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

ENCLOSURE 2

SAFETY EVALUATION BY THE

OFFICE OF NUCLEAR REACTOR REGULATION

GENERAL ELECTRIC COMPANY'S METHODOLOGY FOR DETERMINING RATES

OF GENERATIONS OF OXYGEN BY

RADIOLOYTIC DECOMPOSITION (NEDO-22155)

In June 1982 General Electric (GE) issued the subject report containing a description of the methodology for determining rates of generation of oxygen by radiolytic decomposition of water in the inerted Mark I containments. In this report, GE assumes that after an accident water in the containment will boil for 12 hours only. During this time it will undergo radiolytic decomposition with oxygen generated at the rates corresponding to $G(O_2)=0.1$. Where $G(O_2)$ is a number of molecules of oxygen generated by 100 ev of radiant energy absorbed. This value was based on the results from the measurements of the hydrogen evolution rate in the offgas systems during normal (boiling) operation and during refueling shutdowns and confirmed by the experiments performed in the KRB Nuclear Power Plant.

For radiolysis of water beyond 12 hours, when boiling ceases, $G(O_2)=0$ was assumed and consequently there was no net generator or radiolytic oxygen. This last assumption was based on the analytical results obtained by Knolls Atomic Power Laboratory (Reference 1) and by Argonne National Laboratory (Reference 2) in connection with the Three Mile Island accident. The values of $G(O_2)$ in the GE report differ considerably from the value of $G(O_2)$ in Regulatory Guide 1.7 which for both boiling and non-boiling cases recommends $G(O_2)=0.25$. However, this value is not based on any specific mechanism of radiolysis but is chosen to bound all possible cases and consequently it tends to overpredict the rates of generation of radiolytic oxygen. In 1982 an extensive effort was undertaken by the Northeast Utilities and by the NRC in connection with the Millstone 1 licensing action to determine a more realistic method for calculating rates of radiolytic oxygen generation. In performing this task the staff was assisted by a consultant from BNL. The results of this effort: have indicated that $G(O_2)$ is not a constant parameter but varies with the amount of hydrogen dissolved in water and with the concentrations of certain impurities, most notable among them iodine. Since concentrations of these substances may vary with time and may be different for different accidents, the true value $G(O_2)$ should be expressed as a function of these variables.

In general, an increase of concentration of hydrogen in water results in a decrease of radiolysis due to promotion of recombination reactions. On the other hand an increase of iodine concentration tends to promote radiolysis by destroying free radicals which are required for the recombination reactions to proceed. The highest rate of oxygen generation is achieved when $G(O_2)=0.22$,

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which is the highest theoretical limit for gamma radiation. This occurs when water is completely free of dissolved hydrogen, or when the concentrations of dissolved iodine are extremely high. However, in most cases $G(O_2)$ will be lower and at certain concentrations of hydrogen and iodine the rates of radiolytic dissociation and recombinations reactions may become equal resulting in $G(O_2)=0$ and no net generation of radiolytic oxygen. During the boiling regime hydrogen will be stripped by vapor bubbles and it is expected that $G(O_2)$ will be higher than in non-boiling water.

Quantitative evaluation performed by the staff was based on the model developed by the BNL consultant (Reference 3) and on the experimental data from ORNL (Reference 4). For pure water (no iodine) it was determined experimentally that with no dissolved hydrogen and no boiling $G(O_2)=0.08$. However, when under non-boiling conditions the concentration of dissolved hydrogen reached 2.5 cc/kg of water, corresponding to equilibrium hydrogen pressure of 0.16 atm., $G(O_2)$ became zero and generation of radiolytic oxygen stops. This finding contradicts the information in the GE report where $G(O_2)=0$ was assumed for all non-boiling cases.

For water containing dissolved iodine no applicable experimental data were available and the staff calculated $G(O_2)$ corresponding to the maximum credible iodine concentration in water using the BNL model. Since all iodine in the containment water comes from failed fuel, an accident had to be postulated which would result in a release of this amount of iodine. In such an accident fuel was assumed to fail by oxidation of Zirconium cladding and hence, in addition to released iodine, additional hydrogen was produced. Concentrations of both these substances had to be considered in calculating $G(O_2)$.

The accident considered consisted of a LOCA in which 5 percent of fuel cladding was oxidized by reaction with steam producing failure of all fuel rods and overheating of the core, but without initiation of fuel melting. This case represented maximum degradation of core allowed by 10 CFR 50.44(d)(1) and 10 CFR 50.46(b)(3). The analyses performed by Sandia (Reference 5), based on the experimental work on fuel rods from the H. B. Robinson plant, have indicated that for this type of accident 30 percent of total fuel iodine inventory was released. The released iodine consisted of the initial gap inventory and of the iodine diffused from the overheated fuel. Assuming that all the released iodine was dissolved in water and using plant parameters corresponding to a typical BWR with Mark I containment, the iodine concentration in water was determined to be 1.11 E-5 moles/liter and the partial pressure of hydrogen in the containment 0.12 atm. This partial pressure corresponds to an equilibrium concentration of 1.9 cc hydrogen/kg of water. Inserting this value of iodine concentration into the BNL mathematical model a relationship between $G(O_2)$ and partial pressure of hydrogen in the containment was developed. From this relationship it was determined that for a non-boiling case, when partial pressure of hydrogen was 0.12 atm., $G(O_2)=0.19$. It also found that $G(O_2)$ would not reach zero value until partial pressure of hydrogen in the containment reaches 1 atm. For boiling case, when hydrogen is stripped from the solution, $G(O_2)$ would be slightly higher, somewhere between 0.19 and 0.22.

