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IMPROVEMENTS IN THE HOT PRESS PROCESS

J. C. TVERBERG

APRIL 1, 1959

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ABSTRACT

The hot press process has been altered so as to eliminate the slight wrinkling near the ID base. This was done by incorporating a three minute time delay in the pressing cycle. The pressing time was decreased to five minutes to restrict formation of the brittle inter-metallic compound, Ni_2Al_3 .

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IMPROVEMENTS IN THE HOT PRESS PROCESS

INTRODUCTION

Initial evaluation of hot-pressed fuel elements was rather discouraging due to their relatively poor in-reactor performance. A concerted effort was then made to improve the process by eliminating many of the undesirable characteristics. ⁽¹⁾ Foremost in the list of improvements was the development of the single-stroke double action hot work punch. ⁽²⁾ However, certain process flaws became evident with the use of this punch. The most serious flaw was a wrinkling of the ID tube near the fuel element base. The wrinkling was not serious, but indicated a process weakness. This wrinkle would result in a statistical number of inferior fuel elements on a production basis. Hot-pressed fuel elements have been shown to be a feasible fuel for the Hanford reactors, ⁽³⁾ as annual savings over \$3, 000, 000 would be realized. Feasibility of hot-pressed fuel elements was also indicated by production test PT-IP-45-A in which the test elements were irradiated to the goal exposures of 400, 600, and 800 MWD/T without incident. A number of these test elements were irradiated with the above mentioned wrinkle. Therefore in preparation for a run-to-rupture production test, an effort was made to eliminate these defects and to make any other needed process improvements.

SUMMARY

A more pronounced wrinkling of the ID tube was observed with a change in component vendors. This was due to the presence of a 1/8-inch by 45 degree chamfer on the base of the newer cans which was not included on the older components. Annealing the components prior to canning, to

1. Foust, W. E., Design of PT-IP-45-A: Irradiation of Fuel Elements Fabricated by the Hot Press Process, HW-48328, February 5, 1957.
2. Foust, W. E., Hot Press Canning at Hanford, HW-48329, February 11, 1957.
3. Blanton, W. A., Study of Potential Incentives for the Hot Press Process, HW-56822, July 18, 1958.

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[REDACTED]

lower the yield strength, proved unsuccessful in removing the fold. An attempt to change the pin coating schedule also proved to be unsuccessful. A small aluminum ring placed in the annulus between the inner and outer base punches corrected the wrinkling effect. This however, added an extra assembly step to the process as well as an additional weld zone. The additional weld zone was of no concern as the weld section was removed in the tru-line machining operation. A controlled time delay between the die seating and the element pressing was also found to remove the fold. A delay of three minutes was sufficient to allow the aluminum to soften to the point where plastic flow would readily occur. Continued investigations proved the pressing time could be reduced to five minutes following the three minute time delay. This investigation not only resulted in a better fuel element, but also represented a net savings of seven minutes in the original pressing cycle.

DISCUSSION

Several of the fuel elements which comprised production test PT-IP-45-A had a slight folding or wrinkling of the aluminum in the ID tube near the base of the element. These folds never exceeded 0.005-inches in depth. Although the wrinkles had no adverse effect on fuel element life during low level irradiation, objectional characteristics could develop during longer exposures.

Aluminum components for the recently fabricated run-to-rupture production test were procured from the Hunter Douglas Aluminum Corporation. Hot press components in the past were supplied by the Aluminum Company of America. An increase in the depth of folding was found on fuel elements fabricated from the newer components. This was caused by the presence of a 1/8-inch by 45 degree bevel on the base of each Hunter Douglas can. Figure 1 illustrates the depth of the deepest fold discovered during destructive testing. Residual aluminum between the wrinkle and weld zone was only 0.024 inches, and between the wrinkle and the uranium core was 0.060 inches.

[REDACTED]

Fold Removal

Each component was prepared for pressing by the process outlined in Figure 2. Only the pressing cycle times were changed. Methods investigated in wrinkle removal were aluminum component annealing, change in pin coating schedule, addition of an aluminum ring to the punch annulus, and a controlled time delay. Each of these methods is described in detail in the following sections.

1. Aluminum Component Annealing

Aluminum components were annealed at 500 degrees Centigrade for 30 minutes, then water quenched. Although this annealing operation lowered the yield strength of the aluminum, the tendency to wrinkle remained unchanged.

2. Change of Pin Coating Schedule

Pin lubricant was often found embedded in the folded portion of the fuel element. Presence of this lubricant indicated that the excess lubricant had been scraped from the pin during assembly, then deposited near the base of the element. This lubricant prevented the folds from welding together, and thus caused the deep wrinkle. To eliminate excess lubricant on the pins, the following lubrication schedule was investigated: freshly coated; one pressing after coating; and two pressings after coating. Fuel elements were assembled with these pins and pressed for 15 minutes at a temperature of 600 degrees Centigrade and a pressure of 12 tons per square inch. No beneficial effect on fold removal was found from this schedule change. Also, difficulty was encountered during the removal of the pin from the element assembled with the schedule of two pressings after pin coating.

