AmerGen
A PECO Energy/British Energy Company

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Phone: 717-944-7621

July 27, 2000
5928-00-20228

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

Dear Sir or Madam:

Subject: THREE MILE ISLAND, UNIT 1 (TMI-1),
OPERATING LICENSE NO. DPR-50
DOCKET NO. 50-289
RESPONSE TO THE REQUEST FOR ADDITIONAL INFORMATION REGARDING TECHNICAL SPECIFICATION CHANGE REQUEST 255 PERTAINING TO THE HYDROGEN RECOMBINERS

The purpose of this letter is to provide the response to the June 11, 1997 NRC request for additional information regarding Technical Specification Change Request 255 for Three Mile Island Unit 1 (TAC No. M98522) related to calculations showing that the hydrogen recombiners will accommodate additional sources of hydrogen. Our submittal of October 23, 1998 (1920-98-20412) responded to other requests for additional information regarding Technical Specification Change Request 255 and deferred the request for additional information related to the hydrogen recombiners. Attachment 1 addresses the question related to the recombiners as a result of your review of the February 7, 1997 GPU Nuclear submittal and includes a relevant bases change to clarify this issue. Please include this bases change with the next amendment. The bases change was approved in accordance with our 10 CFR 50.59 process.

Please contact V. Lewis Killpack, Jr. of the TMI Nuclear Safety and Licensing Department at (717) 948-8196 regarding any additional concerns or questions on this issue.

Sincerely,

Mark E. Warner
Vice President, TMI Unit 1

MEW/vlk

Enclosures:
(1) Additional Information Regarding June 11, 1997 Request for Additional Information
(2) Bases Description of Change
(3) Technical Specification Bases Mark-up
(4) Calculation No. C-1101-901-5360-007 Rev. 8, Hydrogen Generation Inside Containment
(5) Revised Technical Specification Bases Page

A001

cc: Administrator, Region I
TMI-1 Senior Project Manager
TMI Senior Resident Inspector
Chairman, Board of Supervisors of Londonderry Township
Director, Bureau of Radiation Protection, PA Department of Environmental Resources
Chairman, Board of County Commissioners of Dauphin County

File No. 99033
Ref. 96054/98121

AMERGENENERGY, LLC

Operating License No. DPR-50
Docket No. 50-289
Technical Specification Change Request No. 262

COMMONWEALTH OF PENNSYLVANIA)
) SS:
COUNTY OF DAUPHIN)

This Technical Specification Change Request is submitted in support of Licensee's request to change Appendix A to Operating License for Three Mile Island Nuclear Station, Unit 1. As a part of this request, proposed replacement pages for Appendix A to the License are also included. All statements contained in this submittal have been reviewed, and all such statements made and matters set forth therein are true and correct to the best of my knowledge.

AMERGEN ENERGY COMPANY, LLC

BY: _____
Vice President, TMI Unit 1

Sworn and Subscribed to before me
this 27th day of July, 2000.

_____
Notary Public

Notarial Seal
Linda C. Witter, Notary Public
Londonderry Twp., Dauphin County
My Commission Expires Sept. 25, 2000
Member, Pennsylvania Association of Notaries

Enclosure 1
Additional Information Regarding
June 11, 1997 Request for Additional Information

Issue 1 – Regarding calculations showing that additional sources of hydrogen will be accommodated.

Item 1 In your submittal dated February 7, 1997, one of the requested changes to the Technical Specifications for the TMI-1 plant addresses a proposed decrease of the allowable time interval between a loss-of-coolant accident and operation of a hydrogen recombiner from 9.8 to 9.0 days. The reason given for this change is that the additional hydrogen generated after an accident from corrosion of zinc on the galvanized scaffolding stored in the containment will cause higher hydrogen buildup rates. Please provide your calculation showing that this additional source of hydrogen will be accommodated by changing the recombiner starting time from 9.8 to 9.0 days.

Response to Issue 1 - Since the original submittal of Technical Specification Change Request dated February 7, 1997, events have changed. The calculations and safety evaluation have been revised to reflect the changes and are enclosed. The revised calculations show that the maximum potential hydrogen that could be generated in the containment as a result of a loss-of-coolant accident would be accommodated by starting the recombiner 8.6 days after the postulated accident. However, we believe that these numbers are too specific for the Technical Specification Bases. The proposed change replaces this statement with "Hydrogen generating material in the reactor building is limited to ensure that the capacity of one hydrogen recombiner can maintain post LOCA hydrogen concentration below 4 volume percent. The Three Mile Island Nuclear Generating Station, Unit 1 Final Safety Analysis Report Section 6.5 shows that adequate time (at least several days) is available to place a hydrogen recombiner in service."

In addition to establishing limits of the hydrogen recombiner, calculations were done to determine the maximum amount of aluminum or zinc that a single hydrogen recombiner could process and still maintain a volume of 3% or less hydrogen in the Reactor Building.

The specific requirements for starting the recombiner were moved from the Technical Specifications Section 4.4.4.1, Bases, to Section 6.5.3.2.d of the Updated Final Safety Analysis Report to be more consistent with the B&W Plant Revised Standard Technical Specifications, NUREG-1430. A mark-up of the proposed Technical Specification Bases is enclosed.

Enclosure 2

Bases Description of Change

1.0 Purpose:

The existing bases statement, "TMI-1 UFSAR Section 6.5.3.1 indicates that the hydrogen recombiner system is not required until 9.8 days following a LOCA. This is adequate time to place a recombiner in service.", is too specific. The proposed change replaces this statement with "Hydrogen generating material in the reactor building is limited to ensure that the capacity of one hydrogen recombiner can maintain post LOCA hydrogen concentration below 4 volume percent. The TMI-1 UFSAR Section 6.5 shows that adequate time (at least several days) is available to place a hydrogen recombiner in service."

The proposed change (1) better describes the requirements for a hydrogen recombiner, (2) ensures that adequate time is available to initiate a recombiner (at least several days), (3) moves the specific number of days required to the Three Mile Island Nuclear Generating Station, Unit 1 UFSAR and the calculation, and (4) changes the combustible limit listed in the Technical Specifications from 4.1% to 4% to agree with Regulatory Guide 1.7. The change will eliminate the need to revise the Technical Specification bases each time the inventory of aluminum or zinc is modified in containment and is consistent with B&W Plant Revised Standard Technical Specifications, NUREG-1430. Appropriate evaluations are performed per the FSAR and AmerGen Calculation C1101-901-5360-007 (enclosed) to ensure that the hydrogen concentration will not exceed 4 volume percent after a LOCA and to ensure that adequate time is available to initiate a recombiner.

Additionally, the inventory of zinc and aluminum has changed in the reactor building and therefore the time listed in the current Technical Specification basis (9.8 days) is no longer correct. These changes to inventory were evaluated under 10 CFR 50.59 and the FSAR and calculation C1101-901-5360-007 was updated to reflect the changes.

2.0 Conclusion

The purpose of the proposed change is to ensure that the Technical Specification Bases is consistent with the design bases for TMI-1 with respect to the Post LOCA Hydrogen Recombiner System and consistent with the B&W Plant Revised Standard Technical Specifications, NUREG-1430. This proposed change will allow the Hydrogen Recombiner to operate and function as designed and guarantee that hydrogen will be controlled below 4 volume percent inside containment.

Based on the above evaluation it is concluded that there is no impact on nuclear safety or safe operations, nor are there any environmental concerns or unreviewed safety questions.

Enclosure No. 3
Technical Specification Bases Mark-up

4.4.4 Hydrogen Recombiner System

Applicability

Applies to the testing of the hydrogen recombiner and associated controls.

Objective

To verify that the hydrogen recombiner and associated controls are operable.

4.4.4.1 Specification

a. Perform a system functional test for the hydrogen recombiner each refueling interval by verifying that the reaction chamber gas temperature is maintained $\geq$ 1200°F for at least 4 hours.

b. Visually examine the hydrogen recombiner enclosure and verify there is no evidence of abnormal conditions each refueling interval.

c. Perform a resistance to ground test for each heater phase each refueling interval and verify that the resistance to ground for any heater is phase $\geq$ 10,000 ohms.

Bases

The surveillance program above provides high assurance that the hydrogen recombiner system will be available to perform its post-LOCA function of maintaining the containment hydrogen concentration below 4.1 volume percent. This system is not credited to mitigate any accident analyzed in Chapter 14 of the TMI-1 FSAR. The frequency of the surveillance of the hydrogen recombiner system is based on the safety significance of the system. **Hydrogen generating material in the reactor building is limited to ensure that the capacity of one hydrogen recombiner can maintain post LOCA hydrogen concentration below 4.0 %. The recombiner will be placed in service in accordance with TMI-1 Final Safety Analysis Report Section 6.5. This Section of the FSAR shows that adequate time (at least several days) is available to place a hydrogen recombiner in service.** ~~TMI-1 FSAR Section 6.5.3.1 indicates that the hydrogen recombiner system is not required until 9.8 days following a LOCA. This is adequate time to place a hydrogen recombiner in service.~~

Enclosure 4
Calculation No. C-1101-901-5360-007 Rev. 8
Hydrogen Generation Inside Containment

GPU NUCLEAR

CALCULATION COVER SHEET

(Ref. EP-006T)

Subject:	Calculation No.	Rev. No.	System Nos.	Sheet
TMI-1: HYDROGEN GENERATION INSIDE CONTAINMENT	C-1101-901-5360-007	8	901	1 of 21

1. Is this calculation within the scope of the GPUN Operational Quality Assurance Plan? (If **YES**, a verification is required.) ☒ Yes ☐ No

2. Does this calculation contain assumptions / design inputs that require confirmation? (If **YES**, provide CAP or appropriate configuration control number(s)) (e.g., ECD, PFU, MD, PCR, etc.) _____ ☐ Yes ☒ No

3. Does this calculation require revision to any existing documents? (If yes, provide CAP or appropriate configuration control number(s)) _____ ☐ Yes ☒ No

