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A Review of Radiolysis Concerns for Water Shielding in Fission Surface Power Applications

Michael P. Schoenfeld[1]

[1]NASA Marshall Space Flight Center, ER24, MSFC, AL 35812
(256) 544-4557 michael.p.schoenfeld@nasa.gov

Abstract. This paper presents an overview of radiolysis concerns with regard to water shields for fission surface power. A review of the radiolysis process is presented and key parameters and trends are identified. From this understanding of the radiolytic decomposition of water, shield pressurization and corrosion are identified as the primary concerns. Existing experimental and modeling data addressing concerns are summarized. It was found that radiolysis of pure water in a closed volume results in minimal, if any net decomposition, and therefore reduces the potential for shield pressurization and corrosion.

Keywords: radiolysis, water shield, water decomposition,

PACS: 28.41 Qb, 28.50-k

INTRODUCTION

With the space program focus to emphasize more on permanent return to the Moon and eventually manned exploration of Mars, there has been a renewed look at fission power to meet the difficult technical & design challenges associated with this effort. This is due to the ability of fission power to provide a power rich environment that is insensitive to solar intensity and related aspects such as duration of night, dusty environments, and distance from the sun, etc. One critical aspect in the utilization of fission power for these applications of manned exploration is shielding. Although not typically considered for space applications, water shields have been identified as one potential option due to benefits in mass savings and reduced development cost and technical risk (Poston, 2006). However, the water shield option requires demonstration of its ability to meet key technical challenges including such things as adequate natural circulation for thermal management and capability for operational periods up to 8 years. Thermal management concerns have begun to be addressed and are not expected to be a problem (Pearson, 2007). One significant concern remaining is the ability to maintain the shield integrity through its operational lifetime. Shield integrity could be compromised through shield pressurization and corrosion resulting from the radiolytic decomposition of water.

RADIOLYSIS

Process

The radiolysis process can be separated by function into three distinct stages. First incident radiation deposits its energy into the water through various interaction mechanisms resulting in ionized or excited water. Then, the water begins to rapidly adjust to the almost instantaneous presence of the ionized and excited water even before the molecules can adjust through their normal agitation. Atomic adjustments ensue and result in the formation of chemically active free radicals. With the presence of chemically active species, diffusion driven chemical processes then occur. During this stage both water decomposition and reformation can result through competing reactions. In a closed volume, the decomposition products accumulate which in return lead to water reformation. The reactions compete until decomposition-reformation equilibrium is reached (Monson, 1955).

Energy Deposition

Although the water in a water shield would be exposed to a mixed field of charged and uncharged radiation, the resulting effect of ionizing radiation would be charged particles. X-rays and γ-rays will create a varying spectrum of electrons primarily from photoelectric affect and Compton scattering. Fast neutrons will scatter losing their energy and creating ionized nuclei such as recoil protons. Thermal neutrons can be absorbed in the nucleus and release high energy γ-rays (2.2 MeV for H) or release an α particle such as from the neutron absorption by boron in borated water. The energy deposited results in ionized water (H_20^+) and excited water (H_20^*). This occurs within 10^{-15} seconds within local regions of the charged particle track.

Atomic Adjustment

Rapidly after the formation of H_20^+ and H_20^*, atomic process adjust for the added energy resulting in the formation of the following chemically active radicals through the corresponding mechanisms. These radical yields result within 10^{-15} to 10^{-12} seconds, at which point they begin to randomly migrate driven by diffusion (Turner, 1995).

$$\begin{gathered} H_2O^+ + H_2O \rightarrow H_3O^+ + OH \\ H_2O^* \rightarrow \begin{pmatrix} H + OH \\ H_2O^+ + e^- \end{pmatrix} \\ e^- \rightarrow e^-_{aq} \end{gathered} \tag{1}$$

Chemical Reactions

With the chemically active radicals diffusing, the spatial distribution or location of the radicals becomes the determining aspect of what chemical reactions occur. If the radicals are close enough to react with each other and undergo radical-radical reactions, water decomposition results through the following reactions.

$$\begin{gathered} H + H \rightarrow H_2 \\ OH + OH \rightarrow H_2O_2 \end{gathered} \tag{2}$$

Water decomposition results in the formation of the molecular decomposition products hydrogen (H_2) and hydrogen peroxide (H_2O_2). Hydrogen peroxide can also decompose into oxygen (O_2) (Monson, 1955) which would be more significant in a water shield application with temperatures above 200°F. As such, the expected molecular decomposition products are $H_2(g)$ and $O_2(g)$. Depending on the extent of decomposition and specifics of the shield design, this could result in corrosion, formation of explosive mixtures in a gas space above the water, or shield pressurization.

