



LOFT TECHNICAL REPORT
LOFT PROJECT DIVISION

IDAHO NUCLEAR CORPORATION

TITLE Hydrogen Production and Control During LOCA and LOCE		REPORT NO.
		LTR 10-15, Rev. B ^[a]
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SECTION Experiment and Safety Analysis		
BRANCH MTAD	DATE March 5, 1974	

- * Revisions
- # Additions

SUMMARY

Hydrogen may be produced in the LOFT system by metal-water reaction, radiolytic decomposition of water, corrosion of materials, and dissolved hydrogen in the primary coolant and suppression tank solution following a loss-of-coolant accident (LOCA) or a loss-of-coolant experiment (LOCE). The hydrogen will accumulate in the containment vessel test chamber following a LOCA and in the blowdown suppression tank or primary system following a LOCE. Four cases were considered in the analysis of possible results from hydrogen production. Case 1 was a LOCA to the test chamber, Case 2 was a LOCE to the suppression tank, Case 3 was a LOCE case where hydrogen generated in the primary system after blowdown was investigated, and Case 4 was a LOCE case to analyze the possibilities of isolating and refilling the primary system after blowdown. The time limits calculated in this report represent the time at which a flammable mixture is reached. Control measures for maintaining the limits of hydrogen and oxygen below safe limits will be taken before the time limits are reached if possible. The following results were obtained:

- (1) For Case 1, the hydrogen concentration in the test chamber remains below the combustible level for up to 133 days after a LOCA. This allows more than adequate time to vent the accumulated hydrogen prior to approaching the combustible limit. The test chamber is equipped with monitors to detect the hydrogen accumulation which allows visibility for the administrative control of the accumulation.
- (2) For Case 2, a LOCE to the blowdown suppression tank, all hydrogen and oxygen formed is assumed to go into the suppression tank. Since the primary system and suppression system are free of oxygen, both oxygen and hydrogen need to be generated in order to have a flammable mixture. This results in the oxygen concentration being the limiting factor for determining whether or not a flammable mixture exists. The results show that the oxygen concentration remains below the combustible limit for up to 12 days.

[a] This LTR has been revised to incorporate the changes requested in letter, W. H. Layman, AEC-RSR, to Manager, AEC-ID, "Approval of Section 13.0 of the LOFT IDOER" RSR:O:PM072 (February 6, 1974).

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This time can be increased to >200 days by isolation from the primary coolant system. This allows adequate time to vent the gases prior to obtaining a combustible mixture. The blowdown suppression tank is equipped with a continuous sampler monitor (CSM). The CSM system will be used to obtain a gas sample which can then be analyzed for hydrogen and oxygen. This, plus its fission product monitoring capability, will be used to aid in the administrative control of the hydrogen accumulation in the blowdown suppression tank.

- (3) For Case 3, combustible proportions of hydrogen and oxygen continue to be generated in the primary system after the blowdown. Because of the water leg between the suppression tank and primary system, the volume of the suppression tank was not included in the calculations. To be conservative, all the hydrogen and oxygen are assumed to remain in the primary system and the blowdown suppression header system. Dilution with nitrogen, therefore, is necessary to keep the level of oxygen below the combustible limit. Pressurization of the primary and header systems will be limited to 105 psig because of the design limits of the suppression system. This pressure would occur ~10 days after blowdown (see Table I).
- * (4) In Case 4, the primary system isolation valves are shut and the system refilled with water. If there is no primary system flow and the system is unpressurized, pockets of hydrogen and oxygen will form from radiolysis so the high-point vents must be used to vent the gases to the suppression tank. To prevent large accumulations, venting should be on a frequent basis.

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1.0 INTRODUCTION

During and after a LOCA, hydrogen gas may accumulate within the test chamber as a result of (a) a metal-water reaction involving the zirconium fuel cladding and the reactor coolant, (b) radiolytic decomposition of the primary coolant and emergency core coolant (ECC) solutions (oxygen will also evolve in this process), (c) corrosion of materials in the containment test chamber by primary coolant and ECC solutions, and (d) dissolved hydrogen gas in the primary coolant. If a sufficient amount of hydrogen gas accumulates in the test chamber, it may react with the oxygen present in the containment atmosphere. Since the atmosphere in the containment provides an excess of oxygen to support combustion, it is essential to determine the time after LOCA at which the hydrogen gas concentration could reach the combustible limit of 4% by volume (see Figure 1).

