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SEAM-WELDED TUBULAR FUEL ELEMENTS FOR USE IN CP-5

by

L. C. Hymes

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Metallurgy Division

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INTRODUCTION

Operation of the CP-5 reactor at Argonne National Laboratory was scheduled to be suspended in November 1958 to allow alterations to be made to increase the rated output of the reactor to 10 megawatts.

The need arose for a small amount of additional fuel to maintain the reactor in operating status from September 1, 1958 until the scheduled shutdown date.

Because the time available was not enough to complete the development of a cermet tubular fuel element which was underway, it was decided to adapt the Argonne Low Power Reactor (ALPR) fuel plates for this purpose. Much of the material necessary for production of fuel elements using the ALPR cores was readily at hand. All that was necessary was a means of adapting the flat plates to be used as tubular fuel elements. This was accomplished by introducing a cross rolling step in the ALPR rolling schedule, to obtain the necessary core width, and roll forming tubes from these plates. These roll-formed and seam-welded fuel elements were to be placed in the center of the fuel element subassemblies already in the reactor. When this was done, the additional tubes occupied the position normally employed for placement of samples for irradiation.

MANUFACTURING PROCEDURE

Core Material

Core blanks used were punched from plates rolled from Al-17.5 w/o U-2 w/o Ni vacuum castings. The uranium was highly enriched (92.3% U^{235}). The total U^{235} content of the eight cores used is presented in Table I.

Table I

U^{235} CONTENT AND CORE LENGTH OF SEAM WELDED TUBULAR FUEL ELEMENTS

Tube No	Core No	U^{235} (gm)	Core Length as Drawn (in)	Tube No	Core No	U^{235} (gm)	Core Length as Drawn (in)
1	A68-10	39.7	26 1/2	5	A62-17	40.4	26-7/16
2	A66-11	39.8	26-3/8	6	A60-5	40.4	26
3	A63-12	40.5	26 1/4	7	A52-17	40.5	26 1/8
4	A62-18	40.4	26 3/16	8	A50-9	40.4	25 7/8

Composites

The picture-framed composites of core blank and cladding were produced in the manner developed for and used in the production of fuel for the ALPR reactor. In essence, the core is clad in a picture frame of X8001 aluminum alloy by means of the silicon-bonding process developed by Noland and Walker.⁽¹⁾ The outside dimensions of the composite are 6 in. long x $9\frac{1}{2}$ in. wide x 0.472 in. thick. The core blank itself is 6.875 in. long x 3.313 in. wide x 0.200 in. thick. The composites are machined at the outer edges after silicon bonding to remove AlSi squeezed out during the hot pressure-bonding operation. All the core blanks and components used in producing the composites were nondestructively tested according to the procedure used for the ALPR fuel and components.⁽²⁾

Rolling

In order to obtain a finished tube with the desired diameter, a rolling schedule which incorporated cross rolling of the composites had to be used. Several composites containing normal uranium were carried through this procedure to determine the exact schedule to be used.

Use of the composites without cross rolling was attempted initially. This entailed expansion of the tubes which were roll formed and welded from these plates. The expansion of the tube and subsequent reduction in wall thickness proved to be an excessive amount of cold working and resulted in failure of the tubes in the drawing operation. Because of this, the method was abandoned.

The rolling schedule used to obtain the width and subsequent diameter desired is included in the flow sheet presented as Table II. The plates were preheated for one hour at 550°C prior to rolling and were reheated for 10 min. between each hot roll pass.

The plates in the as-rolled condition had a total thickness of 0.079 in. This was made up of 0.023-in. clad, 0.033-in. core and 0.023-in. clad.

Inspection and Shearing Prior to Roll Forming

After rolling, the plates were blister annealed at 550°C for one hour and visually inspected for blisters. They were then roller leveled and subjected to inspection by an ultrasonic technique using through transmission.⁽²⁾ Of the eight plates produced, three showed slight indications of nonbond near the extreme ends in the area beyond the core and outside the useful plate area. These were correlated with light blisters found in the visual inspection. These areas were removed in subsequent shearing operations, and further testing revealed no remaining flaws.