If the radicals are spaced apart, it will be more probable that they will diffuse into the bulk of the water without reacting. In this case, the radical decomposition products will be available for reacting with the molecular decomposition products in (2) resulting in radical-molecular reactions that promote water reformation through the following mechanisms.

$$\begin{pmatrix} H + H_2O_2 \rightarrow H_2O + OH \\ OH + H_2 \rightarrow H + H_2O \end{pmatrix} \xrightarrow[\text{net effect}]{} H_2 + H_2O_2 \rightarrow 2H_2O \tag{3}$$

$$\begin{pmatrix} OH + H_2O_2 \rightarrow H_2O + HO_2 \\ H + HO_2 \rightarrow H_2O_2 \end{pmatrix} \xrightarrow[\text{net effect}]{} H + OH \rightarrow H_2O \tag{4}$$

$$\begin{pmatrix} H + O_2 \rightarrow HO_2 \\ OH + HO_2 \rightarrow H_2O + O_2 \end{pmatrix} \xrightarrow[\text{net effect}]{} H + OH \rightarrow H_2O \tag{5}$$

$$2H_2 + O_2 \rightarrow 2H_2O \tag{6}$$

Reaction (3) is beneficial since it converts decomposition products into water which promotes the water reformation process. Although reactions (4) and (5) also reform water, it is done with out replenishing the radicals (the products do not consist of additional radicals). As such, reactions (4) and (5) reform water but reduce the rate of the water reformation process. In addition, however, the recombination of hydrogen and oxygen in reaction 6 reforms water and promotes the water reformation process. This reaction can be thermally catalyzed or radiation induced.

Trends and Behavior

From this understanding of the radioytic decomposition of water, the affects of key processes parameters can be predicted and compared with some of the extensive experimental and simulated work already conducted.

Linear Energy Transfer (LET)

As mentioned earlier, the effect of ionizing radiation on water is to generate charged particles that deposit their energy in the water inducing the first stage of radiolysis. Linear Energy Transfer (LET) quantifies the energy deposited to the water from the charged particles. With increasing LET, more localized energy deposition would occur resulting in more radical production along the track of the charged particle. As such, there would be a high probability of radical-radical interactions corresponding to the large density of radicals in the track. This is illustrated in figure 1 (Allen, 1961). Therefore, increasing LET will favor more water decomposition. Figure 2 (Allen, 1961) indicates this by how H and OH radicals decrease while H_2O_2 and H_2 molecules increase with increasing LET.

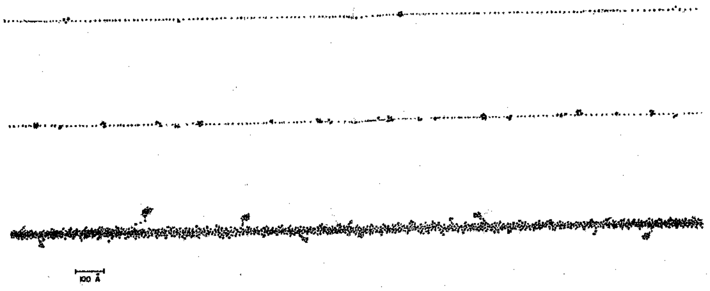


FIGURE 1. "Schematic of water decomposition by charged particles. Each dot represents deposition of 20 ev, or approximately, one water molecule decomposed. Upper line, 40 kev electron, LET 0.08 ev/Å. Middle, 18 Mev deuteron, 0.5 ev/Å. Bottom, 5,5 Mev α-ray, 9 ev/Å. A 1 Mev-electron would on the average show no events in the length here depicted" (Allen, 1961).

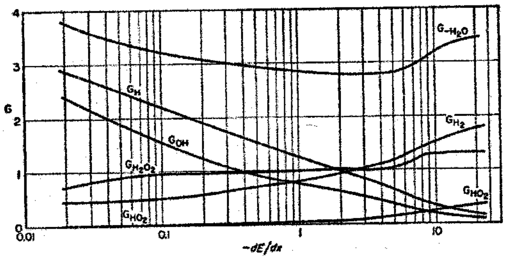


FIGURE 2. "The affect of LET on the yield of radical and molecular decomposition products. Yield is indicated by a G value that represents the number of species per 100 eV absorbed energy." (Allen, 1961).

