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PROGRESS REPORT FOR THE PROJECTION WELDED BRAZED CLOSURE

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WELDED BRAZED CLOSURE

L. R. Vancott

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PROGRESS REPORT FOR THE PROJECTION

WELDED BRAZED CLOSURE

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Introduction

This report covers progress on the Projection Welded Brazed Closure following the work done by P. A. Ard and W. I. Steinkamp which was reported in HW-69592. Their report describes welding studies made on 0.593-inch diameter rod and 1.050-inch OD by 0.500-inch ID tubular fuel. Briefly, conclusions of the report were:

1. Zircaloy to Zircaloy projection welds on 0.593-inch diameter rods withstand long term autoclave tests without corroding.
2. Microphotographs show complete fusion of the projection weld.
3. Closures on tubular elements, 1.050-inch OD by 0.500-inch ID, appeared to be feasible; however, a machine with greater force and current capacity was required. A definite interface extended across the width of the Zircaloy to Zircaloy joint.
4. Caps were completely bonded to the uranium surface by several brazing alloys. A thin copper plating on the cap yielded the best bond.

Tooling and Equipment

In order to continue the investigation of the Projection Welded Brazed Closure on NPR inner fuel, a 600 KVA machine was purchased and installed in October 1962 (Figure 3).

Tooling similar to that used on the 100 KVA welder was scaled up to accommodate NPR inner fuel (1.255-inch OD by 0.428-inch ID) on the 600 KVA welder. Initial weld tests utilizing the scaled up tooling showed that the higher welding currents necessary on N inner fuel entered the OD fuel cladding at the top of the holding collet and caused cladding upset.

The scaled-up segmented collet, Figure 1, adequately positions the fuel but as current enters the collet jaws it "sees" high resistance in the fuel piece and low resistance in the copper jaws. Consequently, all welding current travels the full length of the copper jaws and is forced to enter the fuel at the top of the collet. This highly concentrated current path causes excessive over-heating on the cladding surface and results in cladding upset at the top of the collet jaws.

Figure 2 shows a new collet that eliminates current concentration at the top of the collet by evenly distributing current over the full contacting surface between the collet and fuel element. The collet consists of an assembly of washers (wafers) stacked to form a hollow cone, tapered on the OD. Each wafer is radially split to provide flexibility for clamping and to compensate for variation in work diameter. Material in the wafer stack is selected by its

resistivity properties; i.e., the material with the lowest electrical resistance is used for the bottom wafer or wafers. The resistance gradient is adjusted within the wafer stack such that the resistance of the top two wafers is higher than that of the fuel element. Resistance is also increased from wafer to wafer by the phenomenon of interface resistance. The results are graphically shown in the inset, Figure 3.

Figure 4 shows the wafer collet with the clamping nut removed. Also included in the picture is an as-welded test specimen and the containing ring and plug. The OD containing ring is high density aluminum oxide with a T-1 steel retaining band that is shrunk fit to provide tensile strength. The ID containing plug is 304-L stainless steel that is coated with Electro-Plate 1000. Aluminum oxide and Electro-Plate 1000 are used as insulators to prevent shunting through the containers during welding.

Cap and Fuel Preparation

Fuel specimens are prepared by cutting the fuel to length, and then acid milling uranium from the ends to expose 0.025-inch of Zircaloy cladding, Figure 5. Earlier welding studies used a flat interface between Zircaloy cap and uranium; however, this was changed to a wedge type interface to produce transverse and longitudinal shear stress on the bond rather than all transverse. (See illustration A and B, Figure 6.) The groove in the fuel is machined after acid milling.

Originally the weld samples, both caps and fuel, had a wide dimensional variation which caused excessive uranium movement around the end cap wedge and resulted in uneven copper alloying between the Zircaloy end cap and uranium. Form tools were employed for machining end caps and a tool positioning fixture was used to locate the cutting tool for machining the uranium groove. The form tool and tool positioning fixture allowed parts to be machined in separate shops without difficulty of final assembly.

Result and Discussion of Closure Studies

Relationship of Machine Variables

Tests began with end caps shown in Figure 6-B and fuel as shown in Figure 5 with 0.025-inch acid milling depth and 0.155 groove depth. The intent of the first tests was to establish the relationship between time, temperature, and pressure for this particular joint configuration. Numerous tests were made over a wide range of settings to establish limits for each machine variable.