4. Is this calculation performed as a design basis calculation? (If **YES**, identify design basis parameters.) (See Section 3.3) ☒ Yes ☐ No

Parameter: Post-LOCA hydrogen control

Referenced Calculations and Safety Evaluations (See Section 4.3.2.7)	Rev. No.
1. GPUN Calc C-11010-5370-004, dated 23 November 1981	0
2. GPUN Calc C-1101X-322F-102, dated 13 December 1979	0

Comments:

APPROVALS

Originator: Z. Bart Fu	Date 8/18/99
Verification Engineer/Reviewer: Navin C. Shah	Date 8/18/99
Section Manager: John Jandovitz	Date 8/18/99
Other Verification Engineer/Reviewer	Date
Other Verification Engineer/Reviewer	Date

GPU NUCLEAR

CALCULATION VERIFICATION PLAN/SUMMARY SHEET

(Ref. EP-006T)

Subject:	Calculation No.	Rev. No.	System Nos.	Sheet:
TMI-1: HYDROGEN GENERATION INSIDE CONTAINMENT	C-1101-901-5360-007	8	901	of

PLAN

Scope of Verification:

Item No.	Method/Depth oF Verification Required	Req'd. Comp. Date
1	(Check Applicable Boxes) Design Review ☒ Alternate Calculation ☐ Qualification Test ☐ Other ☐ (Specify below) Verification applies only to the changes in this revision. Verify design input, methods used and results to assure the output is correct. Assure the document is clearly written and understandable for interfaces, methods.	8/14/99

Assigned Verification Engineer N. C. Shah

Other Verification Engineer

Section Manager (*Sign*) John S Jendrzejczyk **Date** 8/3/99

SUMMARY

Summary of verification scope, methods, results and conclusions:

This revision of the calc. used R.G. 1.7 surface corrosion rate for aluminum vs. all aluminum reacting instantaneously in Rev. 7. Based on this change, the results are reasonable since it now takes longer for H_2 (10 days vs. 8.6 days in Rev. 7) generation to reach 3% concentration.

The inputs and method used are verified correct.

The change due modification 8A 412532 was incorporated in this calculation.

Based on this evaluation, the calculation is verified to be acceptable.

APPROVALS (Sign)

Assigned Verification Engineer N. C. Shah N.C. Shah **Date** 8/17/99

Other Verification Engineer **Date**

GPU NUCLEAR

CALCULATION VERIFICATION CHECKLIST

(Ref. EP-006T)

Subject:	Calculation No.	Rev. No.	System Nos.	Sheet:
TMI-1: HYDROGEN GENERATION INSIDE CONTAINMENT	C-1101-901-5360-007	8	901	of

Place an "X" in the applicable box (Yes, No, N/A) for each item.

A **"NO"** response may indicate that the design or verification is incomplete and may require a CAP to be assigned by the responsible Section Manager. The Section Manager shall review each **"NO"** response to determine if the **"NO"** response requires further investigation.

A "N/A" (Not Applicable) response does **not** require any further action by the Verification Engineer.

The Verification Summary (Exhibit 7A) may be used to outline the Verification Engineer's work or to document comments that are deemed appropriate by the Verification Engineer.

ITEMS	Review Check – Design Compliance		
	Yes	No	N/A
1. **Design Input and Data** – Were the inputs correctly selected, referenced (latest revision) and incorporated into the calculation?	☒	☐	☐
2. **Assumptions** – Are assumptions necessary to perform the calculation adequately described and reasonable?	☒	☐	☐
3. **Regulatory Requirements** – Are the applicable codes and standards and regulatory requirements, including issue and addenda, properly identified and their requirements met?	☒	☐	☐
4. **Construction and Operating Experience** – Has applicable construction and operating experience been considered?	☐	☐	☒
5. **Interfaces** – Have the design interface requirements been satisfied?	☐	☐	☒
6. **Methods** –Is the appropriate calculation method used?	☒	☐	☐
7. **Output** – Is the output reasonable compared to the inputs?	☒	☐	☐
8. **Acceptance Criteria** – Are the acceptance criteria incorporated in the calculation sufficient to allow verification that the design requirements have been satisfactorily accomplished?	☐	☐	☒
9. **Radiation Exposure** – Has the calculation properly considered radiation exposure to the public and plant personnel?	☐	☐	☒

Comments:

GPU Nuclear

DOCUMENT NO. C1101-901-5360-007

TITLE TMI-1: HYDROGEN GENERATION INSIDE CONTAINMENT

REV	SUMMARY OF CHANGE	APPROVAL	DATE
1	This calculation is revised for the following reasons: 1) To reflect an increase in hydrogen generating materials resulting from the addition of 12 ounces of brass to the Reactor Building per TFAAI BT5463. 2) To reflect an increase of 0.15 lbs. (2.4 ounces) of zinc inside containment from the proposed installation of two new junction boxes per TFAAI BT6213. 3) To correct the amount of hydrogen generated by aluminum, zinc, and zinc alloys located inside the containment.	/s/ J. P. Logatto /s/ N. C. Shah /s/ D. J. Masiero	11/24/92 11/24/92 11/24/92
2	Revision 2 reflects the following changes to the inventory of hydrogen generating materials inside containment: 1) A reduction of 33.75 lbs. of aluminum resulting from the replacement of 5 light fixtures weighing 57.5 lbs. total with 5 new fixtures weighing 23.75 lbs. total per TFAAI BT6380. 2) An increase of 11 lbs. of aluminum resulting from the installation of one camera and associated equipment.	/s/ J. P. Logatto /s/ N. C. Shah	04/05/94 04/27/94
3	Revision 3 evaluates the effect of increasing the inventory of hydrogen generating material inside containment resulting from the permanent storage of 389 galvanized scaffold poles per TFAAI BT 6436.	/s/ J. P. Logatto /s/ N. C. Shah	03/14/95 03/14/95
4	Revision 4 evaluates the effect of increased radiolytic hydrogen for power levels of 2568,2620, and 2772 MWt. Appendix 2 is added for this purpose. The calculation is also updated to reflect current power level of 2568 MWt.	/s/ S. R. Greco /s/ J. P. Logatto	3/17/97 3/17/97

GPU NUCLEAR	DOCUMENT NO. C1101-901-5360-007
TITLE TMI-1: HYDROGEN GENERATION INSIDE CONTAINMENT	Sheet 1b of 21

REV	SUMMARY OF CHANGE	APPROVAL	DATE
5	Revision 5 evaluates the effect of increasing the inventory of hydrogen generating material inside containment resulting from the installation of a replacement jib crane containing 60 lbs. of aluminum. This revision also removes the comparison between section 6.5.3 and Appendix 14D of the FSAR as outlined on page 10. LAR 96044.09 has been issued to reconcile the discrepancies.	/s/ J. P. Logatto /s/ S. R. Greco /s/ R. J. McGoey	5/23/97 7/3/97 7/6/97
6	Revision 6 corrects the amount of aluminum being added to the Reactor Building as a result of the replacement of the jib crane under BA #412695. The original request specified 60 lbs. of aluminum installed with the new crane. Recent information from the vendor reduces the quantity of aluminum to 15 lbs. This revision also determines the earliest point post-LOCA at which the hydrogen recombiner can be placed in service. The original requirement of 8 days assumed that the hydrogen recombiner was not available until 7 days after an event and that 1 day was required for setup and installation. Since TMI-1 has two installed recombiners, the time to place one in service is shortened. Deleted section D-4 of appendix 2, determination of the time (post-LOCA) for initiation of hydrogen purge.	/s/ J. P. Logatto /s/ N. C. Shah /s/ R. J. McGoey	2/6/98 2/6/98 2/6/98

GPU NUCLEAR	DOCUMENT NO. C1101-901-5360-007
TITLE TMI-1: HYDROGEN GENERATION INSIDE CONTAINMENT	Sheet 1c of 21

REV	SUMMARY OF CHANGE	APPROVAL	DATE
7	Revision 7 is made to this calculation as follows: 1) To clarify the purpose and results section of the calculation. 2) Adds a summation of the total quantity of aluminum and zinc to the Appendix 1 Inventory of Hydrogen Generating Materials Inside the Reactor Building. 3) Corrects a word error in assumption 3.1.1 to state that the percentage of ***Zinc*** added per reference 4.9 is assumed to be 40% maximum. No changes are made to the determination of recombiner capability nor to the allowable margin for future use of zinc or aluminum. The changes documented herein are considered to be editorial and non-susbtantive and therefore do not require revision to the design verification.	/s/ J. P. Logatto	11/30/98
8	Revision 8 is made to this calculation as follows: 1) To include reactor servicing equipment not included in earlier revisions, i.e., RV stud spacers, RV stud plugs and stator tools and all the PI tubes. To include 3 light fixtures per BA 41253 2) To list out all items included, calculate exposed areas of items whose area exposed can be accounted for. 3) To apply the corrosion rate as defined in RG 1.7 for aluminum items. 4) To apply the RG corrosion rate to the 69 PI tubes originally included in the FSAR inventory of 500 pounds.	/s/ Z. Bart Fu	8/18/99

1.0 Purpose

This calculation evaluates and documents the hydrogen producing materials (aluminum and zinc) in the TMI-1 Reactor Building. Specifically, this calculation:

1. Documents the running total of hydrogen producing materials (zinc and aluminum) added to the Reactor Building;
2. Verifies that one hydrogen recombiner will prevent the Reactor Building hydrogen concentration from exceeding 3% by volume after a LOCA. The analysis accounts for the instantaneous oxidation of zinc and aluminum in the reactor building, fuel cladding oxidation, and the radiolytic decomposition rate of water.
3. Determies the total amount of additional zinc and aluminum that can be added without exceeding the ability of one hydrogen recombiner to maintain the reactor building H2 concentration $\leq$ 3%.