Experimental data in Figure 3 (Monson, 1955) confirms this trend through the effect of epithermal neutrons and gamma fluxes on water decomposition indicated by the pressure of the decomposition products. Water in a quartz ampoule at 77°F was irradiated in the ORNL X-10 reactor. When an equilibrium condition was reached, as indicated by a flat slope, various shields were placed around the ampoule. On one run, a paraffin shield removed the epithermal flux allowing the gamma flux to dominate and thereby showing the effect of the low LET radiation. On the other run, a lead shield removed the gamma flux allowing the epithermal flux to dominate and show the effect of increased localized energy deposition. As expected, the gamma flux (low LET radiation) results in reformation where the epithermal neutron flux results in water decomposition. The difference in equilibrium levels between the two runs is due to differences in water purity which will be discussed later but has no bearing on this discussion.

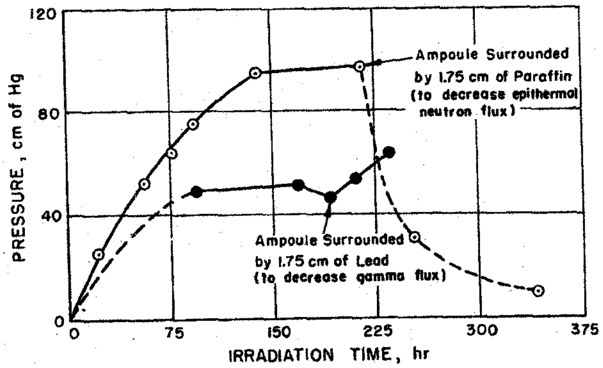


FIGURE 3. "Effect of Change in Nature and Intensity of Radiation upon Water Decomposition Product Equilibrium Pressure as Observed with Partially filled Ampoules Irradiated in Oak Ridge X-10. Redrawn from ORNL-130, Oct. 11, 1949" (Monson, 1955).

Temperature

Temperature effects can be separated in terms of the two competing reactions. Effects on water decomposition are minimal if any (Draganic, 1971), (Allen, 1961). However, increasing temperatures supports water reformation and decreases decomposition (Calkins, 1958). This is due reaction (6). Experimental evidence indicates that at low temperatures, when concentrations of hydrogen and oxygen are high, this reaction substantially bolsters water reformation but not in the vapor phase. However, other experimental results in Figure 4A (Monson, 1955) indicate that the recombination at high temperatures is also appreciable and occurs in both the liquid and vapor phase of water. Oxygen and hydrogen were added, in near stoichiometric proportions, to the vapor phase of an ampoule containing water at 202°F. The total pressure of the ampoule increased with the partial pressure contribution of the added gases. As irradiation begins and catalyzes reaction (6), water reformation occurs indicated by the drop in total pressure. Figure 4B (Monson, 1955) shows that the rate of recombination also increases with temperature up to about 300°F where above this it seems to become independent of temperature although remaining fairly high. In addition to reducing decomposition, higher temperature correspondingly lowers the equilibrium concentration of decomposition products. Experimental evidence in Figure 4C (Monson, 1955) shows increasing the temperature from 97°F to 230°F reduced the equilibrium partial pressure from 14 to 1.2 psi attributing this to reaction (3).

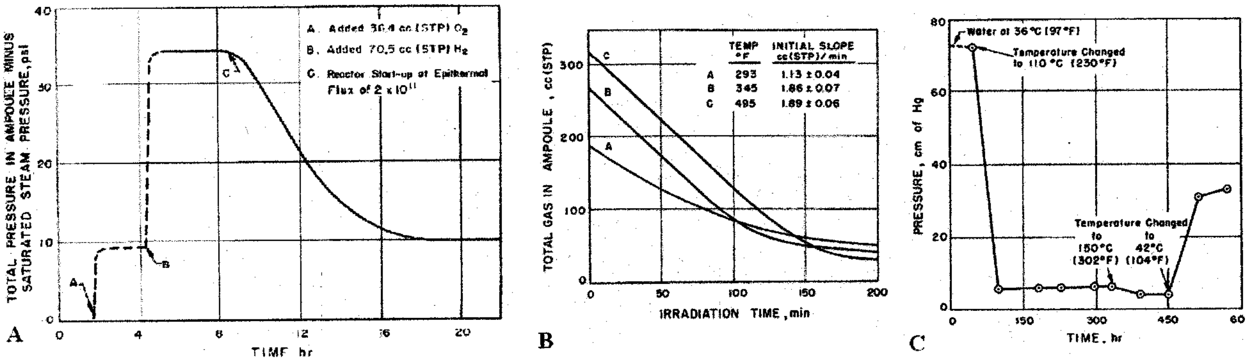


FIGURE 4. [A] "Radiation-induced Recombination of Hydrogen and Oxygen in an Ampoule Partially Filled with Water. Redrawn from ANL-4628, May 1, 1951." [B] "Effect of Temperature upon Rate of Combination of Hydrogen and Oxygen in an Ampoule Partially Filled with Water and Under Irradiation in the Chalk river Reactor (NRX). Redrawn from ANL-5004, March 1953. Initial ratios of hydrogen to oxygen only approximately stoichiomtetric" [C] "Effect of Temperature on the Equilibrium Pressure of Water Decomposition Products as Observed with a Partially Filled Ampoule Irradiated in Oak Ridge X-10 Reactor. Redrawn from ORNL-130. Oct. 11, 1949. Pressures measured at room temperature during periodic removal of ampoule from reactor." (Monson, 1955)