The same type of phenomena may occur during a LOCE which exhausts either into the blowdown suppression tank or in the test chamber. The hydrogen and oxygen sources are the same as for a LOCA except for the following: During blowdowns to the suppression tank, the hydrogen source from corrosion has not been considered, since the materials which corrode in the presence of boric acid to produce hydrogen have specifically been excluded from the suppression tank and primary system. An additional source, however, has been included for suppression tank LOCEs which is the hydrogen and oxygen dissolved in the suppression tank water which is assumed to be released to the suppression tank gas space. This gas space is filled with nitrogen; therefore, both hydrogen and oxygen must be generated to obtain a combustible mixture. After a blowdown, however, hydrogen and oxygen formed in the core from radiolysis may remain in the primary system and the suppression header system. Hydrogen and oxygen generation in these systems presents a special problem, because these gases are formed in stoichiometric proportions, and these systems are relatively free of dilutants, such as nitrogen. The combustible limits, specified in Reference [1], are 4% by volume of hydrogen and 5% by volume of oxygen. These limits are shown graphically in Figure 1 to be 4% hydrogen and 4.9% oxygen. The lower oxygen limit of 4.9% has been used in this analysis.

The general purposes of this study were:

- (1) To determine and report the amount of hydrogen which may be generated and released to the test chamber during and after a LOCA (Case 1)
- (2) To determine and report the amounts of hydrogen and oxygen which may be generated and released to the blowdown suppression tank during and after a LOCE (Case 2)
- (3) To determine and report the amounts of hydrogen and oxygen which may be generated in the primary and suppression header systems (Case 3)
- (4) To determine and report the effect of isolating and refilling the primary system (Case 4)
- (5) To demonstrate that the methods of control for both LOCA and LOCE are adequate to cope with the hydrogen and oxygen generated

- (6) To describe the means, presently available, of measurement of combustible mixtures
- (7) To recommend any design changes necessary.

2.0 METHOD AND ASSUMPTIONS

Hydrogen accumulation in the containment atmosphere following a LOCA to the test chamber or in the blowdown suppression tank following a LOCE to that tank is the result of production from several sources. The LOCA to the test chamber is considered to generate more hydrogen than any LOCE to the test chamber because of the higher fission product release assumptions for the LOCA. The primary sources generally considered are (a) the zirconium-water reaction, (b) radiolytic decomposition of the ECC solution, and (c) corrosion of materials within the test chamber. The last normal source (material corrosion) has not been considered in the analysis for the blowdown suppression tank, since material which would corrode in boric acid solution at an appreciable rate, e.g., aluminum and protective zinc based coatings, are specifically excluded inside the suppression tank. A fourth source, the hydrogen and oxygen dissolved in the suppression tank water and the hydrogen dissolved in the primary system water, was assumed to be released into the gas space in the suppression tank. For the containment analysis, only the hydrogen in the primary system water was assumed to be released into the containment. Each source is described in detail below.

2.1 Hydrogen Generated by Zirconium-Water Reaction

The zirconium-water reaction is described by the chemical equation



The quantity of zirconium which reacts with the core cooling solution will depend on the functioning of the ECCS as well and, in particular, on the portion of the cladding which reaches temperatures of $\sim 2300^\circ\text{F}$, or higher.

The use of a stepwise approach to a LOCE, in order of increasing consequence severity, is not expected to reveal the damage thresholds of zirconium-water reaction. This type of experiment is to be carried out at the Power Burst Facility. It is not considered probable, therefore, that more than a few percent of the total clad will react to produce hydrogen. For the LOCA containment analysis, 5% of the fuel cladding was assumed to experience a metal-water reaction (the assumption required by Safety Guide 7^[1]). For the LOCE case, however, no metal-water reaction was assumed to maximize the oxygen concentration which would allow a combustible gas mixture to occur in a shorter time. Any hydrogen generation from a metal-water reaction would tend to dilute the oxygen; therefore, to neglect the possibility of a metal-water reaction is the most conservative assumption.

2.2 Hydrogen and Oxygen Generated by Radiolysis

Water radiolysis is a complex process involving the reactions of numerous intermediate products. Extensive programs have been conducted to investigate the radiolytic decomposition of the core cooling solution following a LOCA. It is apparent that two environments exist for radiolytic decomposition.