3. Aluminum Ring Addition

Examination of the assembled base punches revealed an annulus between the inner and outer punches. Sudden application of pressure would cause the can base and tube to collapse into the annulus, and with further

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pressing, to form a fold. Collapse of the can base and tube could be prevented if an aluminum ring was placed in the punch annulus as illustrated in Figure 3. Components assembled with this ring were hot pressed for 15 minutes at a pressure of 12 tons per square inch and a temperature of 600 degrees Centigrade. The aluminum ring corrected the folding to the extent shown in Figure 4. The kidney shaped weld zone pictured in Figure 5 was a consequence of the addition of extra metal to the fuel element base. This added weld zone would normally be removed during machining of the tru-line feature. Although complete fold removal was not accomplished, the severity of the folding was reduced considerably. However, positioning of the aluminum rings added an extra assembly step.

4. Time Delay

Aluminum will flow plastically if heated to a temperature of 600 degrees Centigrade prior to application of pressure. A controlled time delay between die seating and hot pressing was the easiest method of obtaining this flow. Time delay conditions ranging from one to three minutes were investigated. A one minute time lag appeared to have no effect on wrinkle formation. However, a two minute delay decreased the fold depth to the extent pictured in Figure 6. Wrinkle effect on the tube cross section is illustrated in Figure 7. When the time delay was increased to three minutes, the fold was completely eliminated as indicated by Figure 8. Figure 9 illustrates the complete absence of the ID tube fold which resulted from the three minute time delay. In view of this evidence, the three minute time lag was adopted. However, as the time lag between the die seating and the element pressing was increased, a corresponding increase in aluminum grain size was observed.

Development of Pressing Time

The effect of pressing time on the formation of the brittle Ni_2Al_3 intermetallic compound was investigated following the successful fold elimination. Incorporating the three minute time lag, pressing time of

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nine, seven, five and three minutes were investigated. The nine minute pressing time yielded the rather heavy layer of intermetallic compound pictured in Figure 10. Pressing for seven minutes resulted in a somewhat thinner Ni_2Al_3 layer as depicted in Figure 11. A five minute pressing time resulted in the extremely thin brittle intermetallic zone illustrated in Figure 12. This pressing time appeared to be short enough to restrict the brittle intermetallic compound formation. A three minute pressing time produced the diffusion zone pictured in Figure 13. Although the structure appeared to be bonded and the intermetallic compound was essentially non-existent, the three minute pressing time was not used as the compound zone did not meet the accepted process specifications.

This procedure was developed for the aluminum can design which incorporated a 1/8 inch by 45 degree bevel on the base. If future operations involved cans without this bevel, the process should be reinvestigated to determine optimum operating conditions.

[REDACTED]

FIGURE 1

Depth of ID tube fold. The opening comes to within 0.024-inch of the weld interface and 0.060-inch of the uranium core. 12-1/2 X

Uranium Core

Statistical Inspection
 Transformation Test
 Vacuum Outgas
 Vapor Degrease
 Nitric Acid Deoxidation
 Tap-Water Rinse
 Electrolytic Etch
 Water Rinse
 Nitric Acid Etch Coat Removal
 Dip Rinse Tap Water
 Spray Rinse Deionized Water
 Nickel Plate
 Rinse in Tap Water
 Spray Rinse in Deionized Water
 Dip Rinse Hot Deionized Water
 Dry

Cap-Tube & Can

Statistical Inspection
 Clean and Deoxidize
 Vapor Degrease
 Water Rinse
 Caustic Etch
 Water Rinse
 Diversy Deoxidation
 Water Rinse
 Rinse
 Acetone Dehydration
 Dry (10 Min. Maximum
 Time in Air)

FIGURE 2
Hot Press Flow Diagram

FIGURE 3

Cross Sectional View of Components Assembled for Pressing.
The aluminum ring was not used in the final production test.

FIGURE 4

Base section of hot pressed fuel element, pressed with aluminum ring in punch annulus. Pressing conditions were 600 degrees Centigrade, pressure of 12 tons per square inch and a time of 15 minutes. 12-1/2 X

FIGURE 5

Cross section of hot pressed fuel element base. Kidney shaped weld zones are the result of the added aluminum ring. 4 X

FIGURE 6

Base weld resulting from a two minute time delay, 13 minute pressing time at a pressure of 12 tons per square inch, and a temperature of 600 degrees Centigrade. 12-1/2 X

FIGURE 7

Appearance of fuel element base showing the extent of folding after a two minute time delay. Pressing conditions are the same as in Figure 6.

FIGURE 8

Base weld zone resulting from a three minute time delay, 12 minute pressing time at a temperature of 600 degrees Centigrade and a pressure of 12 tons per square inch.

12-1/2 X

FIGURE 9

Appearance of fuel element base resulting from a three minute time delay. Pressing conditions are the same as in Figure 8. Notice the complete absence of the fold

4 X

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FIGURE 10

Diffusion zone resulting from a nine minute pressing time following the three minute time delay. Pressing temperature was 600 degrees Centigrade and the pressure was 12 tons per square inch. Sample taken from the center ID of the fuel element. 250 X

FIGURE 11

Diffusion weld zone resulting from a seven minute pressing time after a three minute time delay. Pressing conditions were the same as in Figure 10. Sample taken from the center ID of the fuel element. 250X

FIGURE 12

Diffusion zone resulting from a five minute pressing time after a three minute time delay. Pressing conditions are the same as in Figure 10. Sample taken from the center OD of the fuel element. 250 X

FIGURE 13

Diffusion zone resulting from a three minute pressing time following a three minute time delay. Pressing conditions were the same as in Figure 10. Sample taken from the base ID of the fuel element. 250 X

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