Dose

If an equilibrium decomposition-reformation is reached, dose does not affect the net decomposition beyond a point. If equilibrium is not established, possible in some borated waters, decomposition will continue with increasing dose. When water is first irradiated, only the decomposition process occurs since there are no molecular decomposition products to reform into water. In a closed system, the molecular decomposition products begin to accumulate, some of which are reformed into water effectively slowing down the rate of decomposition. As the concentrations of decomposition products increase, water reformation also increases, in accordance with the mass-action law, until the rate of decomposition is eventually reduced to zero and an equilibrium condition is reached. Equilibrium states have been observed in both the experimental data in Figure 3 and modeling predictions in Figure 5 (Bjergbakke, 1989).

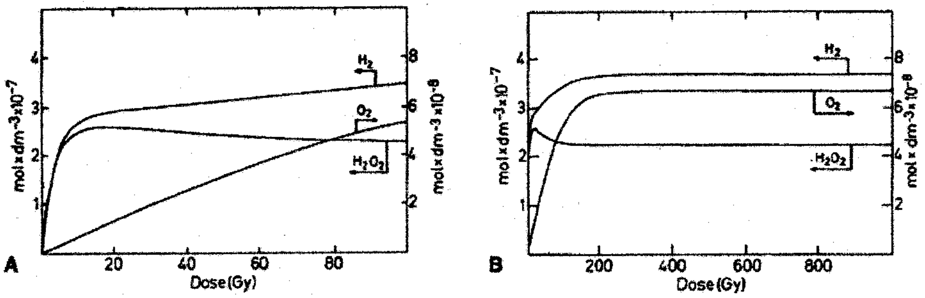


FIGURE 5. Radiolytic products in air-free pure water at 1 Gy / sec adapted from Bjergbakke, 1989.

Dose Rate

Higher dose rates increase interaction density and lead to a higher radical density. This will increase the probability of radical-radical interactions resulting in more decomposition. In a closed volume, as discussed previously, it will also cause more water reformation. The net effect will be to not only speed up the evolution to the equilibrium state but result in a higher equilibrium concentration of molecular decomposition products as shown in Figure 6 (Bjergbakke, 1989). The equilibrium shift may result from the initial decomposition in the close volume occurring much more rapidly.

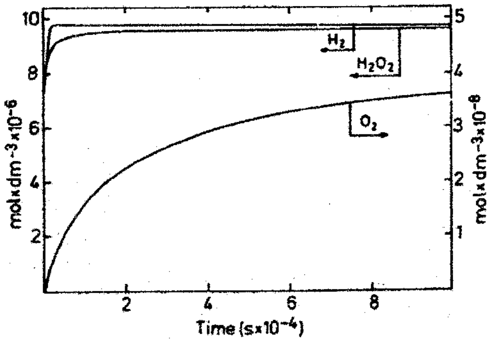


FIGURE 6. Formation of Radiolytic Products in Air-free Pure Water Following a 100 Gy electron pulse delivered in 1 x10^{-6} seconds Adapted from Bjergbakke, 1989.

pH

Draganic provides an overview of the extensive work conducted regarding this trend. In short, multiple facets of research concluded that there is not strong dependence on pH. Only in extreme cases of multimolar solutions represent an area that requires special study. The dependence on the radical and molecular yields on pH in water undergoing γ radiolysis was derived from measurements on formic acid-oxygen solutions shown in Figure 7 (Draganic, 1971).

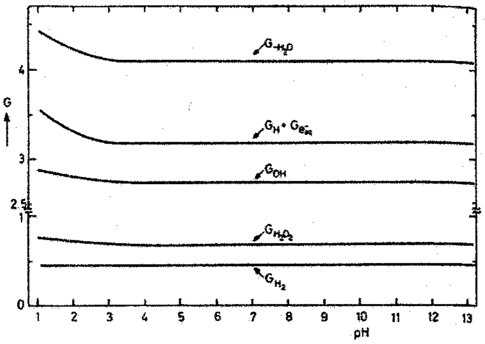


FIGURE 7. The affect of pH on Radical and Molecular Yields of Water γ-radiolysis adapted from Draganic.

