside the primary containment, such as aluminum and zinc (in the form of galvanized steel and metal-rich paints); and (4) thermal, chemical, and radiolytic decomposition of organic components of protective coating systems. Although hydrogen sources (1), (2), and, to some extent (4) above are considered routinely by applicants in their determination of the required capacities of post-LOCA hydrogen control systems, such as hydrogen recombiners, and by us in our evaluation of the adequacy of such systems, there is reason to believe that hydrogen sources (3) and, to some extent, (4) above may not have been adequately considered. Although this may prove to be insignificant in that considerable margin is already provided in the capacities of post-LOCA hydrogen control systems, it may prove to be significant if it turns out that the capacities of the post-LOCA hydrogen control systems are such that the post-LOCA hydrogen concentrations cannot be maintained below their combustible limits.

AUG 24 1978

It is evident from the enclosed memoranda that the staff has solicited further information concerning this matter from external sources. Therefore, in accordance with the provisions of NRR Office Letter No. 19, I am providing for your consideration this recommendation that the appropriate Licensing Boards be notified of this matter.

Cecil O. Thomas, Jr.
Project Manager, LWR-1
Division of Project Management

ccs:
J. Stolz

ENCLOSURE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MEMORANDUM FOR: R. Tedesco, Assistant Director
for Plant Systems
Division of Systems Safety

THRU: J. P. Knight, Assistant Director
for Engineering

FROM: S. S. Pawlicki, Chief
Materials Engineering Branch

SUBJECT: HYDROGEN GENERATION RATES AFTER LOCA

REFERENCES:

1. Wachtell, G. P., The Franklin Institute Research Laboratories, F-C2697, September 1970 - Proprietary
2. Wachtell, G. P., The Franklin Institute Research Laboratories, F-C2928, January 1971 - Proprietary
3. Turner, S. E., NUS Internal Memorandum to W. Mitchell, III, March 7, 1977 CD-SET-112
4. Zittel, H. F., Nuclear Technology, 17 February 1973 pgs. 143-146

By memorandum of February 10, 1978, we proposed to perform a short term review of the available data on zinc corrosion rates and to provide you with a preliminary recommendation for suitable values to be used in calculating hydrogen generation. We have found that there are little data reported in the literature with sufficient experimental detail to allow an appraisal of its validity.

For example, we attempted to determine the experimental basis for the zinc hydrogen generation rates reported in the ANSI WG56.1, ANS N-275 draft standard, but were unsuccessful. We contacted various members of the working group who indicated that the data were based primarily on Franklin Institute work (1, 2). Our own derivation of a hydrogen generation curve from the Franklin Institute data provided the lower curve in Attachment 1 covering only the temperature range from 150°F to 200°F. This curve was corroborated by an independent set of measurements reported by S. E. Turner (3) to the ANS 56.1 Working Group. Zittel at ORNL (4) has reported hydrogen generation rates due to the corrosion of zinc and zinc-base coatings (Points A and B respectively) at 266°F.

Since there is a theoretical basis for expecting a straight line semi-log relation between rate and temperature, to the first approximation, we have drawn a line through the uppermost Zittel point parallel to the data of References 1, 2 and 3. We thereby define an upper limit that encompasses all the limited data that we now have on hand. We recommend that this curve be used for calculating hydrogen generation rates in the interim, until we develop additional data.