* The first is within the reactor vessel through which the ECC solution is passed. Here, decay energy of fission products in the reactor core may break down the ECC water. Essentially all beta energy will be absorbed by the fuel and clad, and of the gamma energy generated, approximately 10% will be absorbed by the ECC solution [1].

The second environment for radiolytic decomposition is within a pool of water such as the sump of the containment vessel or the suppression tank, where decay of fission products which have escaped from the core may cause radiolysis. Both the gamma and beta energy of the released fission products are effective in breaking down the water. The fission product release fractions are discussed in Section 2.5 below.

The hydrogen formed by radiolysis has been estimated using the equations developed by Dr. W. R. Johnson [2]. These equations are valid for the decay times of 0.5 to 200 days and take into consideration the core gammas and the released solid and halogen fission products.

After 0.5 day the production of hydrogen by radiolytic decomposition may be obtained by:

$$V(t) = 1.31 \times 10^{-26} P G \int_0^t [E_c(t) + E_s(t)] dt \quad (2)$$

where

$V(t)$ = volume of hydrogen produced up to time t at STP

P = core operating power, MW(t)

G = molecular hydrogen yield is 0.5/100 eV of radiation energy absorbed

$E_c(t)$ = radiation energy absorbed from the core at time t

$E_s(t)$ = radiation energy absorbed from the sump fission products at time t .

For irradiation times of 2 years, the $\int_0^t E dt$ terms are as follows:

(1) Total gamma energy from core:

(a) 0.5-30 days after blowdown

$$\int_0^t E_c dt = 2.1 \times 10^{27} t^{0.69} \quad (3)$$

(b) 30-200 days after blowdown

$$\int_0^t E_c dt = 4.9 \times 10^{27} t^{0.445} \quad (4)$$

(2) Total solid fission products (beta and gamma energy):

(a) 0.5-30 day, after blowdown

$$\int_0^t E_s dt = 3.8 \times 10^{27} t^{0.69} \quad (5)$$

(b) 30-200 days after blowdown

$$\int_0^t E_s dt = 9.7 \times 10^{27} t^{0.445} \quad (6)$$

(3) Total radioiodides (beta and gamma energy):

(a) 0.5-30 days after blowdown

$$\int_0^t E_s dt = 4.0 \times 10^{26} t^{0.31} \quad (7)$$

(b) 30-200 days after blowdown

$$\int_0^t E_s dt = 1.04 \times 10^{27} \quad (8)$$

* The equations are multiplied by a factor to account for the fractionation of fission products remaining in the fuel and released from the core and to take into account the effectiveness of each. The fractionation of fission products and the effectiveness of the associated energy release for the production of radiolysis is in agreement with the guidelines specified in Reference [1] and the fission product releases defined in Section 2.5. Data on radiolysis for the first half day after blowdown are not available because of the uncertainties about the short-lived fission products. Since the equations do not apply from 0 to 0.5 day, the hydrogen generated was extrapolated using an integrated decay heat curve and the above equations.

2.3 Hydrogen Generated by Corrosion

* An estimate of the area of the surfaces in LOFT that could be painted with a zinc based primer is 34,400 ft² (3.2 x 10⁷ cm²). This surface area assumes that the containment vessel interior and the exposed surfaces on the MTA are all painted with a zinc based primer coating system. From Reference [3], hydrogen evolution values for each containment blowdown with a painting system similar to LOFT's range from 0.0492 to 0.0131 scf of H₂/ft² (1.5 to 0.4 CC/cm²). For conservatism, the highest hydrogen evolution rate was used in the LOFT hydrogen analysis.

* Additional hydrogen will be evolved when decontamination solution comes in contact with exposed aluminum surfaces. Reference [4] restricts the use of aluminum and copper to less than 275 ft². The main source of the aluminum in LOFT is associated with electrical conduit and small

components located on the MTA which have exposed aluminum surfaces. The hydrogen calculations given below assume that the entire 275 ft² consists of aluminum to maximize the hydrogen produced from this source. The following release-rate formula has been used to determine the amount of hydrogen produced from aluminum corrosion: The formula is based on an annual corrosion rate of 200 mils as is specified in Reference [1].

$$H_2 = 0.77 \times A \times (2.5 + 0.2t), \quad (9)$$

where

H_2 = amount of hydrogen generated (ft³ @ STP)

A = area of exposed aluminum (ft²)

t = amount of exposure time (days),

the amount of hydrogen generated from this source was calculated.