Pressure

Draganic documents multiple experiments regarding pressure. The overall conclusions were that pressure does not affect the overall yields of the primary reducing species and that there is no effect on the primary yields of free radical and molecular products in an acid medium. Although the rate constants of some of the reactions studied were appreciably affected by changes in pressure, no effect of pressure on the primary yields of water radiolysis could be proved.

Impurities

Reactions involving ionic impurities and decomposition products depend on the availability of the H and OH radicals which is primarily a function of the γ flux. As such, the effects of impurities are expected to be of considerable importance when the γ flux is high and relatively ineffective when the γ flux is low (Monson, 1955).

Ionic impurities reduce water reformation by removing the H and OH radicals through reactions with them. Br^-, I^- and Cu^{++} ions are among the most reactive and as such, solutions with even the most dilute concentrations will result in extremely high equilibrium concentrations and a net increase in the decomposition rates. In conditions that would result in equilibrium partial pressures of less than 10 psi in pure water, solutions of KBr, KI, and $CuSO_4$ may produce pressures more than 1,500 psi. Similarly, a 0.0088N solution of HCl produced a pressure of 350 psi; 1.03N of H_2SO_4 resulted in 155 psi; and 0.0095N of H_2SO_4 resulted in the same pressure as pure water (Calkins, 1958) (Monson, 1955). Additional supporting experimental evidence is provided by Hart, E.J. Water purity associated with a specific resistance of 10^6 ohm-cm was identified in the CP-3 & CP-3' reactors, by Monson, to provide negligible decomposition.

Suspended impurities do not affect water decomposition or reformation since they do not react with the H and OH radicals. However, impurities such as copper, rhodium, palladium, platinum, silver, iodine, tin, iron and titanium have shown potential to catalyze water reformation at temperatures above 400°F (Calkins, 1958) (Monson, 1955).

Effects from decomposition products essentially depend on the proportions of H_2 to O_2 or H_2O_2. Excess H_2 can reduce decomposition by removing H_2O_2 and O_2 through reactions (3) and (6). At high temperatures subjected to an average neutron and gamma irradiation levels in a reactor, initial introduction and maintenance of H_2 concentrations equivalent to 5 to 10 psi partial pressure reduced decomposition of pure water to practically zero and maintained the O_2 concentration closely equal (Monson, 1955). Experimental results were shown in Figure 4A and simulation results are shown in Figure 8 (Bjergbakke, 1989). Additional confirmations are provided by Hart, E.J. (1956) and Allen, A.O. (1961).

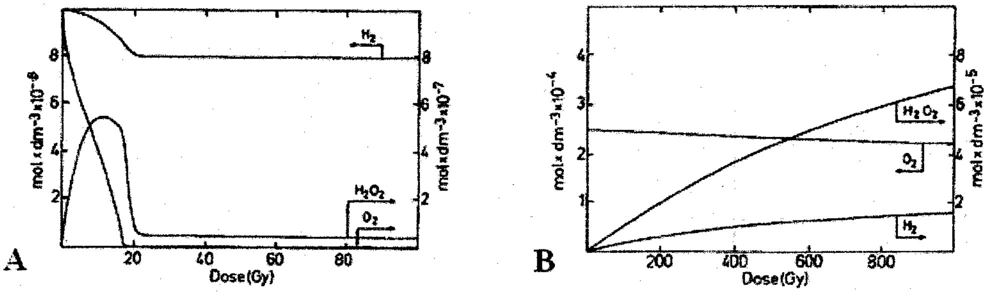


FIGURE 8. [A] Excess Hydrogen Depletion of Oxygen by irradiation at 1 Gy / sec. [B] Excess Oxygen Depletion Leading to Build of Hydrogen and Hydrogen Peroxide in Air-Saturated Water. Dose Rate 1 Gy / sec. Adapted from Bjergabakke.

The presence of excess O_2 promotes H_2O_2 formation and increases the decomposition equilibrium concentrations. In simulation shown in Figure 8B (Bjergbakke, 1989), air saturated water resulted in 10,000 times higher concentration of H_2O_2 than air free water shown earlier in figure 6. Additional confirmations are provided by Hart, E.J. (1956).

Borated water does not affect decomposition in a γ field but can lead to continuous decomposition in a neutron field due to the generation of high LET α particles from the $^{10}B(n,\alpha)^{7}Li$ interaction. Experimental research by Hart, E.J. has shown that no net decomposition is noticed until boron concentration reaches a critical level to overcome the surplus radicals available for recombination from the γ flux shown in figures 8A and 8B (Hart, 1956). Above this level, water decomposition, indicated by H_2 production, is linearly proportional to alpha energy deposition and therefore the boron concentration (Hart, 1956) (Allen, 1961) (Calkins, 1958). However, figure 8C (Hart, 1956) shows H_2 addition increases the critical boron concentration for net decomposition allowing for higher concentrations of borated water before decomposition occurs.