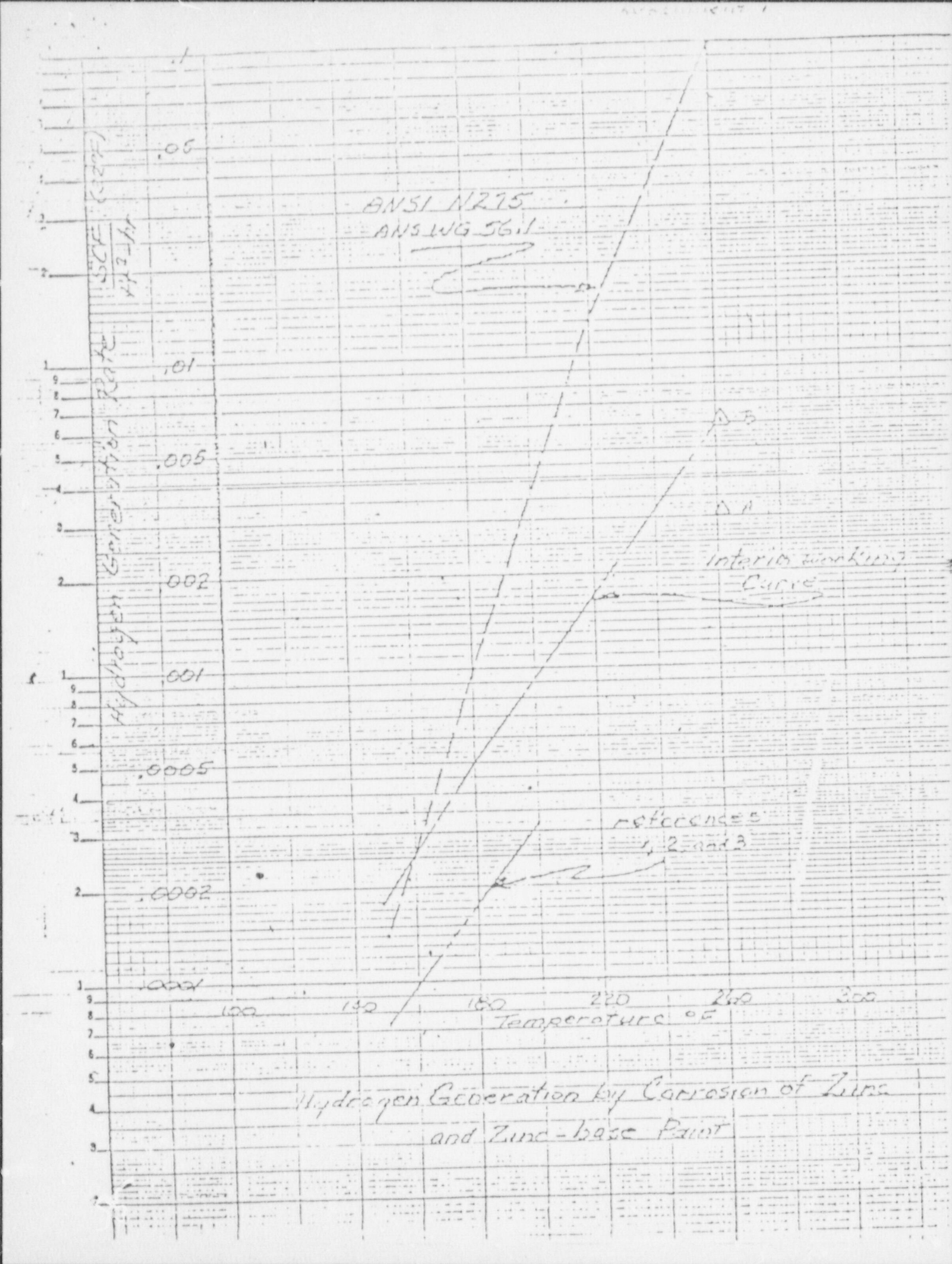
In order to resolve the situation we are pursuing a three pronged approach: (1) our consultants at BNL will continue to search the literature and make personal contact with workers in the field, (2) applicants with plants in the CP and OL stages of licensing are being requested to give us the experimental basis for their hydrogen generation rates, and (3) we are evaluating the need and extent of an experimental program to supplement available data.

If information is developed that would significantly change the recommendations contained in this memorandum, we will immediately notify you. In any case we expect to furnish you with an updated report by the end of July.

S. S. Pawlicki, Chief
Materials Engineering Branch
Division of Systems Safety
Office of Nuclear Reactor Regulation

Enclosure:
As stated

cc: R. J. Mattson, DSS
J. P. Knight, DSS
J. Shapaker, DSS
J. Kudrick, DSS
G. Laimas, DSS
C. Tinkler, DSS
A. Wang, DOR
U. Potapov, DSS
S. S. Pawlicki, DSS
J. Halapatz, DSS
H. F. Conrad, DSS
B. Turovlin, DSS