2.4 Hydrogen and Oxygen Released from Solution

* In order to control the oxygen content in the primary system water during normal operation, excess hydrogen is dissolved in the primary system water to force the decomposition process of water in the reverse direction. According to Reference [5] the concentration of hydrogen may be a maximum 60 CC of H₂/Kg. For both the containment and suppression tank calculations, 261 ft³ (~7394 Kg) of water was assumed to be in the primary system with the maximum concentration of hydrogen. This amounts to 16 ft³ of hydrogen which may be released from the primary system water.

For the suppression tank portion of the analysis, the hydrogen and oxygen dissolved in the suppression tank water were assumed to be released into the gas space of the tank. This amounts to 28 ft³ of hydrogen and 17 ft³ of oxygen.

2.5 General Assumptions

The following assumptions were used for the hydrogen generation in the four cases considered:

- (1) The limits of flammability for hydrogen, oxygen, and water vapor were assumed to be the same as that of nitrogen, oxygen, and hydrogen, because the data available on water vapor was not directly applicable to the LOFT problem. This assumption is conservative since water vapor is actually more effective than nitrogen at suppressing combustion of oxygen and hydrogen.
- (2) Initially the decay heat is distributed as follows [6]:
 - (a) ~20% of the total decay heat from iodines
 - (b) ~7.7% of the total decay heat from rare gases
 - (c) ~72.2% of the total decay heat from solid nonvolatile fission products.

Approximately half of the decay energy is in the form of gamma rays, and 10% of the gammas are absorbed by the water. Betas will contribute their energy only if the fission products are released into the water; otherwise, the energy is absorbed in the fuel.

- (3) To convert the energy release into volumes of hydrogen and oxygen, a yield factor of 0.5 molecules of H₂/100 eV of energy was used as is specified in Safety Guide 7. This is a conservative number for boiling water where violent agitation is occurring. For relatively quiescent pools which could occur after reflood, the yield factor could be as low as 0.15 to 0.20 molecules of H₂/100 eV.
- (4) Since the equations do not cover the noble gases, a separate table (Table C-I of Reference [7]) was used. This table gives the fission product gamma inventory for noble gases and is based on 200 hours of operation at 55 MW. Since the gases which escape should tend to collect above any pool of water which may exist, the gamma rays from the gases were assumed to be 50% effective.
- (5) For the test chamber case, releases as outlined in TID-14844^[8] were assumed and are as follows:

- (a) 50% of iodines
- (b) 100% of the rare gases
- (c) 1% of the solids.

These releases were also used in a LOCE case for comparison with the 20% release case.

- (6) For the LOCE case, releases for a 20% fuel pin perforation were calculated to be as follows^[a]:
 - (a) 11% of the iodines and other halogens
 - (b) 11% of the rare gases
 - (c) 0.11% of the solids.
- (7) The decay heat curve was obtained from LTR 62 B02 010A^[9], which was based on a reactor which had operated at 55 MW for an infinite time before shutdown.
- (8) During the LOFT blowdown suppression tank LOCEs, the sources of hydrogen are metal-water reaction, radiolysis, and dissolved gases. Since the LOFT system initially has no oxygen present, the oxygen concentration, not the hydrogen concentration, is the factor which determines whether or not a flammable mixture exists. Hydrogen produced from metal-water reaction was therefore not considered, since this would dilute any oxygen formed. The only hydrogen and oxygen sources considered for the LOCE cases were radiolysis and the dissolved gases.

[a] Also, refer to Table C-III in Reference [7].

3.0 RESULTS

3.1 Containment Building LOCA (Case 1)

Since the test chamber atmosphere provides sufficient oxygen to support combustion, the important criterion after a LOCA is whether the hydrogen concentration becomes high enough to form a combustible mixture. This LOCA to the test chamber is considered worse than any LOCE which may go to the chamber because of the higher fission product releases assumed for the LOCA. Hydrogen production resulting from a LOCA will be as follows:

- (1) Metal-water reaction (5% reaction) = 250 scf
- (2) Radiolysis (133 days after blowdown) = 1990 scf
- (3) Corrosion (133 days after blowdown) = 7900 scf
- (4) Dissolved in primary system water = 16 scf.

