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MEMORANDUM FOR: C. N. Kelber, Assistant Director
for Advanced Reactor Safety Research
Division of Reactor Safety Research

THRU: L. N. Rib, Special Assistant
for Advanced Reactor Safety Research
Division of Reactor Safety Research

FROM: J. T. Larkins
Experimental Gas-Cooled Reactor
Safety Research Branch

SUBJECT: UPPER LIMIT ESTIMATES OF HYDROGEN FORMATION

Using available information and data (I & E reports, plant status reports, etc.) an upper limit estimate has been made of the amount of hydrogen generated via the zirconium-water reaction and from radiolysis. Also, using available data and expert comments an estimate is included on the amount of hydrogen that could be absorbed by the zirconium cladding.

A hydrogen explosion was reported to have occurred as the primary system was being depressurized to allow operation of the Residual Heat Removal (RHR) system. An estimate of 70,000 scf of hydrogen was assumed to have been burned. This would have represented a hydrogen concentration of 3.33% in containment (2.1 million cubic feet) therefore, the burning or explosion must have been localized or the estimate of the amount of gas involved is too low.

On March 31, 1979 it was estimated that the containment building contained 1.7% hydrogen and that there was a hydrogen bubble in the reactor vessel of approximately 1,000 ft.^{3} at 1,000 psi. Based on available solubility information these three sources would provide a total hydrogen inventory of approximately 113,000 scf of hydrogen. This total inventory in containment would have given a hydrogen concentration of approximately 5.3% (exceeds flammability limit of 4%). Assuming that all of the hydrogen generated (including that which was burnt) was generated from the zirconium-water reaction this would calculate to 42-44% of the available zirconium being oxidized.

On April 4, 1979 it was reported that the containment had a hydrogen concentration of 2.3% (48,000 scf) and there existed a bubble of approximately 200 ft.^{3} in the reactor vessel (~10,000 scf) and with a saturated coolant (27,000 scf) and waste gas tank (1938 ft.^{3} volume and 100 psi) of approximately 56% hydrogen (~5,400 scf) there was a hydrogen inventory of approximately 90,600 scf. This total inventory in containment (4.3%) would still have exceeded the set flammability limit.

The amount of hydrogen being formed from radiolytic decomposition is probably very small, however, using a normal decay curve (B&W report) LASL using the COGAP code calculated and a upper limit of 7 lbs. of hydrogen (1,256 scf) per day being formed in the core and based on 1% of available fission products in the coolant another 2.5 lbs. (449 scf) per day in the coolant. The contribution from the coolant (100,000 gallons) in the containment is approximately 50 scf per day. The total inventory of hydrogen from radiolysis would be 1,755 scf (.08% volume percent in containment) per day. These calculations were based on a G value of 0.45 (molecules of hydrogen evolved 100 ev of radiation absorbed) and do not take into account the amount of hydrogen recombination occurring. The amount of hydrogen recombining to form water could be significant and reduce the amount of hydrogen generated by a factor of 10.

Two hydrogen recombiners were made operational on April 1, 1979 and one unit reportly started processing gas on April 3, 1979. Using the efficiency given that for a 4% hydrogen concentration entering the recombiner that the exiting gas was .1% hydrogen and a process flow rate of 60 cubic feet per minute, I calculated it would take approximately one week to drop the concentration by 25% and 17 days to drop the concentration by 50%.

From an assemblage of various references and conversations, I have concluded that the amount of hydrogen that could have been absorbed by the zirconium cladding was small. Assuming 100 ppm of hydrogen were absorbed in the zirconium cladding, one would calculate only ~815 scf of hydrogen absorbed, which is less than 1% of the amount of hydrogen generated.

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Lastly, on the use of chemicals for gettering dissolved and gaseous hydrogen, Sandia has used unsaturated hydrocarbons (dimerized paraprogylphenyl ether) in the weapons program for controlling hydrogen build-up in a closed system. The effects of radiation and thermal stability have been investigated somewhat, however, some further work would be needed. Sandia has proposed its use in LWR safety for gettering hydrogen from a core-melt accident and it appears to have a good potential for use in preventing hydrogen build-up in a LOCA. I anticipate receiving more information on this subject.

John T. Larkins

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