Hydrogen Generation by Corrosion of Zinc and Zinc-base Paint

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

AUG 9 1978

MEMORANDUM FOR: W. R. Butler, Chief
Containment Systems Branch
Division of Systems Safety

FROM: S. S. Pawlicki, Chief
Materials Engineering Branch

SUBJECT: HYDROGEN GENERATION FROM ZINC CORROSION IN BWR CONTAINMENT POST-LOCA

REFERENCES:

1. Memorandum S. S. Pawlicki to R. Tedesco, Hydrogen Generation Rates After LOCA, March 5, 1978
2. BNL Memorandum, D. vanRooyen to H. F. Conrad, H_2 Release from Zn Corrosion, August 2, 1978
3. BNL-NUREG-24532, Daniel vanRooyen, Hydrogen Release Rates from Corrosion of Zinc and Aluminum, May 1978, Brookhaven National Laboratory

Since we provided CSB with the "interim working curve" of Reference 1, Attachment 1, we have been attempting to clarify the situation as regards the use of this curve in regard to BWRs. We have searched for other experimental data and have re-examined our existing data base.

In Reference 2, Attachment 2, MTEB consultant D. vanRooyen recommends the use of Figure 11, BNL-NUREG-24532 (Reference 3, Attachment 3) for fluids of pH of 7. The curve of Figure 11 is the same as our recommended "interim working curve."

We agree with his recommendation because of the uncertainty surrounding the case of BWR water containment sprays indicates a conservative approach. We agree with the assumption that the change of pH is the most important effect on the corrosion rate. The addition of boric acid and sodium hydroxide will only affect the zinc corrosion rate to the extent that they change the pH of solution.

We concur with his further recommendation of a "realistic" curve (Curve A of Reference 2) for the calculation of hydrogen generation from a borated water spray of a pH of 9.5. In this case, test data from two independent studies are in agreement.

As your know, our trip to GE-San Jose yielded no new data. GE reiterated their position that hydrogen generation from zinc is inconsequential, though they did not offer any documentation of experimental data to substantiate their position.

As the next step in the resolution of a experimentally valid hydrogen generation rate curve, we are preparing a "Users Request" for RES as agreed in the July 27, 1978 meeting.

S. S. Pawlicki, Chief
Materials Engineering Branch
Division of Systems Safety
Office of Nuclear Reactor Regulation

Enclosure:
As stated

cc w/encl:
J. Kudrick, DSS
J. Shapaker, DSS
C. Tinkler, DSS
A. Wang, DOR
F. Almeter, DOR
J. Halapatz, DSS
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H. Conrad, DSS
B. Turovlin, DSS

cc w/o encl:
R. Tedesco, DSS
J. Knight, DSS
R. Mattson, DSS

AUG 4 1978

MEMORANDUM FOR: S. Pawlicki, Chief, Materials Engineering Branch, DSS

FROM: W. Butler, Chief, Containment Systems Branch, DSS

SUBJECT: CSB INPUT FOR RES USERS REQUEST REGARDING POST-LOCA HYDROGEN GENERATION RATES FOR MATERIALS INSIDE CONTAINMENT

As a result of a meeting among representatives of CSB, MTEB, AAB and RES, on July 27, 1978, we agreed to provide portions of the subject RES users request. Specifically, the CSB was to provide a discussion of the problem status and the licensing impact associated with the evaluation of hydrogen generation from certain construction materiass (aluminum and zinc) inside containment. Our input for the subject RES users request is enclosed.

Note that we have addressed hydrogen generation due to corrosion of aluminum and zinc. During our meeting of July 27, 1978, the issue of hydrogen generation from the radiolytic decomposition of organic materials was raised by the AAB. If the AAB finds that hydrogen generated from organic materials is significant, we would recommend its inclusion in the proposed RES program.

If we can be of further assistance please contact us.

/s/

Walter R. Butler, Chief
Containment Systems Branch
Division of Systems Safety

Enclosure:
As Stated

cc: R. Tedesco
J. Shapaker
J. Kudrick
C. Tinkler

Contact:
C. Tinkler, CSB
492-7711

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NRR Reading
CSB Reading

Enclosure

CSB INPUT
FOR RES USERS REQUEST

Status of Problem

Following a loss of coolant accident in a light water reactor (LWR) plant, hydrogen may accumulate inside the primary reactor containment as a result of: (1) a metal-water reaction involving the fuel rod cladding; (2) the radiolytic decomposition of water in the reactor core and containment sump; and (3) the corrosion of certain construction materials by the spray solution. This discussion is limited to the post-LOCA hydrogen produced from certain construction materials inside containment, most notably aluminum and zinc (in the form of galvanized steel and zinc rich primer paints).