This results in a hydrogen concentration in the test chamber of 4.0% by volume, which is the critical point. Hydrogen generation in the containment, therefore, does not present a problem for approximately 133 days.

3.2 Blowdown Suppression Tank LOCE - 20% Fuel Pin Perforation (Case 2)

For a LOCE case when blowdown is into the blowdown suppression tank, the main concern is the oxygen concentration. Unlike a LOCA where the containment atmosphere supplies sufficient oxygen to combust the hydrogen, the suppression tank is initially filled with nitrogen only. Oxygen as well as hydrogen must be formed in order to get a combustible mixture. The sources of hydrogen and oxygen are as follows:

- (1) Zirconium-water reaction (0% reaction assumed) - 0 scf of hydrogen (worst case, since it provides minimum dilution of oxygen)
- (2) Radiolysis (12 days assumed) - 372 scf of hydrogen and 186 scf of oxygen
- (3) Gases dissolved in suppression tank water - 28 scf of hydrogen and 17 scf of oxygen
- (4) Gases dissolved in primary system water - 16 scf of hydrogen.

For these calculations the nitrogen from the suppression tank header system and from one accumulator was also assumed to be swept into the suppression tank during blowdown. The resulting hydrogen and oxygen concentrations in the suppression tank increase with time and reach 10% and 4.9%, respectively, 12 days after LOCE. According to Figure 1, a minimum of 4.9% oxygen is necessary to form a combustible mixture; therefore, for up to 12 days the oxygen level remains below a combustible level.

3.3 Blowdown Suppression Tank LOCE - (Case 3)

If the water in the suppression tank is assumed to act as a block which prevents hydrogen and oxygen in the primary system from flowing into the tank, the residence time in the tank prior to reaching the combustible level can be increased substantially. Analyses indicate that if the water blocks further gas transfer from the primary system 1 day after a LOCE, the allowable residence time is increased to >200 days. At this time, the hydrogen and oxygen concentrations are 4.0% and 2.0%, respectively.

Hydrogen and oxygen would, however, continue to accumulate in the primary system and the blowdown suppression header system from radiolysis in the core. To analyze what happens in the primary system because of the water block, the conservative assumption was made that all hydrogen and oxygen generated either from released or unreleased fission products remained in the primary system and suppression header system and the nitrogen from the accumulators was swept into the suppression tank during blowdown. This makes dilution of the hydrogen and oxygen in the primary system necessary on a continuous basis since stoichiometric mixtures of hydrogen and oxygen are being formed.

- * Three possible hydrogen diluents were examined, i.e., water vapor, steam, and nitrogen. The water vapor and steam were found to be not important sources of diluents because of condensation, which may occur in cool volumes. The calculated amounts of these diluents were found to be inadequate to protect the system for other than short periods of time.
- * The dilution of hydrogen with nitrogen was found to be the only satisfactory method. The volume of nitrogen necessary for dilution was obtained by assuming that the volume percent of oxygen must remain below 4.9%, which is possible if the volume of nitrogen added equals 8.70 times the volume of hydrogen formed. This method will work provided the nitrogen can be mixed thoroughly with the hydrogen and oxygen, which depends largely on the injection points for the nitrogen. This method, though better than the others, is somewhat temporary because the maximum operating pressure of the blowdown suppression system is limited at 105 psig^[a]. The system, therefore, will be within design limits for approximately 10 days, then venting will be necessary.
- * The blowdown suppression tank pressure as a function of time was calculated assuming adiabatic compression. Using adiabatic compression maximizes the resultant system pressure because of the continuous heat losses from the system (i.e., core cooling and heat losses to containment), which adiabatic compression does not consider. The constituents considered in the compression

[a] This pressure is below the blowdown suppression tank design pressure of 150 psig and has been selected as the limiting pressure to meet the manufacturer's recommendations for the peak operational pressure of the installed rupture disc to preclude fatigue failure. The peak operating pressure recommended by the manufacture for the rupture disc is 70% of the burst pressure (150 psig). In addition to the rupture disc pressure limitation, the safety relief valve would limit the peak tank pressure to the relief valve setting of 125 psig.

calculation were hydrogen, oxygen, and nitrogen available in the system. Because of unknown system conditions, the water vapor constituent was not considered in the calculation. However, as mentioned earlier, water vapor is considered to be a better inhibitor to hydrogen combustion than nitrogen. Thus, considering only nitrogen as a dilutant is a conservative assumption. The system volume used for the pressure calculations was 902 ft³ which includes the volume of the primary system, suppression header, and suppression downcomer. The results of the nitrogen dilution method are summarized in Table I which lists time versus volume of hydrogen, volume of nitrogen, and resulting pressure.