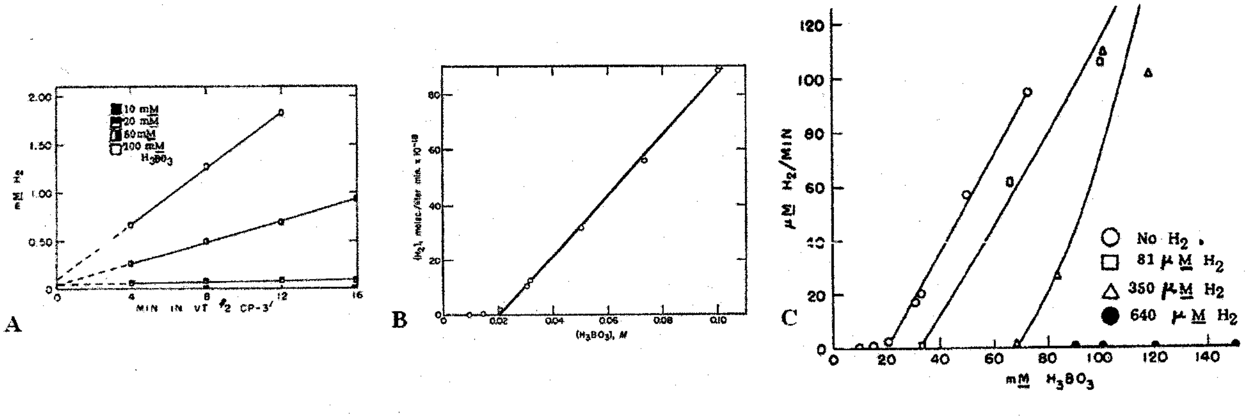


FIGURE 9. [A] H_2 production from Various Concentrations of Borated Water Exposed To Pile Radiation. [B] "Rate of hydrogen evolution in air-free boric acid solutions exposed in Argonne National Laboratory nuclear reactor CP-3'. Curve is calculated as described in text. (From Allen and Schwarz)" (Hart, 1956). [C] "Effect of initial dissolved hydrogen on hydrogen production in boric acid solution irradiated in CP-3'" (Hart, 1956).

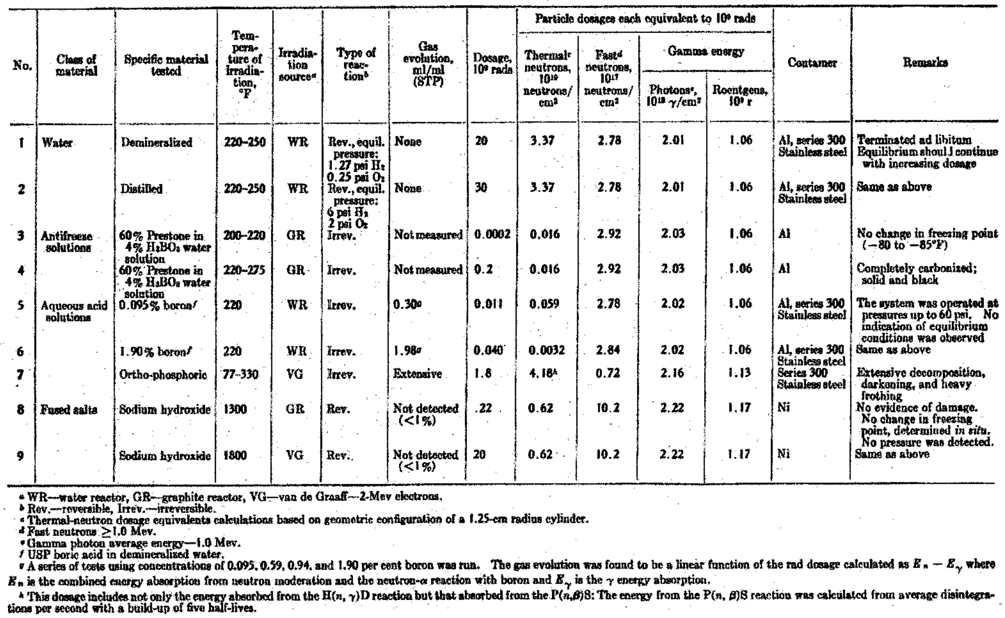
WATER SHIELD APPLICATION

A water shield for a 40kWe 8 year design was selected as a baseline. The shield contains 800 kg of water at an average temperature of 392 K (246 °F) and a boron concentration of 500 ppm. Average dose in water is 29 Grad with an average dose rate of 0.42 MRad/hr.