The lower limit of flammability for hydrogen in oxygen is 4.0% by volume. This calculation uses 3% as the acceptance criteria to provide a reasonable margin below the limit. This calculation must be revised to account for any new additions of zinc or aluminum to the reactor building. This calculation shall remain consistent with FSAR Section 6.5.3 and the bases for Technical Specification 4.4.4.

2.0 Summary of Results

The following results are based on a licensed power level of 2568 MWt. Appendix 2 gives results for other power levels (2620 MWt and 2772 MWt).

1. The current total reactor building zinc and aluminum inventories are:

   Zinc = 877.73 Lbs.

   Aluminum = 2653.95 Lbs.

   A detailed list is provided in Appendix 1, Inventory of Hydrogen Producing Material Inside TMI-1 Reactor Building.

2. Based on conservative assumptions, the reactor building will reach 3% hydrogen at 10 days after a LOCA with the currents zinc and aluminum inventories listed in Appendix 1. Initiating a single recombiner any time before reaching 3% hydrogen by volume will ensure that the concentration does not exceed 3%.

3. The radiolytic decomposition rate of water decreases to within the capacity of a single recombiner at 5 days after a LOCA. Therefore, the total amount of zinc and aluminum in the reactor building must be limited to ensure that hydrogen concentration does not reach 3% before 5 days. Based on current levels of zinc and aluminum, the following additional amounts of zinc (only) or aluminum (only) can be added to the existing inventory:

   Zinc: **The allowable** margin for future use of Zinc only is **1618.65 lbs** based on the assumption that **hydrogen** will reach 3% by volume at 5 days following a LOCA.

   Aluminum: **The allowable** margin for future use of Aluminum only is **446.69 lbs** based on the assumption that hydrogen will reach 3% by volume at 5 days following a LOCA.

3.0 Assumptions and Design Inputs

3.1 Assumptions

3.1.1 The percentage of zinc added per Reference 4.9 is assumed to be 40% maximum.

3.1.2 The change in aluminum inventory per Reference 4.11 is assumed to be a decrease of 33.75 pounds (i.e., replacement of five 11.5 pound fixtures with five 4.75 pound fixtures).

3.1.3 The change in aluminum inventory per Reference 4.12 is assumed to be an increase of 11 pounds with the addition of one camera and associated equipment. Reference 4.12 also requests a pre-evaluation of the effect of the addition of 3 more cameras as a future contingency.

3.1.4 The change in zinc inventory per Reference 4.13 is an increase of 261.63 pounds due to the storage of galvanized scaffold materials inside the Reactor Building.

3.1.5 The change in aluminum inventory per Reference 4.14 is an increase of 60 pounds due to the installation of a new jib crane inside containment.

3.1.6 Reference 4.15 corrects the amount of aluminum added as a result of the jib crane modification to 15 pounds or a decrease of 45 pounds from the previous revision of this calculation.

3.1.7 Hydrogen Recombiner is installed and available for service within 1 day in accordance with reference 4.16

3.1.8 The aluminum inventory is being updated to include 58 RV stud spaces weighing 10 pounds each; 58 RV stud hole plugs at 3.5 pounds each; 2 stator removal tools weighing 80 pounds each (Refer to Appendix I)

3.2 Design Inputs

3.2.1 The hydrogen recombiner has an efficiency of 97.5% per Reference 4.4.

3.2.2 Hydrogen production for as-built plant conditions is based on the values given in FSAR Section 6.5.3 per Reference 4.5.

3.2.3 Hydrogen production rate and total accumulated hydrogen by radiolysis are based on GPUN calculation #1101X-322F-102 (Reference 4.4) data adjusted to 2568 MWt power using an adjustment ratio of 2568/2535 (see appendix 2).

3.3.4 Reference 6.5.3 includes 69 PI tubes weighing 20 pounds each. These will be evaluated separately.

3.3.5 To be conservative, only use the upper limit, 200 mil/yr, as corrosion rate.

4.0 References

4.1 GPUN Calculation #11010-5370-004, "Hydrogen Production From Zinc", dated 23 November 1981.

4.2 TFAAI Request #BT 4936, R.G. 1.97: Additional Zinc Inside Containment

4.3 Verbal request for additional Aluminum inside containment for TMI-1 (W. Naylor) per BA#412232 (Fuel Handling Bridge Upgrade) and BA#412537 (TV Cameras) per attachments 1 & 2.

4.4 GPUN Calcluation #1101X-322F-102, "TMI-1 Restart Task RM-12 - Hydrogen Recombiner Sizing", dated 13 December 1979.

4.5 FSAR Section 6.5.3, Update 7, July 1988.

4.6 Rockwell International Thermal Hydrogen Recombiner Manual #VM-TM-0250.

4.7 USNRC Regulatory Guide 1.7.

4.8 Verbal request for additional Zinc inside containment for TMI-1 under BA#412232.

4.9 TFAAI Request #BT 5463, Reactor Building Fuel Handling Bridge Upgrade, BA#412564.

4.10 TFAAI Request #BT 6213, NI Upgrade - Additional Zinc.

4.11 TFAAI Request #BT 6380, Reactor Building Light Fixtures/Hydrogen Producing Material

4.12 TFAAI Request #BT 6383, Evaluate Additional Cameras Inside Containment.

4.13 TFAAI Request #BT 6436, RB Scaffold Storage

4.14 Verbal request for addition of Aluminum inside containment for TMI-1 under BA#412695

4.15 ETTS Request #4185, Correction of amount of aluminum added under BA#412695

4.16 GPUN Inter-Office Memo #E250-98-001 (Weston to Greco), dated 8 January 1998
Subject: Hydrogen Recombiner Operation.

4.17 Inter Office Memo E250-99-006, from F. Jaxheimer to B. Fu, Hydrogen Generating Items Update

4.18 TFAAI Request #BA 412532, Light Fixtures

5.0 Calculation

A. Calculation of Hydrogen Generation

1. Per reference 4.1, 1 lb of zinc will generate 5.5 scf of hydrogen. As requested by reference 4.2, additional zinc in the amount of 2.4 ounces in two junction boxes will be located inside the Reactor Building. The hydrogen generated by this additional zinc can be calculated as:

   (2.4/16) x 5.5 scf = 0.825 scf hydrogen

2. Per refernce 4.4, 1 lb of aluminum will generate 19.93 scf of hydrogen. As requested by reference 4.3, 5.7 lbs of aluminum (under BA#412232) and 44 lbs of aluminum (under BA#412537) will be added inside containment. Hydrogen generated by this additional aluminum can be determined as follows:

   (44 + 5.7) x 19.93 scf = 990.521 scf hydrogen

3. Per reference 4.8, fittings for the pneumatic control system of the Fuel Handling Bridge modification contain approximately 10 lbs brass with 35% zinc composition. The amount of hydrogen generated is:

   (10 x 0.35) x 5.5 scf = 19.250 scf hydrogen

4. Per reference 4.9, 12 ounces of brass will be added (under BA#412564) with a zinc content of 40%. The hydrogen generated by this amount of zinc is:

   0.4 x (12/16) x 5.5 scf = 1.650 scf hydrogen

5. Per reference 4.1, 1 lb of zinc will generate 5.5 scf of hydrogen. As requested by reference 4.10, additional zinc in the amount of 2.4 ounces in two junction boxes will be located inside the Reactor Building. The hydrogen generated by this additional zinc can be calculated as:

   (2.4/16) x 5.5 scf = 0.825 scf hydrogen

6. Per reference 4.11 and assumption 3.5, 33.75 lbs of aluminum will be removed from the Reactor Building. The decrease in hydrogen produced is:

   -33.75 x 19.93 scf = -672.64 scf hydrogen

7. Per reference 4.12, one camera assembly with 11 lbs of aluminum was added to the Reactor Building on 3/18/94. Reference 4.12 requested an evaluation of the effect of this increase on generation of hydrogen inside containment. The effect of 11 lbs of aluminum is:

   11 x 19.93 scf = 219.23 scf hydrogen

8. Reference 4.12 and BA 412532 added 3 more camera units, each containing 11 lbs of aluminum, as a contingency for future additions. The hydrogen produced is:

   33 x 19.93 scf = 657.69 scf hydrogen

9. Per reference 4.13, 92 - 13 ft scaffold poles weighing 27 lbs each and 297 - 10 ft poles weigning 21 lbs each will be permanently stored inside the reactor building. The poles have a zinc content of 3% (maximum) resulting in an increase in zinc inventory of 261.63 pounds. The hydrogen produced is:

   261.63 x 5.5 scf = 1438.97 scf hydrogen

10. Per reference 4.14, the replacement jib crane includes 60 lbs of aluminum in the housing. The hydrogen produced by the additional aluminum is:

    60 x 19.93 scf = 1195.80 scf hydrogen

11. Per reference 4.15, the correct value for aluminum contained in the replacement jib crane is 15 lbs. Therefore, this revision removes 45 lbs of aluminum from the calculation and the decrease in hydrogen produced is:

    -45 x 19.93 scf = -896.85 scf hydrogen

12. Corrosion rate per RG 1.7 (reference 4.7) = 200 mils/year in NaOH spray.
This rate equals 0.5479 mils/day = 4.5662 E-05 ft/day

For each square foot exposed the corrosion rate in volume is:

1 ft^2 x 4.5662E-05 = 4.5622E-05 ft^3/day

The specific weight of aluminum is 168.68 lb/ft^3

therefore, the corrosion rate by weight is

4.5622e-05ft^3/day x 168.68 lb/ft^3 = 0.007702266 lb/day per ft^2 exposed

Per Appendix 1, Group IV, the amount of material being considered is:

1. 69 PI tubes with a total exposed area of 824 ft^2. This results in a corrosion rate of:

   824 x 0.007702 = 6.346667316 lb/day

2. 58 RV stud spacers with a total exposed area of 263.62 ft^2. This results in a corrosion rate of:

   223.65 x .007702 = 1.722611827 lb/day

3. 58 RV stud hole plugs with a total exposed area of 142.28 ft². This results in a corrosion rate of:

142.28 x .007702 = 1.095878429 lb/day

4. 2 stator removal tools with a total exposed area of 42 ft². This results ina corrosion rate of:

42 x 0.007702 = 0.323495179 lb/day

The total of the above exposed areas results in corosion rate of:

9.4886528 lb/day

At 11 days the hydrogen production from the above exposed area is 2080.2 scf

At 10 days the hydrogen production from the above exposed area is 1891.1 scf

Therefore, the total hydrogen generated by Group I aluminum and zinc items in the Reactor Building to date is (refer to Appendix I):

0.825 + 990.5 + 19.25 + 1.65 + 0.825 - 672.6
+ 219.2 + 657.69 + 1438.97 + 1195.8 - 896.85 = 2955.27 scf hydrogen.