3.4 Primary System Isolation (Case 4)

In this case, the primary system isolation valves are shut and the primary system is refilled with water. In Case 3 it was shown that isolating the suppression tank in less than 1 day will allow the tank to go for over 200 days without any problems. The remaining problem is the stoichiometric mixture of hydrogen and oxygen being formed in the core. Since the formation of this mixture cannot be prevented, one of three courses of action can be taken.

First, the gases can be vented as they are formed, directly to the blowdown suppression tank. This can be accomplished using the high-point vents in the primary system. Venting of the gases, however, is limited to a maximum of 12 days after blowdown, because the accumulation in the suppression tank becomes the same as discussed in Case 2. The 12 days is the sum of the days before and after isolation.

The second course of action is to vent the gases through a hydrogen recombiner and then into the suppression tank. In this case, the suppression tank would be receiving water and as mentioned previously the tank could be below safe limits for over 200 days if isolation occurred in less than 1 day.

Finally, the third alternative is to vent directly to the atmosphere. This is only possible if the fission product inventory is low or if the gases are filtered first.

Venting of the primary system after refilling would not completely prevent pocketing, but would prevent large accumulations during periods of no primary system flow. While beyond the scope of this study to determine the effects of combustion from a stoichiometric mixture of hydrogen and oxygen, the possibility of a small pocket causing damage to a system designed for 2500 psia is felt to be relatively small. The peak pressures resulting from a hydrogen explosion would be only 6.8 times the original system pressure^[10]. Using this pressure increase plus a factor of 4 to scope the possible dynamic magnification effect due to pressure wave reflection, a maximum pressure limit of about 100 psia will be established on the primary system until the system has been vented of potential hydrogen accumulation. This action will prevent component damage in the unlikely event of a hydrogen explosion.

3.5 Blowdown Suppression Tank LOCE - TID-14844 Fission Product Release

The results for this case are similar to those for the 20% fuel pin perforation case except for the radiolysis source. This is a much more

TABLE 1
RESULTS OF NITROGEN DILUTION METHOD

Item	Time (days)	20% Fuel Pin Perforation		Resulting Pressure (psia)
		Volume H ₂ (ft ³ STP)	Volume N ₂ (ft ³ STP)	
1.	0.000012 (1 sec)			
2.	0.000023 (2 sec)			
3.	0.000116 (10 sec)			
4.	0.000694 (1 min)	0.4	3.5	
5.	0.002773 (4 min)			
6.	0.01042 (15 min)	3.3	28	
7.	0.02083 (30 min)	5.3	46	
8.	0.04167 (1 hr)	9.2	80	
9.	0.08333 (2 hr)	15.3	133	
10.	0.125 (3 hr)	20.4	177	
11.	0.20833 (5 hr)	29.7	258	
12.	0.33333 (8 hr)	42.8	372	
13.	0.5	56.0	487	
14.	1.0	91.5	796	12
15.	1.5			
16.	2.0	146.4	1274	24
17.	2.5			
18.	3.0	191.8	1669	35
19.	3.5			
20.	4.0	232.1	2020	45
21.	5.0	269.1	2342	56
22.	6.0	303.5	2642	66
23.	7	336.0	2925	76
24.	8	367	3194	86
25.	9	396.7	3453	96
26.	10	425.2	3701	106
27.	12	479.7	4175	126
28.	14	531.1	4623	145
29.	16	580.2	5050	164
30.	18	627.2	5459	183
31.	20	672.5	5853	202
32.	22	716.4	6236	220
33.	24	758.9	6606	239
34.	26	800.3	6966	257
35.	28	840.7	7317	276
36.	30	880.1	7660	294

severe case which results in the oxygen concentration approaching the combustible limit 8 days after the LOCE. Isolating the system 1 day after a LOCE increases the allowable residence time to 79 days, before flammable limits are reached. Pressurizing with nitrogen to 105 psig (see Section 3.4) in addition to the isolation would increase the allowable residence time. At 200 days with isolation and nitrogen pressurization, the hydrogen and oxygen concentrations are 5.0% and 2.5%, respectively.

