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ZIRPLEX DISSOLUTION OF THE ANNUAL GLADD-
 ING OF SIMULATED POWER FUEL ELEMENTS

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INTRODUCTION

The current interest in a tube-in-tube type Zircaloy-2 clad UO_2 fuel element for use in the power reactors provided the incentive for a study of the dissolution of cladding from an annular space. The objectives of the study were to compare the estimated rate of dissolution in the annuli with rates on fully exposed metal. Because of an interest from the design standpoint, heat balance data from the study are reported.

SUMMARY AND CONCLUSION

The results of a dissolution of unoxidized Zircaloy-2 cladding from simulated power fuel annuli indicate that the decaying of annular fuel elements should proceed uniformly on all surfaces. The maximum dissolution rate of 63 mils per hour and integrated rate of > 15 mils per hour attained during the dissolution in $5.5 \text{ M NH}_4\text{F} - 0.5 \text{ M NH}_4\text{NO}_3$ are equivalent to rates attained during the dissolution of fully exposed Zircaloy-2 in solutions of the same concentration. The 30 - 50 mil cladding was dissolved in less than two and one-half hours exposing essentially all of the simulated core material. The concentration of zirconium in the dissolver solution and the instantaneous dissolution rates are plotted as a function of reaction time in Figure 1.

At a boil-up rate of $0.528 \text{ lb. mol/hr. ft}^2$, a net heat output of approximately $21,000 \text{ BTU/ft}^2$, $140 \text{ K cal/gm. mol.}$ attributed to the heat reaction, was measured during the dissolution. A graph of heat input, heat output, and boil-up rate is given in Figure 2.

DISCUSSION

The simulated power reactor fuel elements were constructed from Zircaloy-2 tubing, 30 - 50 mils thick with an inside diameter of 1.62 inches and uranium rod clad in 32 mil Zircaloy-2 with an outside diameter of 1.1 inches. The rods and tubes were in three foot lengths with the rods spaced inside the tubes by tabs welded to the surface of the rods forming 0.26 inch cylindrical annuli. The outer surface of the tubing was coated with polyvinyl acetate-polyvinyl chloride plastic so that dissolution would occur only on annular cladding.

The dissolution vessel was a vertical tube batch reactor 7.5 inch inside diameter by eight-foot high equipped with a condenser, reflux meter, and water addition line. A steam jacket with an Armstrong steam trap supplied heat to the tube. A perforated basket with a solid bottom plate was used for charging the elements. Because of the solid bottom plate, it was necessary to place the element in the basket at an angle to provide flow access to the annuli. Even with this precaution, the flow access was somewhat restricted.

A solution of $5.5 \text{ M NH}_4\text{F} - 0.5 \text{ M NH}_4\text{NO}_3$ with an F/Zr mole charge ratio of 7 was used to dissolve the cladding from four of the simulated fuels. The solution was heated to boiling in 21 minutes, and the reaction was carried out at the boiling point for 109 minutes using a constant boil-up rate of $0.528 \text{ BTU/hr. ft}^2$. Makeup water was added continuously to replace the condensate which was diverted to

The instantaneous dissolution rates for the reaction were calculated from the slopes on the curve of zirconium concentration in dissolver solution versus time shown in Figure 1. These instantaneous dissolution rates are shown in Figure 1. The integrated dissolution rate could not be determined directly for the reaction because of the non-uniformity of the cladding. However, a comparison of the dissolution curve with other data shows the integrated rate to be > 15 mils per hour.

The heat of reaction was determined for the dissolution by a technique which largely eliminated the heat losses to the atmosphere. Basically, a curve of actual heat input (input losses) to the reaction versus steam jacket pressure was developed prior to the dissolution by a water boil-up calibration. Then the heat input during the dissolution was determined from the jacket steam pressure by use of these data. The output was calculated from the condensate reflux rate, and the dissolver solution and addition water sensible heat requirements for heating from 70° to 216° F. A graph of these data in the form of heat input, heat output, and boil-up rate is given as Figure 2.

The net heat input to the dissolver of $17,850 \text{ BTU/ft}^2$ was required to heat the solution to boiling and maintain a boil-up rate of $0.528 \text{ lb. mol./hr. ft}^2$ during the reaction. The calculated heat output was $20,706 \text{ BTU/ft}^2$ with the heat of reaction supplying the extra heat. The heat of reaction from steady state portions of the reaction cycle was determined to be approximately $-140 \text{ K Cal/gm. mol}$.

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Figure 1

Figure 2