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POST OFFICE BOX P
OAK RIDGE, TENNESSEE

ORNL
CENTRAL FILES NUMBER

CF-56-4-66

DATE: April 11, 1956

SUBJECT: HRT Fuel Concentration as a Function of
Poison Level

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APR 19 1956

Distribution

Distribution see page 2

Photostat Price \$ 1.80

Microfilm Price \$ 1.80

Available from the
Office of Technical Services
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Washington 25, D. C.

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592 001

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3.

HRT FUEL CONCENTRATION AS A FUNCTION OF POISON LEVEL

by

C. W. Nestor, Jr. and P. R. Kasten

Summary

Placing corrosion specimens within the core region will increase the fuel concentration required for criticality, due to the neutron poisoning effect of the specimens and their holders. Calculations based upon a preliminary coupon holder design indicate that the poisoning effect will be less than about 11% poisons. This maximum poisoning would increase the core critical concentration by $\sim 23\%$ at 280°C (from ~ 7.1 gm 25/kg D_2O to ~ 8.7 gm 25/kg D_2O). all

Introduction

The amount of neutron poisoning introduced by corrosion samples and their holders is dependent upon the volume of metal, position, and material used. Tentative plans* for a corrosion specimen holder call for a titanium metal pipe inserted into the core region, with a specimen holder made of titanium attached to this pipe. The pipe had a metal cross-sectional area of about 1 sq. in, and the specimens and holder had a combined metal cross-sectional area of about 2 sq. in.

The pipe would have an effective length of ~ 1 foot when exposed to neutrons of average importance. The holder and specimens were considered to have a length of 1 foot and exposed to neutrons of maximum importance. Under the above conditions, there would be ~ 0.21 and 0.42 liters of metal exposed to neutrons of average and maximum importance, respectively.

*R. H. Chapman - personal communication

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592 002

Results

For the nuclear calculations, poison was considered to be added uniformly to the core of the HRT. Two group calculations were done, which appears to be an adequate treatment based on some multigroup results.* The results of these calculations are given in Figure 1 which gives core fuel concentration as a function of average core poison fraction (poison fraction based on fission cross section). The nuclear values used in the calculation are given in the Appendix. As given in Figure 1, increasing the core poison fraction from zero to 10% increases the critical concentration by $\sim 20\%$ (from 6.7 to 8.0 gms $^{25}\text{D}_2\text{O}$).

In applying the above results, the corrosion samples and their holder were "homogenized," and then weighted by the importance function according to the location of the metal. If all the metal were titanium, there would be ~ 2830 gm Ti present. This would correspond to $\sim 11.6 \frac{\text{gm Ti}}{\text{kg D}_2\text{O}}$, which would be equivalent to $\sim 8.3\%$ poison if the Ti were uniformly distributed. Since the importance of neutrons at the center of the core is ~ 1.5 times their average importance,** the metal would be equivalent to about 11% poison distributed uniformly. However, the above assumed all metal to be titanium, which has a relatively high thermal absorption cross section. If the metal were all stainless steel, the equivalent uniform poison fraction would be $\sim 6.8\%$; use of Zr would further reduce the poisoning effect.

* C. W. Nestor, Jr., HRP Quarterly Progress Report, ORNL 2057, pp 66-68

** M. C. Edlund and P. M. Wood, Phys. of HRT: Statics, ORNL 1780, p 30

Figure 1
Critical Concentration Required
in HRT as a function of Core
Poison Level

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592 004

As seen from Fig. 1, increasing the poison fraction from 0 to 11% and from 0 to 7% will increase the critical fuel concentration by about 23 and 13%, respectively. However, even with 11% poisons, the critical concentration appears to be less than 9 gm 25/kg D₂O.

Discussion

The critical mass calculations considered that $\eta(25)$ was independent of the neutron energy. If an appreciable number of fissions occurred at energies in the resonance region, the critical mass would increase to some extent, since $\eta(25)$ is $\sim 1.6-1.8$ in the resonance region.* A guess, based on some multigroup calculations by Safonov** would be that $\sim 20 - 30\%$ of the fissions could be caused by neutrons of above thermal energy. This would result in critical concentrations of $\sim 3.5 - 9.5\%$ higher than given above. Even with the above correction, the critical concentration would not exceed 10 gm 25/kg D₂O, with 11% poisons present.

* S. Oleksa - Nuclear Science and Technology, Vol. 1, No. 3, June 1955, pp 275-290

** G. Safonov - Nuclear Science and Technology, Vol. 1, No. 4, October 1955, pp 361 - 380

APPENDIX

DATA USED IN NUCLEAR CALCULATIONS

HRT dimensions

Core ID- 32"
 a Core radius 16" = 40.6401 cm
 Blanket ID- 60"
 Blanket radius 30" = 76.2003 cm
 t Shell thickness 1/4" = 0.635003 cm
 T_B Blanket thickness 13 3/4" = 34.9251 cm

HRT soup composition

25 fuel
 99.75% D₂O moderator
 0.005 gm moles CuSO₄/kg D₂O } core
 99.75% D₂O
 0.00004 gm moles Cu SO₄/kg D₂O } reflector
 Mean temperature = 280°C; $\rho_{D_2O} = 0.8395 \text{ gms/cm}^3$

Nuclear data

99.75% D₂O at 280°C:

$$\tau = 195 \text{ cm}^2$$

$$D_1 = 1.67 \text{ cm}$$

$$D_2 = 1.23 \text{ cm}$$

$$\Sigma_a = 5.277 \times 10^{-5} \text{ cm}^{-1}$$

$$\sigma_a^D = 0.316 \times 10^{-3} \text{ bn}$$

$$\sigma_a^H = 0.213 \text{ bn}$$

$$\sigma_a^{Cu} = 2.38 \text{ bn}$$

$$\sigma_a^S = 0.316 \text{ bn}$$

$$\sigma_a^{25} = 424 \text{ bn}$$

$$\eta_{25} = 2.08$$

$$\frac{\sigma_f^{25}}{\sigma_a^{25}} = \frac{1}{1 + \alpha_{25}} = 0.8446$$

averaged over a Maxwellian, assumed $\frac{1}{v}$, from 2200 m/sec values in BNL 325

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592 006