Decomposition of pure, air free water in a mixed gamma and neutron flux is unlikely. Similar behavior is expected in borated water if boron concentrations are below a critical level. At temperatures at or above 202 F (367 K), radiation induced recombination of H_2 and O_2 occurs in both the water and vapor stage bolstering water reformation and lowering the equilibrium decomposition product concentrations. The experimental results number 1 and 2 in Figure 10 (Calkins, 1958) support this indicating a maximum H_2 partial pressure of 6 psi and 2 psi for O_2.

Data from test numbers 1 and 2 in figure 10 are compared to the water shield application in Table 1. The data is at comparable temperatures and dose for the eight year shield lifetime. The data reflects higher thermal neutron flux where the shield would be exposed to a higher fast flux tending towards more decomposition. However, the shield would also be exposed to more gamma fluence that would support recombination. Overall, Table 1 indicates that the relevant radiolysis parameters for the selected baseline are similar to the experiments in figure 10 which thereby should be fairly representative of the expected results in the water shield.

In test numbers 5 and 6 (figure 10), significant decomposition is indicated by gas evolution and test termination with pressure rise up to 60 psi attributed to the boron in the water. Footnote g in figure 10 explains that gas evolution, and hence decomposition, was found to be a linear function of rad dosage. Recalling work by Hart, E.J., this linear behavior of decomposition indicates that boron levels were beyond critical concentrations in those tests. Hart's work identified a critical boric acid concentration of 0.02 M in their experiments. The baseline design has been shown to benefit from boric acid concentrations around 0.046 M. Although this concentration is higher than the critical level identified in Hart's experimental work, it is unclear if it surpasses the critical concentration for the water shield since Hart's critical concentration may not necessarily be directly applied due to differences in other relevant radiolysis factors. For example, the water shield's critical concentration may be higher than 0.02 M since it is exposed to a lower dose rate than in Hart's work. Regardless, Hart demonstrated that the addition of H_2 can effectively increase the critical concentration which can be employed as part of the shield design if necessary.



No.	Class of material	Specific material tested	Temperature of irradiation, °F	Irradiation source[a]	Type of reaction[b]	Gas evolution, ml/ml (STP)	Dosage, 10^9 rads	Particle dosages each equivalent to 10^9 rads				Container	Remarks
								Thermal[c] neutrons, 10^{19} neutrons/cm²	Fast[d] neutrons, 10^{17} neutrons/cm²	Gamma energy			
										Photons[e], 10^{18} γ/cm²	Roentgens, 10^9 r		
1	Water	Demineralized	220-250	WR	Rev., equil. pressure: 1.27 psi H_2 0.25 psi O_2	None	20	3.37	2.78	2.01	1.06	Al, series 300 Stainless steel	Terminated ad libitum Equilibrium should continue with increasing dosage
2		Distilled	220-250	WR	Rev., equil. pressure: 6 psi H_2 2 psi O_2	None	30	3.37	2.78	2.01	1.06	Al, series 300 Stainless steel	Same as above
3	Antifreeze solutions	60% Prestone in 4% H_3BO_3 water solution	200-220	GR	Irrev.	Not measured	0.0002	0.016	2.92	2.03	1.06	Al	No change in freezing point (−80 to −85°F)
4		60% Prestone in 4% H_3BO_3 water solution	220-275	GR	Irrev.	Not measured	0.2	0.016	2.92	2.03	1.06	Al	Completely carbonized; solid and black
5	Aqueous acid solutions	0.095% boron[f]	220	WR	Irrev.	0.30[g]	0.011	0.059	2.78	2.02	1.06	Al, series 300 Stainless steel	The system was operated at pressures up to 60 psi. No indication of equilibrium conditions was observed
6		1.90% boron[f]	220	WR	Irrev.	1.98[g]	0.040	0.0032	2.84	2.02	1.06	Al, series 300 Stainless steel	Same as above
7		Ortho-phosphoric	77-330	VG	Irrev.	Extensive	1.8	4.18[h]	0.72	2.16	1.13	Series 300 Stainless steel	Extensive decomposition, darkening, and heavy frothing
8	Fused salts	Sodium hydroxide	1300	GR	Rev.	Not detected (<1%)	.22	0.62	10.2	2.22	1.17	Ni	No evidence of damage. No change in freezing point, determined *in situ*. No pressure was detected.
9		Sodium hydroxide	1800	VG	Rev.	Not detected (<1%)	20	0.62	10.2	2.22	1.17	Ni	Same as above

[a] WR—water reactor, GR—graphite reactor, VG—van de Graaff—2-Mev electrons.