Note: Prior to Rev. 8, there are 500 ib of aluminum assumed from the FSAR. In this rev, the 500 lb are itemized. Part of the 500lb are listed in Group II (refer to App. I) at a total of 256 lb of Al, the rest of them, which used to be uncoated PI tubes, are inluded in Group IV.

Based on the TMI-1 FSAR (reference 4.5) the hydrogen generated by zircaloy-water reaction, corrosion of aluminum (256lbs, Group II, App. I) and corrosion of zinc (612 lbs, Group III App. I) is:

Hydrogen generated by zircaloy-water reaction:	20000 scf
+ Hydrogen generated by aluminum corrosion:	5102.08 scf
+ Hydrogen generated by corrosion of zinc:	3366 scf
TOTAL	28468.08 scf

3% hydrogen by volume = 0.03 x (2.0E6) = 60000 scf

Therefore, the hydrogen generated by radiolytic decomposition prior to reaching 3% by volume:
V = 60000 - (28468.08 + 2955.27) = 28576.65 scf hydrogen

Per figure 5 of reference 4.4 and Table II.a, appendix 2:
Accumulated hydrogen of 28576.65 scf by radiolysis will occur at approximately
t= 9.8 days
A starting value at 10 days wil be used.

At this point, an iterative solution will be used to determine the radiolytic decomposition prior to reaching 3% by volume.
V =60000 - (28468.08 + 2955.27 + corrosion of exposed aluminum)
At 10 days the hydrogen production from the above is
V = 60000 - (28468.08 + 2955.27 +1891.09) 26685.56

Per figure 3 of reference 4.4 and appendix 2, table I.a:
The hydrogen production rate at 10 days = 1.09755365 scfm

Using the hydrogen recombination efficiency of 97.5%, the required recombiner capacity of the reactor building air at 3% hydrogen concentration is:
1.0976/(0.03 x 0.975) = 37.52 scfm RB air

Per Table 2-2 of reference 4.6, the TMI-1 Hydrogen Recombiner has a capacity of 50 scfm; therefore, a single recombiner has the capability to remove the hydrogen production rate of 1.0975536 scfm

B. Margin for future use of Aluminum and/or Zinc

Per reference 4.16, the hydrogen control system would be available for operation within 1 day of a design basis LOCA. With the assumption of 1 day required for installation, the margin for the future use of Aluminum or Zinc is evaluated 2 days post-LOCA.

(Note:Two Hydrogen Recombiners are in place and ready for use at TMI-1.)

The hydrogen generated by radiolysis at 2 days post-LOCA can be obtained from figure 5 of reference 4.4 or appendix 2, Table IIa:

Vt = 10,677 scf hydrogen

Hydrogen production rate from figure 3 of reference 4.4 or appendix 2, Table I.a:

124.076 scf/hr = 2.068 scfm hydrogen

Required hydrogen recombiner capacity:

2.068/(0.03 x 0.975) = 70.7 scfm RB air at 3% hydrogen concentration

> 50 scfm TMI hydrogen recombiner capacity

Since the required hydrogen recombiner capacity exceeds that available with one unit, it is necessary to determine the time at which the generation rate equals the recombination rate.

50 scfm RB air at 3% hydrogen concentration

50 x 0.03 x 0.975 = 1.4625 scfm hydrogen

1.4624 x 60 x 24 = 2106.0 scf/day

Per table IIa, hydrogen production reaches 2106 scf per day between 4 and 5 days post-LOCA.

Therefore, margin for future use of aluminum and/or zinc will be evaluated at 5 days post-LOCA.

The hydrogen generated by the corrosion of aluminum and zinc, and the metal-water reaction is:

V2 = 28468.08 + 2955.27 + 1891.09 scf = 33314.44 scf

Therefore, the available hydrogen volume generated by future use of aluminum and zinc can be determined:

V3 = 60000 - (Vt + V2) = 60000 - (17783+ 33314.44) = 8902.56 scf

The margin for future use of Zinc only:

WZn =8902.56/5.5 = 1618.65 lbs Zinc

The margin for future use of Aluminum only:

WAl = 8902.56/19.93 = 446.69 lbs Aluminum

(Note that these margins are for either zinc or aluminum, not both.)

APPENDIX 1

Inventory of Hydrogen Generating Materials Inside TMI-1 Reactor Building

Zircaloy (Lbs)	Hydrogen Produced (SCF)	Aluminum (Lbs)	Hydrogen Produced (SCF)	Zinc (Lbs)	Hydrogen Produced (SCF)	Calc. Section	Reference
----	20,000	high temperature paint 200	3,986	Myers Hub conduit 612	3,366	4.5	FSAR 6.5.3
		Tags and Name plate 2					FSAR 6.5.3
		RCP Ring Girder paint 20					FSAR 6.5.3
		RB Elevator Machinery 20					FSAR 6.5.3
		Polar Crane Collector Arms 4.3					FSAR 6.5.3
		Device for Polar Crane 4.7					FSAR 6.5.3
		Pipe Hanger Name Plate 5					FSAR 6.5.3
				2 junction boxes 0.15	0.825	5.A.1	TFAAI BT 4936
		Light Fixtures 49.7	990.5			5.A.2	BA 412232
		69PI tubes 1380					Ref. 4.17, Memo-fj
		RV Stud Spacers 580					Ref. 4.17, Memo-fj
		RV Stud Hole plugs 203					Ref. 4.17, Memo-fj
		Stator Removal Tools 160					Ref. 4.17, Memo-fj
				Fittings 3.5	19.25	5.A.3	BA 412232
			RB Fuel Handling Bridge upgrade	0.3	1.65	5.A.4	BA 412564
				2 junction boxes 0.15	0.825	5.A.5	TFAAI BT 6213
		Light fixtures taken out -33.75	-672.64			5.A.6	CMR-91-061 TFAAI BT 6380
		1 Camera assembly 11	219.23			5.A.7	EER 94-0099 TFAAI BT 6383
		3 light fixtures 33	657.69				TFAAI BT 6383 BA 412532
				Scaffold poles 261.63	1439.0	5.A.9	TFAAI BT 6436 BA 412658
		Jib Crane Housing 60	1195.8			5.A.10	BA 412695
		Revised Jib Crane Housing -45	-896.85			5.A.11	ETTS 4185
Total Inventory		***2653.95 lbs. Al***		***877.73 lbs. Zn***			

For calculation purpose, items in the above table are divided in three groups

Group I from the above table: (Calc 5.0 A, items from 1 to 11)
(weight in lb): 0.15Zn+49.7Al+3.5Zn+0.3Zn+0.15Zn-33.75Al+11Al+33Al+261.63Zn+60Al-45Al
(Hydrogen Produced in SCF): 0.825+990.5+19.25+1.65+0.825-672.6+219.2+657.69+1438.97+1195.8-896.85

Group II from the above table: (Calc 5.0 A, 12)
(weight of aluminum in lb): 200Al+2Al+20Al+20Al+4.3Al+4.7Al+5Al = 256lbs
(Hydrogen Produced in SCF): 5102.08

Group III from the above table: (Calc 5.0 A, 12)
(weight in lb): 612 Zn. (Hydrogen Produced in SCF): 3366

Group IV from the above table: (items with know exposed area calculated using corrosion rate, refer to Sheet 1 attached for detail calculation of the exposed areas)
Component areas are calculated as follows:

1. Stud Support Spacers
Calculation is based on B&W Drawing 99563 C Rev.3
Area per spacer is 3.856 ft2.
There are total of 58 spacers.
Total area is 223.65 ft2.

2. Stud Plugs
Calculation is based on B&W Drawing 128778E Rev.2
Area per plug is 2.453 ft2.
There are total of 58 stud plugs.
Total area is 142.28 ft2.

3. Stator Tools
Calculation is based on Vendor Manual,Page 6-16A, Part Number 706544-1052
Area per tool is 21 ft2.
There are total of 2 Stator Tools.
Total area is 42 ft2.

4. P.I. Tubes
Calculation is based on EER No. 95-0286
Area per PI tube is 11.91 ft2.
There are total of 69 PI Tubes.
Total area is 824 ft2.

Appendix 2

A. Purpose

This addendum reviews the impact of stepwise power uprate increases on hydrogen generation in containment starting from the original design basis of 2535 MWt to the following levels:

2568 MWt.....implemented prior to cycle 7
2620 " .....proposed for cycle 12
2772 " .....proposed for cycle 13

B. Design Inputs

1. Per Section 5.A, hydrogen generation rom corrosion of zinc and aluminum in containment and the zircaloy-water reaction are 15365 scf and 20000 scf respectively.
2. Hydrogen production rates and total accumulation of hydrogen from radiolytic decomposition of water are per Reference 4.4. Production rates are summarized in Tables I and Ia.