The staff has noted in its review of applicant analyses of hydrogen production and accumulation as presented in safety analysis reports that there are very large (order of magnitude) differences in the assumptions for corrosion rates for certain materials. Since the rate of hydrogen production and accumulation within the containment is the controlling factor governing the functional design of the plants' combustible gas control systems, it is important that corrosion rates of various materials be known with better precision.

The potential for hydrogen generation from aluminum under post-LOCA conditions has led applicants to limit the use of aluminum in PWR containments. On the other hand, zinc based primers and galvanized steel are used extensively. We have noted, however, that one applicant has limited the mass of zinc inside containment because of its concern over the potential for post-LOCA hydrogen generation.

Applicant analyses of post-LOCA hydrogen production and accumulation in BWR plants do not consider the corrosion of aluminum or zinc as sources of hydrogen. The reason for this is that the pH for the primary coolant and suppression pool water is essentially neutral. However, one applica[nt] has recently suggested that aluminum and zinc corrosion will occur even with neutral pH water. The staff at this time does not have recommended values for hydrogen generation rates for aluminum or zinc materials in neutral pH steam-water environments.

Licensing Impact

To properly evaluate the functional design of a LWR plant's combustible gas control system following a postulated LOCA, it is essential that meaningful data be available regarding the corrosion of materials such as aluminum and zinc. Therefore, the proposed program will study in depth the parameters which influence the corrosion of materials leading to hydrogen generation. If the hydrogen generation rates for aluminum and zinc are found to be significant, the hydrogen production and accumulation analyses for LWR plants and in particular the BWR plants must be appropriately revised and the impact on performance requirements for combustible gas control systems evaluated.

AUG 8 1978

MEMORANDUM FOR: James P. Knight, Assistant Director for Engineering, DSS

THRU: Richard H. Vollmer, Assistant Director for Site Analysis, DSE

FROM: Gordon L. Chipman, Jr., Acting Chief, Accident Analysis Branch, DSE

SUBJECT: POST DBA HYDROGEN GENERATION RATES

The memorandum, Tedesco to Knight, dated 1/30/78 identified the need for realistically conservative zinc corrosion rates for use by CSB in confirmatory analyses of combustible gas production in post-accident environments. The memorandum, Pawlicki to Tedesco, dated 2/10/78 committed MEB to initiate a RES program to develop the necessary data should existing experimental data be found inadequate.

A RES program designed to develop hydrogen generation rate data was discussed in a meeting on July 27, 1978 attended by MEB, CSB, PSB, AAB and RSR. Based on this meeting and our evaluation of gas production in post-accident environments, we believe that existing experimental data are inadequate.

The AAB has review responsibility for organic materials in-containment under SRP 6.1.2, "Organic Materials". Included in its scope of review is the assessment of hydrogen and hydrocarbon gas generation under DBA conditions from thermal, chemical and radiolytic effects on organic components of protective coating systems. At present, useful data on these effects is lacking. We request that the proposed RES program include consideration of all materials in nuclear protective coating systems and should be directed to include the development of data on hydrogen and hydrocarbon gas generation under synergistic chemical, thermal and radiolytic DBA environmental conditions. We can provide assistance as necessary in drafting a specific research proposal.