4.0 CONCLUSIONS

4.1 Containment Vessel Test Chamber (FDD 1.2^[11])

4.1.1 Hydrogen Production

The hydrogen concentration in the test chamber remains below the combustible level for up to 133 days after a LOCA.

4.1.2 Means of Control

Postexperiment cleanup with circulation of the containment atmosphere through roughing, HEPA, and charcoal filters for removal of fission products is planned to commence within 2 days following an experiment. This will allow venting of the test chamber when sufficiently low concentrations of radionuclides are achieved so that offsite exposure limits do not exceed AEC Manual Chapter 0524^[12] guidelines. As a result, the hydrogen concentration in the containment will be further diluted; therefore, combustible concentrations in the containment will not be reached after a LOCA.

4.1.3 Means of Measurement

The containment atmosphere is monitored to determine if there is a hydrogen buildup due to a LOCA or containment exhausted LOCE. The detectors will be used to verify that the hydrogen concentration is below the combustible limit.

4.1.4 Necessary Design Features

The above discussion indicates the necessary design features include (a) roughing, HEPA, and charcoal filters for postexperiment cleanup, (b) a vent system for the test chamber, and (c) a containment atmosphere monitor to determine the hydrogen buildup. The containment vessel design contains all of these necessary design features.

4.2 Blowdown: Suppression Tank (LOCE - 20% Fuel Pin Perforation) (SDD 1.1.2^[13])

4.2.1 Hydrogen and Oxygen Production

For this case, the oxygen concentration is limiting, and the results show the hydrogen and oxygen concentrations remain below the combustible limit for up to 12 days after a LOCE. This time is increased to >200 days if the water in the suppression tank acts as a block to prevent hydrogen and oxygen in the primary system from flowing into the suppression tank.

4.2.2 Means of Control

There are several means of control of the concentrations of hydrogen and oxygen which are venting, reflooding, dilution with an inert gas (nitrogen), combination of venting and dilution, or isolation of the blowdown suppression tank from the primary system which reduces the source of radiolysis in the suppression tank. First, if the radioactive level is low enough during the first 12 days, the gases will be vented which will alleviate the combustible problem. Nitrogen can be added to reduce the hydrogen concentration below the combustible limit if needed. If the radioactive level is too high to vent prior to 12 days, the blowdown suppression system can be isolated from the primary coolant system by closing the isolation and quick-opening valves, thus reducing the source of the radiolysis in the tank. The primary system could then be either pressurized or refilled.

If the primary system isolation valves are closed and the system is refilled, the high-point vents must be used to prevent accumulation of large pockets of hydrogen and oxygen. If the radioactivity level is low enough, venting directly to the atmosphere may be allowable. This may be accomplished with a filter, since the quantities of gases will be small. Venting to the suppression tank is feasible only if the tank was isolated before it becomes saturated with hydrogen and oxygen. Otherwise, the combustible gases must be recombined before being injected into the suppression tank.

Venting of the primary system after refilling would not completely prevent pocketing but would prevent large accumulations. While beyond the scope of this study to determine the effects of combustion from a stoichiometric mixture of hydrogen and oxygen, the possibility of a small pocket causing damage to a system designed for 2500 psia is felt to be relatively small. However, as mentioned earlier, the primary system pressure will be maintained below 100 psia to prevent potential peak pressures in excess of the design limit in the event of a hypothetical explosion.

In addition, the blowdown suppression system can be pressurized with nitrogen to keep the oxygen and hydrogen mixture below the limits of combustibility until the fission products have decayed to a level acceptable for venting. Nitrogen pressurization, however, is only an intermediate solution; for extended periods of time, a vent will be necessary to relieve the pressure so that additional nitrogen may be added to dilute the mixture remaining in the suppression tank.

4.2.3 Means of Measurement

The atmosphere of the blowdown suppression system is analyzed for fission products by the CSM system. This system will be used to determine if and when the pressure suppression tank can be vented to the atmosphere. This system will also be used to obtain a gas sample which can then be analyzed for hydrogen and oxygen.

4.2.4 Necessary Design Features

The above discussion indicates the necessary design features include (a) an isolation system between the primary coolant system and blowdown suppression tank, (b) a vent system for the blowdown suppression tank, (c) a system for pressurizing with nitrogen, and (d) an atmosphere monitoring system for fission products, hydrogen, and oxygen. The blowdown suppression system contains all of the necessary design features except the capability of monitoring the hydrogen and oxygen directly; however, this function may be accomplished by analysis of the sample from the CSM system. If venting is used, the use of a recombiner should be considered.