Table II

FLOW SHEET - PRODUCTION OF CP-5 SEAM-WELDED TUBULAR ELEMENTS

1. Assemble compacts by silicon pressure bonding.
2. Machine compacts.
3. Hot roll compacts using following schedule:

1st pass	0.348 in. Cross
2nd pass	0.280 in. Cross
3rd pass	0.233 in. Longitudinal
4th pass	0.130 in. Longitudinal
5th pass	0.088 in. Longitudinal
Cold Finish	0.079 in. Longitudinal
4. Blister anneal for 1 hour at 550°C.
5. Inspection, visual and ultrasonic.
6. Radiograph.
7. Shear to desired width.
8. Roll form tubes.
9. Seam weld tubes.
10. Anneal, 1 hour at 550°C.
11. Weld 12 in. lead to one end of tube.
12. Size tubes on draw bench.
13. Radiograph.
14. Machine to length.
15. Assemble fuel, bottom end cone, and handle.

Each plate was radiographed in order to locate the exact position of the core. Accurate location of the core was necessary to facilitate shearing to the exact dimensions required while maintaining enough aluminum at the edges to permit a seal weld. The individual core widths were found to range from $5\frac{20}{32}$ in. to $5\frac{25}{32}$ in., whereas the core lengths were $23\frac{1}{2}$ in. to $24\frac{3}{8}$ in. This variation in core length was a result of the out-of-square condition of the ends of the cores which apparently occurred as a result of cross rolling.

The plates were sheared so as to leave $\frac{1}{8}$ in. of aluminum at each edge of the core and the ends were sheared square. Approximately 5 in. of aluminum was present at each end of the core at this time, making an overall plate length of 33 in.

Roll Forming and Welding of Tubes

The plates were formed into tubes approximately 2 in. in diameter with the edges butted as indicated in Figure 1. The roll forming was done on a press brake with the aid of rollers to achieve the desired diameter.

Figure 1. Appearance of roll-formed (bottom) and seam-welded (top) fuel tubes prior to draw bench operations.

The tubes were seam welded over the entire length with an inert gas-shielded arc weld. The appearance of the seam weld is illustrated in Figure 1. During welding, the tubes were held in a fixture which kept the edges butted tightly together. A tranverse section of a tube illustrating a typical weld before drawing appears in Figure 2.

After seam welding, the tubes were annealed at 550°C for one hour. A 12-in. length of 2-in.-OD, $\frac{1}{16}$ -in. wall, 2S aluminum tubing was then welded to one end of the roll-formed and seam-welded tube, as illustrated in Figure 3. This was to provide a lead for the tube during the drawing operation.

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Figure 2. Transverse section of fuel tube wall before drawing operation to round out tube, illustrating position of core with respect to seam weld.

Figure 3. Roll-formed and seam-welded fuel tube with aluminum tube attached as lead for draw bench operation.

Sizing of Tubes on Draw Bench

In the as-welded condition, the tubes were slightly elliptical, with major and minor axes of 2.08 in. and 1.88 in., respectively. The desired outside diameter of the finished tube was 1.813 in. This diameter was obtained by a series of two steps on the draw bench. The first step was accomplished using a 1.875-in. die and a 1.717-in. pin. The second draw utilized a 1.813-in. die and a 1.665-in. pin. The final wall thickness of the tube was 0.074 in. These drawing operations raised the weld drop through and resulted in a uniform wall thickness and a round tube.

The tubes were radiographed after drawing to relocate the end of the core. The cores in the tubes as drawn were $25\frac{7}{8}$ in. to $26\frac{7}{16}$ in. long. The core lengths of the individual elements are included in Table I.

Assembly of Completed Fuel Tube

The drawn tubes were machined so as to leave $\frac{3}{4}$ in. of aluminum below the core. They were then faced off to an overall length of 29 in. leaving $1\frac{13}{16}$ to $2\frac{3}{8}$ in. of aluminum above the core.

The fuel-containing tube was then incorporated in an assembly by welding, as illustrated in Figure 4. The overall length of this assembly was $97\frac{19}{32}$ in.

Figure 4. Roll-formed, seam-welded, and drawn tubular fuel elements.

Service

Several of these fuel tubes are in service at this time and are performing satisfactorily. An additional 22 fuel tubes manufactured by the same procedure have been subsequently supplied for use in CP-5.

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