/S/

Gordon L. Chipman, Jr., Acting Chief
Accident Analysis Branch
Division of Site Safety and
Environmental Analysis

cc: See attached sheet

OFFICE	AAB:DSE	AD:SA/DSE				
SURNAME	GChipman/bm	RHVollmer				

cc: J. E. Knight
R. Tedesco
R. Vollmer
W. Paulson
W. Butler
W. Johnson
J. Wing
K. Campe

Distribution
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AAB Reading
AAB File
DSE Reading

AUG 1 5 1978

DRAFT

MEMORANDUM FOR: S. Levine, Director
Office of Nuclear Regulatory Research

FROM: H. R. Denton, Director
Office of Nuclear Reactor Regulation

SUBJECT: POST-LOCA HYDROGEN GENERATION RATES FOR MATERIALS INSIDE CONTAINMENT

A. Background and Status of Problem

Following a loss of coolant accident in a light water reactor (LWR) plant, hydrogen may accumulate inside the primary reactor containment as a result of: (1) metal-water reaction involving the fuel rod cladding, (2) the radiolytic decomposition of the water in the reactor core and containment sump, and (3) the corrosion of certain construction materials by the spray solution. The metal-water reaction involving the fuel rod cladding and the radiolytic decomposition of the water in the reactor core and containment sump is discussed in Regulatory Guide 1.7, "Control of Combustible Gas Concentrations in Containments Following a Loss-of-Coolant Accident." The acceptable rates for the generation of hydrogen from the corrosion of construction materials in containment, particularly aluminum and zinc (in the form of galvanized steel and metal-rich paints) is not adequately defined in the Guide.

The staff has noted in its review of applicant analyses of hydrogen production and accumulation, as presented in safety analysis reports (SAR), that there are very large (order of magnitude) differences in the assumptions for corrosion rates for certain materials. Since the rate of hydrogen production and accumulation within the containment is the controlling factor governing the functional design of the plants' combustible gas control systems, it is important that corrosion and hydrogen generation rates of various materials be known with better precision.

The potential for hydrogen generation from aluminum under post-LOCA conditions has led applicants to limit the use of aluminum in PWR containments. However, zinc based paints and galvanized steel is used extensively. We have noted, however, that one applicant has limited the mass of zinc inside containment because of its concern over potential for post-LOCA hydrogen generation.

Applicant analyses of post-LOCA hydrogen production and accumulation in BWR plants do not consider the corrosion of aluminum or zinc as sources of hydrogen. The reason for this is that the pH for the primary coolant and suppression pool water is essentially neutral. However, one applicant has recently suggested that aluminum and zinc corrosion will occur even with neutral pH water.

To properly evaluate the functional design of a LWR plant's combustible gas control system following a LOCA, it is essential that meaningful data be available regarding the corrosion of materials such as aluminum and zinc and the degradation, with subsequent hydrogen evolution, of metal-based paints.

The staff (MTEB) and their consultants have reviewed the available experimental data and have developed conservative curves depicting hydrogen generation rates due to the corrosion of zinc (galvanized steel) in post-LOCA environments. These curves were recommended for calculating hydrogen generation.

B. Informational Deficiencies

The present data base for establishing hydrogen generation rates is very limited. Most of the information reported in the literature is not ammenable to the evaluation of the experimental basis or procedures. In addition, there is little information reported of the results of tests at lower temperature (~~85-140°F~~ 130-180°F) or with a range of pH's. Information is lacking on the effects of additives, such as boric acid and sodium hydroxide versus neutral unadjusted water, upon the corrosion rates of zinc.

In evaluating the literature data prior to developing the recommended hydrogen generation curve, a number of unanswered questions were apparent about some of the parameters of the corrosion rate. The following questions should be answered by the research program:

1. For metal coatings, aluminum or zinc (galvanizing), what is the effect on hydrogen generation of,
   a. variations in metal coating
   b. composition of metal coating
   c. method of application

d. alloying of metal coating with steel substrate

2. Is oxygen depletion of the atmosphere a factor in hydrogen evolution?

3. Are there two slopes (activation energies) in the zinc hydrogen generation curve? One slope for metal-steam reaction above boiling and a metal-liquid reaction below boiling?

4. If the pH is controlled to a fixed value will a change of ppm (x?) of an additive have an effect on the hydrogen evolution, i.e., is boron concentration a factor?

5. Is there an induction period for the start of hydrogen evolution from paint or metal coatings? Does the temperature have an effect? Does preconditioning, i.e., static exposure to humid containment atmosphere, effect the induction period, if any?

6. Does aging effect the performance of the coatings?

7. Do variations in the metal pigments (size, shape, quantity, composition) have an effect on the degradation of the coatings?