HYDROGEN PRODUCED BY RADIOLYTIC DECOMPOSITION OF THE POST ACCIDENT EMERGENCY COOLING SOLOUTIONS

$S_H(t)$ = Hydrogen production rate

$$S_H(t) = \frac{P}{(B)(N)} \cdot \frac{G_C E_C(t) + G_S E_S(t)}{100} \quad \text{lb-mole/sec}$$

$$V_H(t) = 1.3E{+}06 \times S_H(t) \quad \text{scf/hr}$$

Power =	Power level	2535/2568/2620/2772	MWt
B =	Conversion factor	454	gm-mole/lb-mole
N =	Avogadro's Number	6.023E+23	molecules/gm-mole
G_C =	Radiolytic hydrogen yield in core	0.5	molecules/100 ev
$E_C(t)$ =	Gamma ray fission product energy absorbed by core coolant	$(f_\gamma)c\ H_\gamma(t)$	ev/sec-MWt
G_S =	Radiolytic hydrogen yield in solution	0.5	molecules/100 ev
$E_S(t)$ =	Energy absorbed in coolant outside core due to fission products dissolved in coolant	$(f_{\gamma+\beta})_S H_{\gamma+\beta}(t) + f_I H_I(t)$	ev/sec-MWt
$(f_\gamma)c$ =	Fraction of fission product gamma energy absorbed by coolant in core region	0.1	
$(f_{\gamma+\beta})_S$ =	Fraction of total solid fission product energy absorbed in coolant outside the core	0.01	
f_I =	Fraction of iodine isotope energy absorbed in coolant outside core	0.5	
$H_{\gamma+\beta}(t)$ =	Total solid fission product energy production rate	$2.0\ H_\gamma(t)$	ev/sec-MWt
$H_\gamma(t)$ =	Gamma energy production rate	$(5.1912e^{-9.8E-5t} + 0.8743e^{-6.5E-6t} + 0.6557e^{-5.7E-7t} + 0.4098e^{-7.4E-8t} + 0.0150e^{-8.0E-10t}) \times 10^{22}$	ev/sec-MWt
$H_I(t)$ =	Iodine isotope production rate	$(0.8197e^{-6.1E-5t} + 0.3279e^{-1.1E-5t} + 0.0574e^{-1.0E-6t}) \times 10^{22}$	ev/sec-MWt

C. Methodology

1. Determine the total hydrogen production in standard cubic feet (scf) as a function of time by estimating the volume under hydrogen production rate curves ($V_H(t)$ -vs- time(t)) from the above tables. Estimates were performed for various time increments using the formula for area of a trapazoid: $A = [((V_H(t_1)+V_H(t_2))/2](t_1 - t_2)$. Cumulative area, $A(T) = \Sigma A$. Tables II, IIa, IIb, and IIc summarize this data.

2. Given the current estimates of hydrogen generated by zircaloy-water reaction and aluminum/zinc corrosion, determine the time post-LOCA that hydrogen concentration in containment reaches 3% by volume for 2568, 2620, and 2772 MWt.

3. Calculate the required recombiner capacity for 2568, 2620, and 2772 MWt.

4. Calculate the margin for future use of aluminum and/or zinc at 2568 MWt.

D. Calculation

1. Time, post-LOCA, to reach 3.0% by volume hydrogen concentration in containment.

   Per Section 5.A this calculation, the hydrogen generated by radiolytic decomposition prior to reaching 3.0% by volume is 26466scf. A plot of accumulated hydrogen, A(T) data from Tables II, IIa, IIb, and IIc as a function of time provides the following times to reach 3.0% by volume hydrogen. See Figure 1.

2568 MWt: 10 days	26595.80 scf	1.0976 scfm
2620 MWt: 10 days	27134.34 scf	1.1198 scfm
2772 MWt: 9 days	28773.36 scf	1.2298 scfm

2. Hydrogen Recombiner Capacity

   H_2 production rate at 10 days estimated from Table Ia (2568 MW) is 1580.477 scf/day =1.0976 scfm

   H_2 production rate at 10 days estimated from Table Ia (2620 MW) is 1612.48 scf/day = 1.1198 scfm

   H_2 production rate at 9 days estimated from Table Ia (2772 MW) is 1770.841 scf/day = 1.2298 scfm

   Using the H_2 Recombiner efficiency of 97.5%, the required Recombiner capacity of the reactor building air at 3% for the different power levels is:

1.0976/(0.03 x 0.975) =	37.523 scfm RB air
1.1198/(0.03 x 0.975) =	38.283 scfm RB air
1.2298/(0.03 x 0.975) =	42.043 scfm RB air

   TMI H_2 Recombiner capacity = **50 scfm** Reference 4.6, table 2-2

3. Margin for future use of aluminum and zinc.

   Calculation Section 5.B is updated to reflect power operation at 2568 MWt. Margins at higher power should be evaluated prior to implementation. Since hydrogen recombiners are installed and capable of initiation within one shift, the 8 days for hydrogen control system initiation guidance as recommended by the original SRP (USNRC Reg Guide 1.7) should be reconsidered. Earlier start times will provide greater margin for future use of aluminum and zinc.

4. UFSAR Appendix 14D

SECTION DELETED

Figure 1

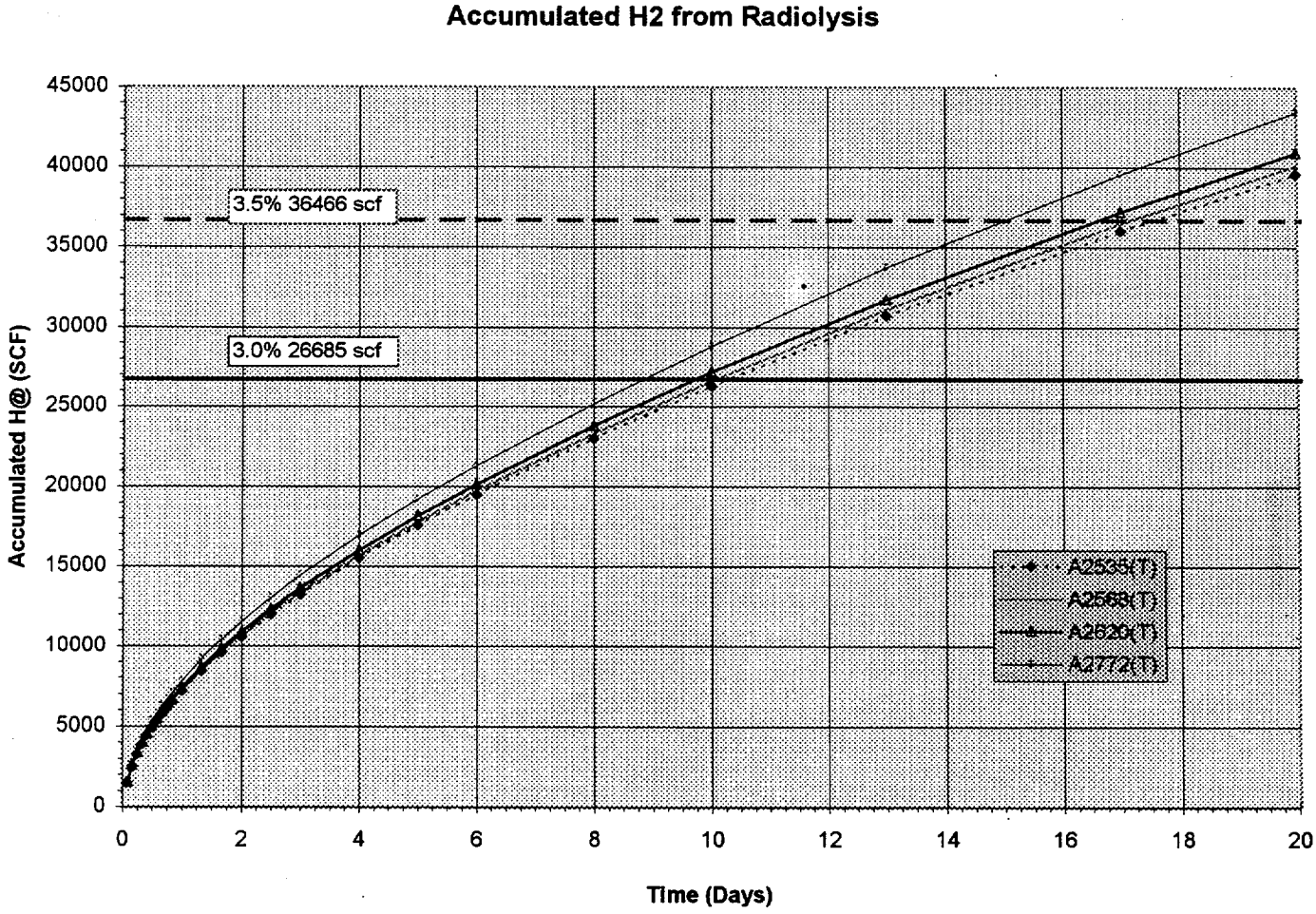
Accumulated H2 from Radiolysis
Accumulated H@ (SCF)
Time (Days)
3.5% 36466 scf
3.0% 26685 scf
A2535(T)
A2568(T)
A2620(T)
A2772(T)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
0
2
4
6
8
10
12
14
16
18
20

