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SUBJECT: Rates of Corrosion Product Removal from Circulating System by Film Formation and Settling

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FROM: J. C. Suddath

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ABSTRACT

Iron oxide deposits removed from high pressure system of HRT after the first power run will be analyzed for Fe-59 in an attempt to determine the time these deposits were circulated prior to deposition (settling or film formation). Deposits available are (1) film from corrosion specimens (stainless steel, zirconium and titanium) and (2) settled particles.

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The rate of solids removal by the hydroclone in the HRT is expected to be small compared to the rates of removal of suspended solids by deposition and settling. This is based on observations of experimental loops.

In the HRT system, as well as in the experimental loops, solids have been found both as settled particles and as adhering deposits on corrosion coupons. It is therefore obvious that some of the corrosion products are in suspension for some finite period of time. The design of an effective solids collector requires a knowledge of the time of suspension.

Fe^{58} , from corrosion of the stainless reactor system, circulating with the fuel through the high flux region of the core, will capture neutrons and form Fe^{59} (half-life 46 days). The amount of Fe^{59} formed will be commensurate with the time of exposure to the neutron flux in the core. The ratio of Fe^{59} to Fe^{58} deposits, and in the settled particles, will be indicative of the average circulation time of these materials.

Samples of film material from corrosion coupons (zirconium, titanium, and stainless steel), and samples of settled particles collected from quiescent regions of the reactor system, are available for Fe^{59} and Fe^{58} analysis. The average time of circulation may be computed from the following equation:

$$t = \frac{A_T}{2.53 \times 10^3} - 62$$

where

t = average time iron was circulating (sec)

A_T = activity of Fe^{59} ($\frac{\text{dis/min}}{\text{gm total Fe}}$)

Appendix

The activity of Fe^{59} in deposited material will be determined, and back-calculated to the time of power run. Since the total time of operation is short compared to half-life of Fe^{59} , a midpoint of the run should be a satisfactory time; that is, decay during the run may be ignored. The specific activity (as back-calculated) will be indicative of the period of time that the material circulated plus the time of exposure to the delayed flux in the external loop.

Owing to circulation of Fe through the core flux,

$$A_o = \frac{\text{dis/sec of Fe}^{59}}{\text{gm Fe}} \quad \text{with no decay time}$$

$$A_o = \lambda^{59} N_o \quad \text{where } N_o = \frac{\text{atoms Fe}^{59} \text{ produced}}{\text{gm Fe}}$$

$$N_o = \sigma^{58} \phi \frac{N^{58}}{M_{\text{Fe}}} t$$

$$\sigma^{58} = 2.5 \times 10^{-24}$$

t = average time material circulates

$$\phi \approx 3 \times 10^{12} \text{ n/cm}^2\text{-sec at 0.4 Mw (average over high pressure system)}$$

$$\frac{N^{58}}{M^{Fe}} = \frac{0.0031 \text{ gm Fe}^{58}}{\text{gm Fe}} \times \frac{0.6023 \times 10^{24} \text{ atoms Fe}^{58}}{58 \text{ gms Fe}^{58}} = 3.22 \times 10^{19} \frac{\text{atom Fe}^{58}}{\text{gm Fe}}$$

$$N_o = (2.5 \times 3 \times 3.22 \times 10^7 \frac{\text{atoms}}{\text{gm sec}}) t$$

$$A_o = \lambda N_o = (1.744 \times 10^{-7} \frac{\text{dis/sec}}{\text{atom}}) (24.15 \times 10^7 \frac{\text{atoms}}{\text{gm sec}} \times t) = (42.1 \frac{\text{dis/sec}}{\text{sec}}) t/\text{gm}$$

$$A_o = (42.1)(t) \frac{\text{dis/sec}}{\text{gm sec}}$$

Fe^{59} activity from delayed neutrons alone, A'_o is,

$$A'_o = 1.4 \times 10^{-11} \phi_d \tau_d (\frac{\text{dis/sec}}{\text{gm}}) \text{ where } \phi_d = \text{n/cm}^2\text{-sec } \tau_d = \text{sec of power oper.}$$

ϕ_d = thermal neutron flux in loop due to delayed neutrons

$$\phi_d = (1 - \alpha)(0.0075) k \phi_c \quad (\text{average over loop})$$

ϕ_c = thermal flux in core

α = fraction of delayed born in core region ≈ 0.70

$$k = \frac{\text{self absorption in loop}}{\text{self absorption in core}} \approx \frac{1 + (MB_c)^2}{1 + (MB_L)^2} \approx 0.03$$

$$\phi_d = (0.30)(0.0075)(0.03) \phi_c = 0.675 \times 10^{-4} \phi_c$$

$$\phi_c = 2.14 \phi$$

$$\phi_d = 1.44 \times 10^{-4} \phi = (1.44 \times 10^{-4})(3 \times 10^{12}) = 4.33 \times 10^8 \text{ n/cm}^2\text{-sec}$$

$$A_o' \approx (1.4 \times 10^{-11})(4.33 \times 10^8)(5 \times 24 \times 3600 \text{ sec}) \approx 2.62 \times 10^3 \frac{\text{dis/sec}}{\text{gm}}$$

$$A_T = A_o + A_o' = (42.1 t + 2.62 \times 10^3) \frac{\text{dis/sec}}{\text{gm}} \quad \text{where } t = \text{cir. sec}$$

$$A_T = 42.1 (t + 62 \text{ sec}) \frac{\text{dis/sec}}{\text{gm}} \quad (\text{average over loop})$$

$$A_T = 2.526 \times 10^3 (t + 62 \text{ sec}) \frac{\text{dis/min}}{\text{gm}}$$

Estimation of k

$$k \approx \frac{P_{NL}(\text{loop})}{P_{NL}(\text{core})}$$

$$P_{NL} \approx \frac{1}{1 + (MB)^2} \quad P_{NL}(\text{core}) = \frac{1}{k_{\infty}} \approx \frac{1}{2}$$

$$M^2 \approx \frac{1}{B^2(\text{core})} \approx 290 \text{ cm}^2$$

$$B^2(\text{loop}) \approx \left(\frac{2.405}{2 \times 2.54} \right)^2 \approx 0.224 \text{ for } 4" \text{ D pipe}$$

$$P_{NL}(\text{loop}) = \frac{1}{1 + (290)(0.224)} = \frac{1}{66} = 0.01515$$

$$k = \frac{0.01515}{0.5} \approx 0.03$$

Estimate of ϕ

ϕ = average thermal flux over entire circulating system

Average power $\approx 0.4 \text{ Mw}$

$$0.4 \times 3.38 \times 10^{16} = (350 \times 10^{-24}) \left(\frac{0.6023 \times 10^{24}}{235} \right) (5000) \phi$$

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$$\phi = \frac{(0.4)(3.38)(235)}{(350)(0.6023)(5000)} \times 10^{16} = \frac{317.7}{1.06 \times 10^6} \times 10^{16}$$

$$\phi = 3 \times 10^{12} \text{ n/cm}^2\text{-sec}$$

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