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SUBJECT: Pressurization of HRE-3 with an Oxygen-Inert Gas Mixture

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SUMMARY

Calculations made on the possibility of pressurizing HRE-3 with oxygen-helium and oxygen-argon mixtures indicate that such a system is feasible, but not necessarily more desirable than use of oxygen alone. The explosion hazard would not be reduced significantly by use of the inert gas and the off-gas design problems would be somewhat more difficult.

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Results and Conclusions

Calculations which have been made on the possibility of gas pressurizing the HRE-3 with a mixture of oxygen and helium or oxygen and argon indicate that such a system is feasible, but not necessarily more desirable than the use of oxygen alone.

Figure 1 shows the percentage of oxygen in the pressurizing gas versus the mole fraction of oxygen in solution in the pressurizer at various pressurizer temperatures. The reversal in the trend of oxygen solubility, which this graph indicates as occurring at about 260°C, is due to the fact that at the lower temperatures Henry's Law constant is the controlling factor, while at the higher temperatures the vapor pressure of D₂O is controlling. This graph indicates that there will probably be little problem in getting the required amount of oxygen into solution. The major difficulty is in disposing of the gases after their release to the low pressure system. If this gas contains a considerable quantity of contaminated inert gas, the volume requirement of the charcoal adsorption beds becomes quite high in comparison to that required for a system pressurized with oxygen alone, since in the latter case, the off-gas volume may be reduced by burning off the oxygen. Even though the adsorption coefficient for krypton and xenon is higher by a factor of two with the helium as the carrier gas rather than oxygen, this factor is more than offset by the increased amount of gas that must pass through the charcoal bed. As an alternate to the use of large charcoal beds, a compressor might be used to compress the gases for re-use or storage until decay has taken place; in this case the oxygen might be burned off to decrease the storage volume.

Since the percentage of oxygen in the pressurizing gas will probably be above 20%, it appears that the use of the inert gas will not greatly change the explosion hazard. There is still a considerable excess of oxygen present, and if 2 or 3% deuterium should accumulate in the vapor space, the explosion hazard would still exist.

Helium appears more desirable than argon as a pressurizing gas because of its lower cross-section. Although there is no readily-available data on the solubility of argon above 100°C, it also appears that helium is probably less soluble than argon.

Method of Calculation

Two basic assumptions were made in arriving at the curves in Figure 1:

1. A state of equilibrium is reached in the pressurizer between the gas and the liquid.
2. The deuterium has all recombined before it reaches the pressurizer, and hence the deuterium partial pressure in the pressurizer is zero.

An example of one set of operating conditions follows:

Assuming a deuterium formation rate in the core, which is the maximum in the system, of 5.13×10^{-5} g moles D₂/sec per mole solution,⁽¹⁾ and a CuSO₄ concentration of 0.03 g moles Cu/liter⁽¹⁾, let:

(1) "Preliminary HRE-3 Design Data," CF 57-11-74, November 29, 1957.

x = Cu concentration, g moles Cu/liter solution
 y = mole fraction D_2 in the solution in the core
 V = D_2 production rate, moles D_2 /mole solution per sec.
 k = recombination rate = 0.972 liters solution/g mole Cu per sec. (2)

then:

$$y_{\max} = \frac{V}{kx} = \frac{5.13 \times 10^{-5}}{0.972 \times 0.03} = 1.76 \times 10^{-3} \text{ g moles } D_2/\text{mole solution}$$

If a design value of 100% excess oxygen in solution is arbitrarily taken, and assuming all the radiolytic D_2 has been completely recombined before reaching the pressurizer, the required oxygen concentration in the pressurizer is $y_{\max}/2$. Further, assuming that the pressurizer is under equilibrium conditions at 300°C, and using a Henry's Law constant of 2.0×10^5 psi/mole-fraction O_2 in solution, the required partial pressure of O_2 in the pressurizer is:

$$p_{O_2} = \frac{1.76 \times 10^{-3}}{2} \times 2.0 \times 10^5 = 176 \text{ psi}$$

The required inert gas partial pressure at 1500 psia total system pressure is then:

$$p_{\text{gas}} = 1500 - p_{O_2} - p_{D_2O} = 54 \text{ psi}$$

The mole percentage of oxygen in the pressurizing inert-gas-oxygen mixture is then about 76.5%. This result could have been obtained from Figure 1 after the required oxygen concentration in the solution and the pressurizer temperature had been established.

If the core and blanket systems were pressurized with a mixture of oxygen and helium of this composition, on a dump, about 0.5 lb moles of oxygen and 0.162 lb moles of helium would be evolved from the contents of the high-pressure core system, and about 1.26 lb moles of oxygen and 0.324 lb moles of helium from the blanket high-pressure system. Thus, about 175 ft³ (STP) of contaminated helium gas would have to be disposed of after the dump.

Figure 1. Required Percentage of Oxygen in the Pressurizing Gas Mixture

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