Table I

TMI-1 Hydrogen Production by Radiolysis

Time		$S_H(t)$	$V_H(t)$	$S_H(t)$	$V_H(t)$	$S_H(t)$	$V_H(t)$	$S_H(t)$	$V_H(t)$
Hours	Seconds	lb-mole/sec	scf/hr	lb-mole/sec	scf/hr	lb-mole/sec	scf/hr	lb-mole/sec	scf/hr
		2535 MWt		2568 MWt		2620 MWt		2772 MWt	
0	0	6.768E-04	874.729	6.856E-04	886.116	6.995E-04	904.059	7.400E-04	956.509
1	3600	5.493E-04	709.931	5.564E-04	719.173	5.677E-04	733.736	6.006E-04	776.304
2	7200	4.548E-04	587.845	4.607E-04	595.497	4.701E-04	607.555	4.973E-04	642.803
3	10800	3.843E-04	496.775	3.894E-04	503.242	3.972E-04	513.432	4.203E-04	543.219
4	14400	3.314E-04	428.315	3.357E-04	433.890	3.425E-04	442.676	3.624E-04	468.358
5	18000	2.912E-04	376.403	2.950E-04	381.302	3.010E-04	389.024	3.184E-04	411.593
6	21600	2.605E-04	336.657	2.639E-04	341.039	2.692E-04	347.945	2.848E-04	368.131
7	25200	2.367E-04	305.898	2.397E-04	309.880	2.446E-04	316.155	2.588E-04	334.497
8	28800	2.180E-04	281.814	2.209E-04	285.482	2.253E-04	291.263	2.384E-04	308.161
9	32400	2.033E-04	262.714	2.059E-04	266.134	2.101E-04	271.523	2.223E-04	287.275
10	36000	1.914E-04	247.358	1.939E-04	250.579	1.978E-04	255.653	2.093E-04	270.484
11	39600	1.817E-04	234.836	1.841E-04	237.893	1.878E-04	242.710	1.987E-04	256.791
12	43200	1.737E-04	224.470	1.759E-04	227.392	1.795E-04	231.996	1.899E-04	245.456
13	46800	1.669E-04	215.759	1.691E-04	218.568	1.725E-04	222.994	1.825E-04	235.931
14	50400	1.612E-04	208.329	1.633E-04	211.041	1.666E-04	215.314	1.763E-04	227.806
15	54000	1.562E-04	201.898	1.582E-04	204.526	1.614E-04	208.668	1.708E-04	220.774
16	57600	1.518E-04	196.254	1.538E-04	198.809	1.569E-04	202.835	1.660E-04	214.602
17	61200	1.480E-04	191.237	1.499E-04	193.726	1.529E-04	197.649	1.618E-04	209.116
18	64800	1.445E-04	186.722	1.463E-04	189.153	1.493E-04	192.983	1.580E-04	204.179
19	68400	1.413E-04	182.616	1.431E-04	184.993	1.460E-04	188.739	1.545E-04	199.689
20	72000	1.384E-04	178.846	1.402E-04	181.174	1.430E-04	184.843	1.513E-04	195.566
21	75600	1.357E-04	175.355	1.374E-04	177.638	1.402E-04	181.235	1.484E-04	191.749
22	79200	1.332E-04	172.100	1.349E-04	174.340	1.376E-04	177.870	1.456E-04	188.189
23	82800	1.308E-04	169.044	1.325E-04	171.245	1.352E-04	174.712	1.430E-04	184.848
24	86400	1.286E-04	166.162	1.302E-04	168.325	1.329E-04	171.733	1.406E-04	181.696
25	90000	1.264E-04	163.429	1.281E-04	165.557	1.307E-04	168.909	1.383E-04	178.709
26	93600	1.244E-04	160.830	1.261E-04	162.924	1.286E-04	166.223	1.361E-04	175.866
27	97200	1.225E-04	158.349	1.241E-04	160.411	1.266E-04	163.659	1.340E-04	173.153
28	100800	1.207E-04	155.975	1.222E-04	158.005	1.247E-04	161.205	1.320E-04	170.557
29	104400	1.189E-04	153.698	1.205E-04	155.698	1.229E-04	158.851	1.300E-04	168.067
30	108000	1.172E-04	151.509	1.187E-04	153.481	1.212E-04	156.589	1.282E-04	165.674
31	111600	1.156E-04	149.402	1.171E-04	151.347	1.195E-04	154.412	1.264E-04	163.370
32	115200	1.140E-04	147.372	1.155E-04	149.290	1.178E-04	152.313	1.247E-04	161.150
33	118800	1.125E-04	145.413	1.140E-04	147.306	1.163E-04	150.288	1.230E-04	159.007
34	122400	1.110E-04	143.520	1.125E-04	145.389	1.148E-04	148.333	1.214E-04	156.938
35	126000	1.096E-04	141.691	1.111E-04	143.535	1.133E-04	146.442	1.199E-04	154.938
36	129600	1.083E-04	139.921	1.097E-04	141.743	1.119E-04	144.613	1.184E-04	153.003
37	133200	1.069E-04	138.209	1.083E-04	140.008	1.105E-04	142.843	1.169E-04	151.130
38	136800	1.056E-04	136.550	1.070E-04	138.327	1.092E-04	141.128	1.155E-04	149.316
39	140400	1.044E-04	134.943	1.058E-04	136.699	1.079E-04	139.468	1.142E-04	147.559
40	144000	1.032E-04	133.385	1.045E-04	135.121	1.067E-04	137.858	1.128E-04	145.855
41	147600	1.020E-04	131.875	1.034E-04	133.591	1.055E-04	136.297	1.116E-04	144.204
42	151200	1.009E-04	130.410	1.022E-04	132.107	1.043E-04	134.783	1.103E-04	142.602
43	154800	9.980E-05	128.989	1.011E-04	130.668	1.031E-04	133.314	1.091E-04	141.048
44	158400	9.873E-05	127.609	1.000E-04	129.270	1.020E-04	131.888	1.080E-04	139.540

Table I, cont'd.

Time		$S_H(t)$	$V_H(t)$	$S_H(t)$	$V_H(t)$	$S_H(t)$	$V_H(t)$	$S_H(t)$	$V_H(t)$
Hours	Seconds	lb-mole/sec	scf/hr	lb-mole/sec	scf/hr	lb-mole/sec	scf/hr	lb-mole/sec	scf/hr
		2535 MWt		2568 MWt		2620 MWt		2772 MWt	
45	162000	9.769E-05	126.270	9.897E-05	127.914	1.010E-04	130.504	1.068E-04	138.076
46	165600	9.669E-05	124.970	9.795E-05	126.597	9.993E-05	129.161	1.057E-04	136.654
47	169200	9.571E-05	123.708	9.696E-05	125.318	9.892E-05	127.856	1.047E-04	135.274
48	172800	9.476E-05	122.482	9.600E-05	124.076	9.794E-05	126.589	1.036E-04	133.933
49	176400	9.384E-05	121.290	9.506E-05	122.869	9.699E-05	125.357	1.026E-04	132.630
50	180000	9.294E-05	120.133	9.415E-05	121.696	9.606E-05	124.161	1.016E-04	131.364
51	183600	9.207E-05	119.007	9.327E-05	120.557	9.516E-05	122.998	1.007E-04	130.134
52	187200	9.123E-05	117.914	9.242E-05	119.449	9.429E-05	121.867	9.976E-05	128.938
53	190800	9.041E-05	116.850	9.158E-05	118.371	9.344E-05	120.768	9.886E-05	127.775
54	194400	8.961E-05	115.816	9.077E-05	117.324	9.261E-05	119.700	9.798E-05	126.644
55	198000	8.883E-05	114.810	8.998E-05	116.305	9.181E-05	118.660	9.713E-05	125.544
56	201600	8.807E-05	113.832	8.922E-05	115.314	9.102E-05	117.649	9.630E-05	124.474
57	205200	8.733E-05	112.880	8.847E-05	114.350	9.026E-05	116.665	9.550E-05	123.433
58	208800	8.662E-05	111.954	8.774E-05	113.411	8.952E-05	115.708	9.471E-05	122.420
59	212400	8.592E-05	111.052	8.704E-05	112.498	8.880E-05	114.776	9.395E-05	121.435
60	216000	8.524E-05	110.175	8.635E-05	111.609	8.810E-05	113.869	9.321E-05	120.475