8. Will variations in paint vehicle or topcoat have an effect on the evolution of the hydrogen? Will inhibitors have an effect?

C. Status of Known Programs Directly Related to the Requested Research

There are no known experimental programs being sponsored by the Nuclear Regulatory Commission that is directly related to the requested research. Various other organizations have done experimental research directly related to this problem. None of these organizations now have an ongoing program. The Franklin Institute Research Laboratories (FIRL) has investigated this problem by measuring the hydrogen in a closed vessel while spraying a controlled water solution onto galvanized steel grid. Oak Ridge National Laboratories did a similar experiment but measured the hydrogen content in the vessel only at the end of the experiment rather than at intervals during the experiment as did FIRL. Westinghouse Electric and others did corrosion studies on small galvanized samples but measured only weight loss. Except for the results reported by FIRL it is difficult to evaluate the validity of the results or the technique.

D. Desired Completion Date

The research program should be done in at least two phases, short term and long term. The short term program to be completed by the end of the calendar year should focus upon six experimental runs to corroborate the accuracy of the recommended calculation curves at the lower temperatures. The hydrogen evolution at the lower temperatures (130°-200°F) is important because during post-LOCA the containment environment is at these temperatures for very long periods.

The experimental runs should also compare the hydrogen evolution from galvanized steel when sprayed with pH controlled water when boron is added versus pure water.

The long term program should be designed to answer the questions previously stated. With the many variables to be investigated the long term program will take at least two years.

E. Magnitude of the Research Program

The program will require a reasonably large closed vessel into which several mid-size samples can be exposed. Auxiliary equipment will require provisions for heating the spray solution and controlling the chemical composition of the spray. In addition the atmosphere must be sampled, at intervals; for hydrogen. It is estimated the short term program would cost about 40K-50K. The long term program would cost 150K to 200K.

F. Licensing Impact

The hydrogen generation rates at various temperatures recommended for calculation of hydrogen accumulation in containment are very conservative. The evaluation of the applicants' assumptions in the SARs is difficult if the applicants' assumptions differ from the recommended values by orders of magnitude. This is so because of the limited firm data available to the staff. If the hydrogen generation rates for aluminum, zinc and coatings are found to be significant, the hydrogen production and accumulation analysis for LWR plants and BWR plants, in particular, must be appropriately revised and the impact or performance requirements for combustible gas control systems re-evaluated. There is some evidence that several plants will have to redesign when the present conservative values are used in the evaluation

H. R. Denton, Director
Office of Nuclear Reactor Regulation

cc: R. Boyd
V. Stello
R. Mattson
F. Schroeder
J. Knight
D. Ross
Z. Rosztoczy
R. Tedesco
W. Butler
B. Grimes
V. Noonan
S. Pawlicki
L. Rubenstein
H. Conrad
R. Gamble
A. Wing
C. Tinkler
F. Almeter
B. Turovlin
MA 23
SR 2

ENCLOSURE 2

SERVICE LIST BOARD TRANSMITTALS

OCTOBER 27 ~~AUGUST 28~~, 1978

Case	Boards
Black Fox 1&2	ASLB
Cherokee 1-3	ASLB - ASLAB
Diablo Canyon 1&2	ASLB
FNP	ASLB - ASLAB
GREENE COUNTY	ASLB
Hartsville	ASLB - ASLAB
Hope Creek 1&2	ASLB - ASLAB
Jamesport 1&2	ASLB - ASLAB
Marble Hill 1&2	ASLB - ASLAB
McGuire 1&2	ASLB
Montague	ASLB
North Anna 1	ASLB - ASLAB
Pebble Springs 1&2	ASLB
Perkins 1-3	ASLB
Phipps Bend 1&2	ASLB - ASLAB
Pilgrim 2	ASLB - ASLAB
Seabrook	ASLB - ASLAB - Commission
Shearon Harris 1-4	ASLB - ASLAB
SKAGIT	ASLB
Sterling	ASLB - ASLAB
St. Lucie 2	ASLB - ASLAB - Commission
Three Mile Island 2	ASLB - ASLAB
Tyrone	ASLB - ASLAB
Wolf Creek	ASLB - ASLAB
WPPSS 4	ASLB - ASLAB
Yellow Creek	ASLB