The conclusions of these tests were:

1. Bonding occurs readily at forge pressures over 5000 pounds. Heating rates or duration of heating cycle have little effect on the diffusion depth of copper. Uniform bonding occurred at both high current levels for a short period or low current for a long period. (The difference between a long period and a short period is on the order of 30 cycles at 60 cycle/sec frequency.)

2. Fusion between the Zirc cap and Zirc clad on the OD required current phase shift settings of 74 to 80% of machine capacity. (Phase shift controls the magnitude of welding current and is calibrated in percent of machine capacity.) OD welds within this phase shift range were insensitive to other machine variables such as pressure, cool time, quench, forge delay, etc. Figure 7 shows complete fusion on the OD welds. Phase shift settings that produced good OD welds caused expulsion of the ID welds. Figure 8 shows a typical ID weld. The maximum weld phase shift that would not cause expulsion of the ID was 70%; however, at 70% neither the ID or OD fused.

The problem of obtaining an OD weld and no ID weld is a difference in heating rates between the two projections. The width of the ID projection is 0.030-inch and the width of OD projection is 0.045-inch. The difference in contact width and volume of metal in the projection causes the heating rate of the ID projection to be faster than the heating rate of the OD projection. Because the OD projection heats slower and upsets slower it retards the follow-up rate needed on the ID. Actually, the ID weld reaches fusion conditions but lacks sufficient pressure or follow-up to complete the weld. The OD weld reaches fusion temperature and has sufficient follow-up to produce a weld shown in Figure 7.

Heat Balance

The weld tests just described were made with a flat electrode that uniformly contacted the entire cap surface. Concave electrodes were used to concentrate welding current at the OD projection before cap deformation takes place. The concave electrode provides a shorter initial current path through the OD projection prior to deformation; however, this did not significantly help the heat balance problem.

The OD cap projection width was reduced by tapering the projection on a series of caps to various widths, 0.005-inch, 0.010-inch, and 0.015-inch. (See Figure 5-C.)

Weld tests on the modified caps were simplified by removing the wedge portion of the cap to eliminate any possibility of interference from premature uranium contact. With the wedge removed the joint may be visualized as butt welding two tubes together in a single operation.

Tests on the modified cap showed that with 0.005-inch wide OD projections the heating rate of the ID and OD was quite even. This was observed at phase shift settings below 70%. Figure 9 is a macrophotograph at 68%. Very little fusion occurred on the 68% samples; however, the interfaces are similar and the upset is uniform.

To further increase the heating rate of the OD projection more of the projection was removed as shown in Figure 5-D. The benefits between the tapered and stepped projection was very slight.

Conclusion

The primary difficulty in producing a reactor grade Projection Welded Braze Closure is making the ID cap to clad weld. The barrier between the ID and OD

weld is heat balance. A better heat balance may be obtained by further investigation of the effects of changes in joint design and investigation of the effects of removing magnetic material from the weld area which may have been introducing variables in current flow and distribution.

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LIST OF FIGURES

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1. Segmented Collet
2. Wafer Collet
3. 600 KVA Welder
4. Collet Fuel and Containers
5. Fuel Configuration
6. Evaluation of End Caps
7. OD Projection Weld at 74% Phase Shift 50X
8. ID Projection Weld at 74% Phase Shift 50X
9. Weld Cross Section at 68% Phase Shift, 0.005 Wide OD Projection 10X

FIGURE 1
STANDARD SEGMENTED
COLLET

FIGURE 2
WAFER COLLET
CURRENT DENSITY ADJUSTER

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FIGURE 3

Resistance Welding Machine and Samples

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FIGURE 4

Waffer Collet, Fuel Specimen, Containing Ring, and Plug

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FIGURE 5

Fuel Preparation

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FIGURE 6

Evolution of Projection Welded-Brazed Closure Caps

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Polarized Light (50X)

Bright Field (50X)

FIGURE 7

O.D. Projection Weld at 74% Phase Shift

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Polarized Light 50X

FIGURE 8

I.D. Projection Weld at 74% Phase Shift

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FIGURE 9

Projection Welds at 68% Phase Shift
(.045" OD Clad by 0.030 ID Clad) (1.249 OD x 0.431" ID)
Bright Field 10X

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