Table I.a
TMI-1 Hydrogen Production by Radiolysis

Time		$S_H(t)$	$V_H(t)$	$S_H(t)$	$V_H(t)$	$S_H(t)$	$V_H(t)$	$S_H(t)$	$V_H(t)$
Days	Seconds	lb-mole/sec	scf/day	lb-mole/sec	scf/day	lb-mole/sec	scf/day	lb-mole/sec	scf/day
		2535 MWt		2568 MWt		2620 MWt		2772 MWt	
2.5	216000	8.524E-05	2644.189	8.635E-05	2,678.610	8.810E-05	2732.85	9.321E-05	2891.397
3.0	259200	7.834E-05	2429.999	7.936E-05	2,461.632	8.096E-05	2511.48	8.566E-05	2657.183
3.5	302400	7.320E-05	2270.560	7.415E-05	2,300.117	7.565E-05	2346.69	8.004E-05	2482.837
4.0	345600	6.926E-05	2148.532	7.016E-05	2,176.501	7.158E-05	2220.57	7.574E-05	2349.400
4.5	388800	6.616E-05	2052.400	6.702E-05	2,079.117	6.838E-05	2121.22	7.235E-05	2244.281
5.0	432000	6.365E-05	1974.444	6.448E-05	2,000.147	6.578E-05	2040.65	6.960E-05	2159.037
5.5	475200	6.155E-05	1909.438	6.236E-05	1,934.294	6.362E-05	1973.46	6.731E-05	2087.953
6.0	518400	5.976E-05	1853.808	6.054E-05	1,877.940	6.176E-05	1915.97	6.535E-05	2027.122
6.5	561600	5.819E-05	1805.084	5.895E-05	1,828.582	6.014E-05	1865.61	6.363E-05	1973.843
7.0	604800	5.679E-05	1761.541	5.753E-05	1,784.472	5.869E-05	1820.61	6.210E-05	1926.229
7.5	648000	5.551E-05	1721.960	5.623E-05	1,744.376	5.737E-05	1779.70	6.070E-05	1882.948
8.0	691200	5.433E-05	1685.473	5.504E-05	1,707.414	5.616E-05	1741.99	5.941E-05	1843.050
8.5	734400	5.324E-05	1651.451	5.393E-05	1,672.950	5.502E-05	1706.83	5.821E-05	1805.847
9.0	777600	5.221E-05	1619.438	5.289E-05	1,640.519	5.396E-05	1673.74	5.709E-05	1770.841
9.5	820800	5.123E-05	1589.094	5.189E-05	1,609.780	5.295E-05	1642.38	5.602E-05	1737.660
10.0	864000	5.029E-05	1560.167	5.095E-05	1,580.477	5.198E-05	1612.48	5.500E-05	1706.029
10.5	907200	4.940E-05	1532.468	5.005E-05	1,552.417	5.106E-05	1583.85	5.402E-05	1675.740
11.0	950400	4.854E-05	1505.849	4.918E-05	1,525.452	5.017E-05	1556.34	5.308E-05	1646.633
11.5	993600	4.772E-05	1480.198	4.834E-05	1,499.467	4.932E-05	1529.83	5.218E-05	1618.584
12.0	1036800	4.692E-05	1455.426	4.753E-05	1,474.373	4.849E-05	1504.23	5.130E-05	1591.496
12.5	1080000	4.615E-05	1431.461	4.675E-05	1,450.096	4.769E-05	1479.46	5.046E-05	1565.290
13.0	1123200	4.540E-05	1408.246	4.599E-05	1,426.579	4.692E-05	1455.47	4.964E-05	1539.905
13.5	1166400	4.467E-05	1385.733	4.525E-05	1,403.773	4.617E-05	1432.20	4.885E-05	1515.287
14.0	1209600	4.397E-05	1363.882	4.454E-05	1,381.637	4.544E-05	1409.61	4.808E-05	1491.393
14.5	1252800	4.328E-05	1342.659	4.385E-05	1,360.137	4.473E-05	1387.68	4.733E-05	1468.186
15.0	1296000	4.262E-05	1322.034	4.317E-05	1,339.243	4.405E-05	1366.36	4.660E-05	1445.632
15.5	1339200	4.197E-05	1301.980	4.252E-05	1,318.929	4.338E-05	1345.64	4.590E-05	1423.703
16.0	1382400	4.134E-05	1282.474	4.188E-05	1,299.169	4.273E-05	1325.48	4.521E-05	1402.374
16.5	1425600	4.073E-05	1263.496	4.126E-05	1,279.943	4.210E-05	1305.86	4.454E-05	1381.621
17.0	1468800	4.014E-05	1245.024	4.066E-05	1,261.232	4.148E-05	1286.77	4.389E-05	1361.423
17.5	1512000	3.956E-05	1227.043	4.007E-05	1,243.016	4.088E-05	1268.19	4.325E-05	1341.760
18.0	1555200	3.899E-05	1209.534	3.950E-05	1,225.279	4.030E-05	1250.09	4.264E-05	1322.614
18.5	1598400	3.844E-05	1192.481	3.894E-05	1,208.005	3.973E-05	1232.47	4.204E-05	1303.967
19.0	1641600	3.791E-05	1175.870	3.840E-05	1,191.178	3.918E-05	1215.30	4.145E-05	1285.804
19.5	1684800	3.738E-05	1159.687	3.787E-05	1,174.784	3.864E-05	1198.57	4.088E-05	1268.108
20.0	1728000	3.688E-05	1143.918	3.736E-05	1,158.809	3.811E-05	1182.27	4.032E-05	1250.864
20.5	1771200	3.638E-05	1128.549	3.685E-05	1,143.241	3.760E-05	1166.39	3.978E-05	1234.059
21.0	1814400	3.590E-05	1113.570	3.637E-05	1,128.066	3.710E-05	1150.91	3.925E-05	1217.679
30.0	2592000	2.897E-05	898.617	2.935E-05	910.315	2.994E-05	928.75	3.168E-05	982.630
40.0	3456000	2.399E-05	744.160	2.430E-05	753.847	2.479E-05	769.11	2.623E-05	813.732
50.0	4320000	2.067E-05	641.332	2.094E-05	649.681	2.137E-05	662.84	2.261E-05	701.291
60.0	5184000	1.834E-05	568.828	1.858E-05	576.233	1.895E-05	587.90	2.005E-05	622.008
70.0	6048000	1.659E-05	514.714	1.681E-05	521.414	1.715E-05	531.97	1.814E-05	562.835
80.0	6912000	1.522E-05	472.135	1.542E-05	478.281	1.573E-05	487.97	1.664E-05	516.275
90.0	7776000	1.409E-05	437.062	1.427E-05	442.752	1.456E-05	451.72	1.541E-05	477.923
100.0	8640000	1.312E-05	407.081	1.329E-05	412.381	1.356E-05	420.73	1.435E-05	445.140

Table II
Hydrogen production for 2535 MWt

t1 hr	V(t1) scf/hr	t2 hr	V(t2) scf/hr	V(t1)+V(t2) scf/hr	A scf	A2535(T) scf
0	874.729	2	587.845	1462.574	1462.574	1462.6
2	587.845	4	428.315	1016.159	1016.159	2478.7
4	428.315	6	336.657	764.971	764.971	3243.7
6	336.657	8	281.814	618.470	618.470	3862.2
8	281.814	10	247.358	529.172	529.172	4391.3
10	247.358	12	224.470	471.828	471.828	4863.2
12	224.470	14	208.329	432.799	432.799	5296.0
14	208.329	16	196.254	404.583	404.583	5700.6
16	196.254	18	186.722	382.976	382.976	6083.5
18	186.722	20	178.846	365.568	365.568	6449.1
20	178.846	24	166.162	345.007	690.015	7139.1
24	166.162	32	147.372	313.533	1254.134	8393.2
32	147.372	40	133.385	280.757	1123.028	9516.3
40	133.385	48	122.482	255.867	1023.467	10539.7
48	122.482	60	110.175	232.656	1395.937	11935.7

t1 days	V(t1) scf/day	t2 days	V(t2) scf/day	V(t1)+V(t2) scf/day	A scf	A2535(T) scf
2.5	2644.189	3.0	2429.999	5074.188	1268.547	13204.2
3.0	2429.999	4.0	2148.532	4578.531	2289.265	15493.5
4.0	2148.532	5.0	1974.444	4122.975	2061.488	17555.0
5.0	1974.444	6.0	1853.808	3828.251	1914.126	19469.1
6.0	1853.808	8.0	1685.473	3539.281	3539.281	23008.4
8.0	1685.473	10.0	1560.167	3245.640	3245.640	26254.0
10.0	1560.167	13.0	1408.246	2968.414	4452.621	30706.6
13.0	1408.246	17.0	1245.024	2653.271	5306.542	36013.2
17.0	1245.024	20.0	1143.918	2388.942	3583.413	39596.6
20.0	1143.918	30.0	898.617	2042.535	10212.675	49809.3
30.0	898.617	40.0	744.160	1642.777	8213.884	58023.2
40.0	744.160	50.0	641.332	1385.492	6927.460	64950.6
50.0	641.332	60.0	568.828	1210.160	6050.801	71001.4
60.0	568.828	70.0	514.714	1083.542	5417.710	76419.1
70.0	514.714	80.0	472.135	986.849	4934.245	81353.4
80.0	472.135	90.0	437.062	909.197	4545.984	85899.4
90.0	437.062	100.0	407.081	844.143	4220.716	90120.1

Table IIa
Hydrogen production for 2568 MWt

t1 hr	V(t1) scf/hr	t2 hr	V(t2) scf/hr	V(t1)+V(t2) scf/hr	A scf	A2568(T) scf
0	886.116	2	595.497	1481.613	1481.613	1481.6
2	595.497	4	433.890	1029.387	1029.387	2511.0
4	433.890	6	341.039	774.929	774.929	3285.9
6	341.039	8	285.482	626.521	626.521	3912.5
8	285.482	10	250.579	536.061	536.061	4448.5
10	250.579	12	227.392	477.970	477.970	4926.5
12	227.392	14	211.041	438.433	438.433	5364.9
14	211.041	16	198.809	409.850	409.850	5774.8
16	198.809	18	189.153	387.962	387.962	6162.7
18	189.153	20	181.174	370.327	370.327	6533.1
20	181.174	24	168.325	349.499	698.997	7232.1
24	168.325	32	149.290	317.615	1270.460	8502.5
32	149.290	40	135.121	284.412	1137.647	9640.2
40	135.121	48	124.076	259.198	1036.790	10676.9
48	124.076	60	111.609	235.685	1414.109	12091.1

t1 days	V(t1) scf/day	t2 days	V(t2) scf/day	V(t1)+V(t2) scf/day	A scf	A2568(T) scf
2.5	2678.610	3.0	2461.632	5140.243	1285.061	13376.1
3.0	2461.632	4.0	2176.501	4638.133	2319.067	15695.2
4.0	2176.501	5.0	2000.147	4176.647	2088.324	17783.5
5.0	2000.147	6.0	1877.940	3878.087	1939.043	19722.6
6.0	1877.940	8.0	1707.414	3585.354	3585.354	23307.9
8.0	1707.414	10.0	1580.477	3287.891	3287.891	26595.8
10.0	1580.477	13.0	1426.579	3007.056	4510.584	31106.4
13.0	1426.579	17.0	1261.232	2687.811	5375.621	36482.0
17.0	1261.232	20.0	1158.809	2420.041	3630.061	40112.1
20.0	1158.809	30.0	910.315	2069.124	10345.621	50457.7
30.0	910.315	40.0	753.847	1664.162	8320.811	58778.5
40.0	753.847	50.0	649.681	1403.528	7017.640	65796.1
50.0	649.681	60.0	576.233	1225.914	6129.569	71925.7
60.0	576.233	70.0	521.414	1097.647	5488.236	77413.9
70.0	521.414	80.0	478.281	999.695	4998.477	82412.4
80.0	478.281	90.0	442.752	921.033	4605.163	87017.6
90.0	442.752	100.0	412.381	855.132	4275.660	91293.2