[b] Rev.—reversible, Irrev.—irreversible.

[c] Thermal-neutron dosage equivalents calculations based on geometric configuration of a 1.25-cm radius cylinder.

[d] Fast neutrons ≥1.0 Mev.

[e] Gamma photon average energy—1.0 Mev.

[f] USP boric acid in demineralized water.

[g] A series of tests using concentrations of 0.095, 0.59, 0.94, and 1.90 per cent boron was run. The gas evolution was found to be a linear function of the rad dosage calculated as $E_n - E_\gamma$ where E_n is the combined energy absorption from neutron moderation and the neutron-α reaction with boron and E_γ is the γ energy absorption.

[h] This dosage includes not only the energy absorbed from the $H(n, \gamma)D$ reaction but that absorbed from the $P(n,\beta)S$: The energy from the $P(n, \beta)S$ reaction was calculated from average disintegrations per second with a build-up of five half-lives.

FIGURE 10. Experimental Data Similar to Water Shield Application Adapted From Calkins.

TABLE 1. Experimental Data Test Factors Comparison to Water Shield Application

Application	Water Type	Water Temperature (°F)	Dose (10^9 rads)	Thermal Neutron Fluence (n/cm²)	Fast Neutron Fluence (n/cm²)	Avg Photon Energy (MeV)	ã Fluence (ã/cm²)	Roentgens
water reactor	demineralized	220-250	20	3.37×10^{19}	2.78×10^{17}	1.00	2.01×10^{18}	1.06×10^{9}
water reactor	distilled	220-250	30	3.37×10^{19}	2.78×10^{17}	1.00	2.01×10^{18}	1.06×10^{9}
water shield		246	29	7.30×10^{18}	5.71×10^{19}	1.52	2.78×10^{20}	19×10^{9}

Hydrogen Considerations

Due to the effect of the net H_2 concentration on equilibrium, and hence decomposition and shield pressurization, it is important to understand the balance between all sources of H_2 production and loss. Additional H_2 production could result from corrosion of some materials with water where H_2 is formed without additional formation of O_2. This could have the effect of increasing H_2 concentration and pressure in a non-equilibrium state if there were no other removal mechanisms. Alternatively, in addition to water reformation, H_2 can be lost in the water through any degasification mechanisms (mechanical or diffusion into gas space) or completely out of the shield through diffusion. This could result in low H_2 to O_2 or H_2O_2 ratios leading to increased decomposition. However, equilibrium is expected as experiments have shown with the key factor being H_2 concentration proportions to that of O_2 or H_2O_2. In another regard, the net H_2 concentration and partial pressure could affect corrosion or hydrogen damage in some materials. As such, hydrogen damage or corrosion, other sources of H_2, and H_2 loss by diffusion through the shield should be kept in mind while determining material selection for the water shield tank.

Pressurization

High equilibrium partial pressure of decomposition products are not expected for air free pure water irradiated by neutrons and gamma radiation. This is equally expected for borated water that is below the critical concentration where the decomposition effects from alpha particles do not overwhelm the recombination effects from the gamma radiation. This critical concentration is both a factor of boron and hydrogen concentrations. As such, shield pressurization should not be a concern as long as decomposition is minimized by maintaining a high purity of water and a relatively higher concentration of H_2 as compared to O_2 or H_2O_2.

Corrosion

The potential for corrosion of the shield can arise from exposure to decomposition products, hydrogen and possible varying pH of the water. The likelihood for corrosion can be significantly reduced by minimizing water decomposition through bolstering water reformation (operating temperatures higher than 200 °F, maintaining excess H_2, minimizing O_2 concentrations in the water, etc.). As well, proper material selection can provide additional margin of resistance.

CONCLUSION

Water shields have been identified as an option for fission surface power applications. Corresponding to this application, shield pressurization and corrosion resulting from the radiolytic decomposition of water has been identified as concerns with regards to feasibility and practicality; specifically to weight and shield integrity. A review of the radiolytic decomposition process has indicated key parameters to be the radiation type and intensity, water temperature, dose rate, and water purity. A review of both experimental and modeling data has revealed that the decomposition of water can be minimized. In general, (1) oxygen should be removed as much as economically feasible, (2) small amounts of hydrogen should be dissolved in the water before irradiation, (3) a slight over pressure of a few psi hydrogen should be maintained during irradiation, and (4) the water should remain relative pure on the order of 10^6 ohm-cm. Through minimizing decomposition, low equilibrium partial pressures on the order of a few psi can be expected and if coupled with careful material selection, should sufficiently address any potential for corrosion or shield pressurization.

ACKNOWLEDGMENTS

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