These values differed considerably from those in the NEDO-22155 report. The main difference was probably due to the GE results being applicable to pure water or to water containing only minimal amount of impurities. Including the effect of iodine, which would be released during certain types of LOCA, could drastically change the results.

CONCLUSIONS AND RECOMMENDATIONS

1. The NEDO-22155 report underpredicts generation of radiolytic hydrogen for both boiling and non-boiling cases. This is due to the use of too low values for $G(O_2)$. $G(O_2)$=0.1 for boiling case was based on the measurements made in an environment of zero or low iodine concentrations. $G(O_2)$=0 for non-boiling case was derived from the data calculated by the codes which did not consider effects of dissolved iodine. The results were also in disagreement with the experimental data from ORNL.

2. Since $G(O_2)$ is a function of hydrogen and iodine concentrations in the containment water, it may vary during an accident and is specific for each individual plant.

3. The maximum values of $G(O_2)$, calculated with the NRC radiolysis model for LOCA (5% metal-water reaction and 30% iodine release) in a BWR with Mark I containment, are $G(O_2)$=0.19 for non-boiling and between 0.19 and 0.22 for boiling cases. They are considerably higher than the values presented in the General Electric's NEDO-22155 report.

4. The value of $G(O_2)$=.25 in Regulatory Guide 1.7 is overly conservative. However, it is not very much different from the maximum values calculated for a LOCA using the BNL model. It is recommended, therefore that until a better understanding of post accident radiolytic decomposition of water is developed, this value should be used for predicting generation rates of radiolytic oxygen in the containment.

REFERENCES

1. J. C. Conine, D. J. Krommenhoek and D. Emanual Logan, KAPL Evaluation of Radiolysis Associated with Three Mile Island Unit 2 Incident, dated May 1979.

2. S. Gordon, K. H. Schmidt and J. R. Honekamp, An Analysis of the Hydrogen Bubble Concerns in the Three Mile Island Unit 2 Reactor Vessel, Argonne National Laboratory.

3. NRC Memo and K. I. Parczewski to Victor Benaroya, dated June 23, 1982.

4. H. E. Zittel, Design Considerations of Reactor Considerations Spray Systems - Boiling Water Reactor Accident Studies, ORNL-TM-2412, Part VIII, October 1970.

5. NUREG/CR-2367, Updated Best-Estimate LOCA Radiation Signature, dated August 1981.

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MEETING AGENDA
FOR
DISCUSSION OF PLANT SPECIFIC DESIGN OF ACTIVE COMBUSTIBLE GAS CONTROL SYSTEM

I. INTRODUCTION BY NRC STAFF

II. MEETING OBJECTIVE

To provide sufficient design details of the Nitrogen Injection Capability for each plant to determine if the provisions are adequate to meet the intent of 10 CFR 50.44.

III. AIR-CAD SYSTEM

NRC staff will provide the basis for concluding that the system should not be used for combustible gas control.

- Represents an air source per GL 84-09 guidance
- Potential misuse of system
- Impact of deinerting on course of the accident

IV. LICENSING BASIS AND BWR EPGs

Reconcile any conflicts between original licensing basis and Rev. 4 to the BWR EPGs.

- When will CAD be used (under what system conditions)
- Is the EOP consistent with FSAR assumptions

V. PLANT SPECIFIC DESCRIPTION OF INERTING SYSTEM

The objective is to identify all essential components, design conditions, instrumentation, and power supply for the normal inerting system to determine under what post LOCA conditions the system could be expected to function as a combustible gas control system.

A. System/component description

All components required to operate under post LOCA conditions should be described.

- Design specification (i.e. seismic, redundancy, quality group, etc.) for a parameter where the component has not been designed for, such as seismic, but is expected to survive, provide the basis
- Location

- Design pressure and temperature
- Maximum containment conditions for component operability should also be noted
- Design flow rate as a function of containment pressure

B. System Instrumentation

Instrumentation necessary to operate the system post LOCA should be identified.

- Identify each sensor, number and location
- Location of instrument readout
  (If outside control room, determine accessibility post LOCA)
- System use of sensor output

  What is sensor used for (automatic valve operation? or not). If operator information only, indicate what type of action is anticipated (flow change, system shutoff, etc.)

C. Operational requirements post LOCA

Identify those actions that will be required to initiate system operation and those necessary for monitoring operation. For each action, identify whether it is from the control room or at a remote site.

- Instrumentation needed for startup
- Instrumentation needed for operation
- Power supply (offsite and diesel?)

D. Nitrogen capacity (onsite and time to get added supply)

E. Identification of deviations from GDC 41, 42, and 43

F. Modifications to eliminate deviations from (E)

G. Operational, maintenance, and surveillance history - objective is to obtain some basis for determining system availability.