Table IIb
Hydrogen production for 2620 MWt

t1 hr	V(t1) scf/hr	t2 hr	V(t2) scf/hr	V(t1)+V(t2) scf/hr	A scf	A2620(T) scf
0	904.059	2	607.555	1511.615	1511.615	1511.6
2	607.555	4	442.676	1050.231	1050.231	2561.8
4	442.676	6	347.945	790.621	790.621	3352.5
6	347.945	8	291.263	639.208	639.208	3991.7
8	291.263	10	255.653	546.916	546.916	4538.6
10	255.653	12	231.996	487.649	487.649	5026.2
12	231.996	14	215.314	447.311	447.311	5473.6
14	215.314	16	202.835	418.149	418.149	5891.7
16	202.835	18	192.983	395.818	395.818	6287.5
18	192.983	20	184.843	377.825	377.825	6665.3
20	184.843	24	171.733	356.576	713.151	7378.5
24	171.733	32	152.313	324.046	1296.185	8674.7
32	152.313	40	137.858	290.171	1160.684	9835.4
40	137.858	48	126.589	264.446	1057.784	10893.1
48	126.589	60	113.869	240.457	1442.744	12335.9

t1 days	V(t1) scf/day	t2 days	V(t2) scf/day	V(t1)+V(t2) scf/day	A scf	A2620(T) scf
2.5	2732.850	3.0	2511.479	5244.329	1311.082	13647.0
3.0	2511.479	4.0	2220.573	4732.052	2366.026	16013.0
4.0	2220.573	5.0	2040.648	4261.221	2130.611	18143.6
5.0	2040.648	6.0	1915.967	3956.615	1978.307	20121.9
6.0	1915.967	8.0	1741.988	3657.955	3657.955	23779.9
8.0	1741.988	10.0	1612.481	3354.468	3354.468	27134.3
10.0	1612.481	13.0	1455.466	3067.946	4601.920	31736.3
13.0	1455.466	17.0	1286.771	2742.237	5484.473	37220.7
17.0	1286.771	20.0	1182.274	2469.045	3703.567	40924.3
20.0	1182.274	30.0	928.748	2111.022	10555.112	51479.4
30.0	928.748	40.0	769.112	1697.860	8489.301	59968.7
40.0	769.112	50.0	662.837	1431.948	7159.741	67128.5
50.0	662.837	60.0	587.901	1250.738	6253.688	73382.1
60.0	587.901	70.0	531.973	1119.874	5599.369	78981.5
70.0	531.973	80.0	487.966	1019.939	5099.693	84081.2
80.0	487.966	90.0	451.717	939.683	4698.414	88779.6
90.0	451.717	100.0	420.731	872.448	4362.239	93141.9

Table IIc
Hydrogen production for 2772 MWt

t1 hr	V(t1) scf/hr	t2 hr	V(t2) scf/hr	V(t1)+V(t2) scf/hr	A scf	A2772(T) scf
0	956.509	2	642.803	1599.311	1599.311	1599.3
2	642.803	4	468.358	1111.161	1111.161	2710.5
4	468.358	6	368.131	836.489	836.489	3547.0
6	368.131	8	308.161	676.292	676.292	4223.3
8	308.161	10	270.484	578.645	578.645	4801.9
10	270.484	12	245.456	515.940	515.940	5317.8
12	245.456	14	227.806	473.261	473.261	5791.1
14	227.806	16	214.602	442.408	442.408	6233.5
16	214.602	18	204.179	418.781	418.781	6652.3
18	204.179	20	195.566	399.745	399.745	7052.0
20	195.566	24	181.696	377.263	754.525	7806.6
24	181.696	32	161.150	342.846	1371.384	9177.9
32	161.150	40	145.855	307.005	1228.021	10406.0
40	145.855	48	133.933	279.788	1119.152	11525.1
48	133.933	60	120.475	254.407	1526.445	13051.6

t1 days	V(t1) scf/day	t2 days	V(t2) scf/day	V(t1)+V(t2) scf/day	A scf	A2772(T) scf
2.5	2891.397	3.0	2657.183	5548.580	1387.145	14438.7
3.0	2657.183	4.0	2349.400	5006.583	2503.291	16942.0
4.0	2349.400	5.0	2159.037	4508.437	2254.218	19196.2
5.0	2159.037	6.0	2027.122	4186.159	2093.080	21289.3
6.0	2027.122	8.0	1843.050	3870.172	3870.172	25159.5
8.0	1843.050	10.0	1770.841	3613.890	3613.890	28773.4
10.0	1770.841	13.0	1539.905	3310.746	4966.119	33739.5
13.0	1539.905	17.0	1361.423	2901.328	5802.657	39542.1
17.0	1361.423	20.0	1250.864	2612.287	3918.431	43460.6
20.0	1250.864	30.0	982.630	2233.494	11167.470	54628.0
30.0	982.630	40.0	813.732	1796.362	8981.810	63609.8
40.0	813.732	50.0	701.291	1515.023	7575.116	71185.0
50.0	701.291	60.0	622.008	1323.299	6616.497	77801.5
60.0	622.008	70.0	562.835	1184.843	5924.217	83725.7
70.0	562.835	80.0	516.275	1079.111	5395.553	89121.2
80.0	516.275	90.0	477.923	994.199	4970.993	94092.2
90.0	477.923	100.0	445.140	923.063	4615.315	98707.5

Sheet 1

Refer to Calc 5.0 A. Calculation of Hydrogen Generation

12. Corrosion rate per RG 1.7 (reference 4.7) = 200 mils/year in NaOH spray.
This rate equals 0.5479 mils/day = 4.56621 E-05 ft/day

For each sqaure foot exposed the corrosion rate in volume is:
1 ft^2 x 4.56621E-05 = 4.56221E-05 ft^3/day

The specific weight of aluminum is 168.68 lb/ft^3

therefore, the corrosion rate by weight is

4.56221e-05ft^3/day x 168.68 lb/ft^3 = 0.00770228 lb/day per ft^2 exposed

Per Appendix 1, the amount of material being considered is:

1. 69 PI tubes with a total exposed area of 825 ft^2. This results in a corrosion rate of:

824 x 0.007702 = 6.34668122 lb/day

2. 58 RV stud spacers with a total exposed area of 225 ft^2. This results in a corrosion rate of:

223.65 x .007702 = 1.7226156 lb/day

3. 58 RV stud hole plugs with a total exposed area of 145 ft^2. This results in a corrosion rate of: 142.28 x .007702 = 1.09588083 lb/day

4. 2 stator removal tools with a total exposed area of 44 ft^2. This results ina corrosion rate of:

42 x 0.007702 = 0.32349589 lb/day

The total of the above exposed areas results in corosion rate of:

9.48867353 lb/day

At 11 days the hydrogen production from the above exposed area 2080.2019 scf

At 10 days the hydrogen production from the above exposed area 1891.09263 scf

Refer to Appendix I

Group IV Item Exposed Areas Calculation

1. Stud Spacers.

There are 58 of RV Stud Spacers. The dimesions are based on B&W Drawing 99563C, Rev.3

Area1: (4.75+3.14*3.625+4.75) * 12.5 = 20.9*12.5 = 261.25 (sqin)

2 X Area1 = 552.5 (sqin)

Area2 = 8*1*1 = 8(sqin)

Area3 = 3.14*0.75*(2+4.5+2+1+1) = 24.7 (sqin)

Total area per spacer = 552.5+8+24.7 = 555.2 (sqin) = 3.856(sqft)

Areas of 58 spacers = 223.7 (sqft)

2. Stud Plugs

There are total of 58 stud plugs. The dimensions are based on B&W Drawing 128778E Rev.2

Area1 = 1.6975*3.14*6.75 = 35.79 (sqin)

Area2 = 1.0625*3.14*6.75 = 22.531 (sqin)

Area3 = 1*3.14*2.125 = 6.676 (sqin)

Area4 = 2*3.14*SQ(6.75) = 286.28(sqin)

Area5 = 4*3.14*SQ(0.3125) + 0.3752*3.14*0.3125 = 1.9635 (sqin)

Area per plug = 353.3 (sqin) = 2.453 (sqft)

Area of 58 plugs = 142.3 (sqft)

3. Stator Tools

There are two stator tools. Their dimensions are based on Vendor Manual Page 6-16A.

Area1 = 2*3.14*2.5 = 39.27 (sqin)

Area2 = 5*3.14*190 = 2984.51 (sqin)

Area per tool = 2894.51+39.27 = 3023.78 (sqin) = 21 (sqft)

Area of two tools = 42 (sqft)

4. CRD PI Tubes

There are total of 69 PI tubes. Their dimensions are based on TMI EER No. 95-0286.

Area per tube = (3.25/12)*3.14*14 = 11.92(sqft)

Total area of 69 tubes = 11.92*69 = 822.48 (sqft)

Enclosure 5
Revised Technical Specification Bases Page

4.4.4 Hydrogen Recombiner System

Applicability

Applies to the testing of the hydrogen recombiner and associated controls.

Objective

To verify that the hydrogen recombiner and associated controls are operable.

4.4.1 Specification

d. Perform a system functional test for the hydrogen recombiner each refueling interval by verifying that the reaction chamber gas temperature is maintained $\geq$ 1200°F for at least 4 hours.

e. Visually examine the hydrogen recombiner enclosure and verify there is no evidence of abnormal conditions each refueling interval.

f. Perform a resistance to ground test for each heater phase each refueling interval and verify that the resistance to ground for any heater is phase $\geq$ 10,000 ohms.

Bases

The surveillance program described above provides high assurance that the hydrogen recombiner system will be available to perform its post-LOCA function of maintaining the containment hydrogen concentration below 4.1 volume percent. This system is not credited to mitigate any accident analyzed in Chapter 14 of the TMI-1 FSAR. The frequency of the surveillance of the hydrogen recombiner system is based on the safety significance of the system. **Hydrogen generating material in the reactor building is limited to ensure that the capacity of one hydrogen recombiner can maintain post LOCA hydrogen concentration below 4.0 %. The recombiner will be placed in service in accordance with TMI-1 Final Safety Analysis Report Section 6.5. This Section of the FSAR shows that adequate time (at least several days) is available to place a hydrogen recombiner in service.**