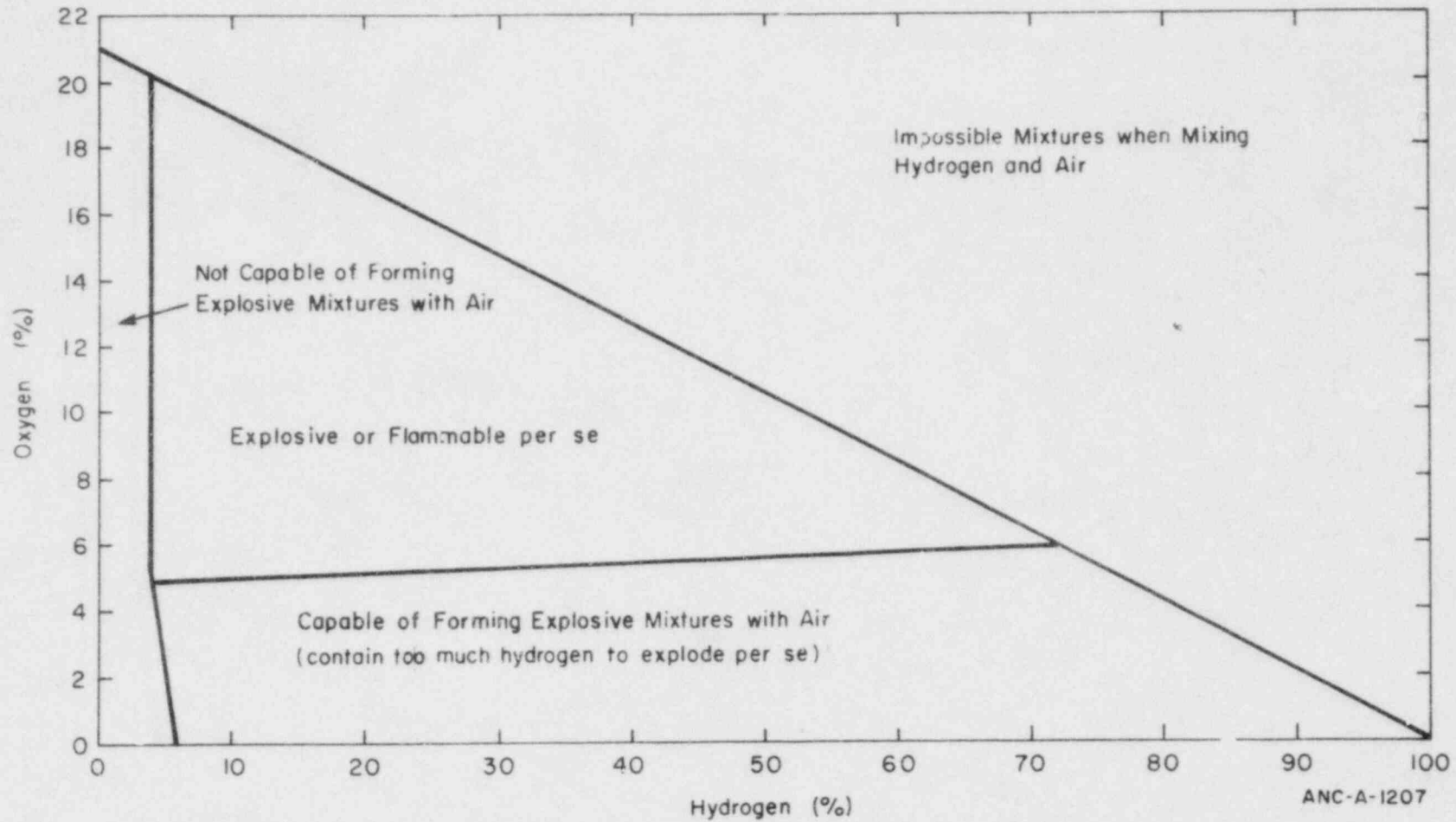


FIG. 1 - RELATION BETWEEN COMPOSITION AND FLAMMABILITY OF HYDROGEN, OXYGEN, AND NITROGEN (REDEAWN FROM REFERENCE 14.)

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