W FILE
RECORD COPY

DPW-54-19-5 - Deleted Version
SRIH--838
[redacted]

REPORT NO. 5

FLAT BONDED FUEL ELEMENTS

Period February 11 - April 10, 1954

Technical Division

DOES NOT CONTAIN
UNCLASSIFIED CONTROLLED
NUCLEAR INFORMATION
Reviewing Official [signature] 4/8/98
T. R. Couchenour, Asst. AED Class Officer

P 8

DECLASSIFIED BY
T. R. COUCHENOUR
ASST AED CLASS. OFFICER
DATE

[redacted]

E. I. du Pont de Nemours & Co. (Inc.)
Explosives Department - Atomic Energy Division
Wilmington, Delaware

[redacted]

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

[redacted]

Report No. 5

FLAT BONDED FUEL ELEMENTS

Period February 11 - April 10, 1954

SUMMARY

A second rolling of conditioned uranium slabs to approximately 183 mils thick strip was carried out at Superior Steel employing conditions expected to avoid the difficulties, particularly surface oxidation and overheating; encountered in the initial August, 1953, rolling. The rolling was largely successful. It reduced the slab to strip under closely controlled, high alpha temperatures with a reduced amount of surface oxidation. In the shearing of the strip, to provide the widths desired for machining to 3-inch wide plate, shear cracking again occurred. Tests with pre-heated strip indicate that shear cracking should be avoidable by carrying out the operation with metal heated to a temperature of at least 100°C. At Atlas Steel Corporation, beta-transformation of long lengths of flats was carried out successfully without significant warp or other adverse dimensional change.

Aluminum components were again delayed. Expected delivery of some of the sheath designs and of the "B" and "C" process tubes did not take place. Results with the long-ordered mandrel extruded smooth sheath continued to prove sufficiently unsatisfactory with respect to surface obtained and dimensional accuracy that it will probably be necessary to abandon the hope of obtaining mandrel-extruded sheaths. Accordingly, particular attention is being paid to obtaining the highest possible quality of aluminum billets to be used in the porthole extrusion of sheaths. Aluminum that is free of oxide and other segregated impurities would be required to avoid inclusions which might penetrate through the sheath, particularly where the metal flows together after leaving the porthole die.

Favorable results obtained in bonding by mechanical hot-pressing and particularly the success with step-pressing have established this as the preferred method for initial use in making long, bonded uranium plates.

[redacted]

I. URANIUM COMPONENTS

A. Metal Supply

A second rolling of uranium slab to flat strips of 183 mils nominal thickness was made at Superior Steel Corporation on February 22 and 23. Conditions were planned to obtain rolling in the high alpha, avoiding the various troubles, such as surface oxide formation and surface cracks, experienced in the first rolling. In general, improvement was experienced and the difficulties of the first rolling were largely avoided.

Fifty-two slabe 1" X 7-15/16" X 72" were heated to approximately 1140°F by average immersion times of 82 minutes in a lithium carbonate-potassium carbonate salt bath held at a temperature of 1150°F. Thirty-five of the slabs were surface conditioned in order to be satisfactory for making strip of the required surface characteristics. The remaining slabs were used to establish operating conditions. Temperatures were closely maintained during the rolling operation in the high alpha with finishing temperatures averaging 1195°F. The average mill through-time from salt bath through the finishing stands was approximately 140 seconds. Reduction from slab to strip was obtained by 5 rough passes and 3 finishing reductions.

Camber for most of the strips was less than 6 inches for the total strip length of 40 - 45 feet. Extreme variation in the thickness of the finished strips was from 182 to 191 mils with most of the strip held within 3 mils of the nominal 183-mil desired thickness. Through eliminating contact with the strip of most of the water from the water-cooled bearings, washing of the lithium-potassium carbonate salt layer from the strip was largely reduced. As a consequence, the uranium oxide layer was decreased and general surface appearance was much better than in the first rolling.

On March 2, thirty-one of the uranium strips rolled at Superior were successfully sheared lengthwise to the 3 plus inch width required for final edge machining. Shearing was performed on a hydraulic shear with a 12-foot blade. Twenty-five of the strips were satisfactory for shearing to obtain the planned two widths per strip. The major defect in the remainder was camber of such magnitude that only one 3-inch width could be secured in the shearing operation. Visual examination of the pieces after shearing showed shear cracks extending up to 1/32-inch from the edge on all pieces examined. A sufficient allowance had been made in the width of the sheared sections to permit machining off the cracks. Shearing of the above pieces was carried out at room temperature. Later shearing experiments carried out at approximately 100°C showed that use of this temperature eliminated the cracks. Employment of this elevated temperature for the shearing operation seems to be entirely practical.

Beta-transformation of 16-foot lengths of strip was carried out at Atlas Steel in a vertical furnace. This procedure for beta transforming long lengths appears entirely satisfactory. The amount of warp or bending was not significant, except in the very ends of the piece. Immersion times involved were of the order of 2 minutes at the longest. Confirmation of the apparently satisfactory transformation will be sought by metallographic examination of sections from the ends of the transformed strips.

B. Uranium Characteristics

As previously reported, metallographic studies have revealed surface layers of large grains, about 0.030 to 0.050 inches deep, in some specimens of as-alpha-rolled uranium plate from the August 3, 1953 Superior rolling. Further study of the 1" X 7" transverse strips in which this anomaly was detected has established that the large grain size layers occur in definitely localized areas or spots of a few inches in diameter. In no case was the whole sample strip covered with the large surface grain layer. The localized nature of the effect indicates that surface oxidation or increased roll friction at spots where the salt coating of the metal was washed off by water on the rolls during rolling may have produced "hot spots" of beta-transformed metal. Lack of cracking in these areas indicates that the over-heating may have occurred just after the plate emerged from the last pass.

II. ALUMINUM COMPONENTS

A. Procurement of Fuel Element Sheaths and of Process Tubes

Delay continues to be experienced with the procurement of the aluminum fuel element sheaths and process tubes. Delivery dates forecast in the previous report would have provided delivery of all items during this report period. However, only the two sizes of ribbed sheaths required for the "B" process tube design were actually delivered. Initial lots of the "B" process tube and of both designs of the "C" process tube are expected to be delivered in the next report period.

Difficulties continue to be experienced in producing by mandrel extrusion the unribbed plain sheath, chosen for evaluation of quality of the sheaths obtainable by mandrel, as against those made by porthole extrusion. The difficulties experienced in obtaining satisfactory surfaces and dimensional tolerances on this item, which has been ordered for more than a year, lead to the present belief that reliance will have to be placed on porthole extrusions. As a consequence, greater attention is being given to the quality of aluminum from which extrusions are made in order to minimize any defects, such as oxide inclusions, at the closures when the metal comes together after going through the porthole die.

B. Attachment of Ribs to Sheathed Fuel Elements

1. Corrosion of Ultrasonically Soldered Aluminum

Aeroprojects' tests of aluminum solders showed that tensile-shear specimens soldered with ternary alloys (approximately 73 Sn-23 Zn-4 Al) consistently retain one-third of their initial tensile strength after 1400 hours exposure to water. Similar specimens failed in less than 500 hours during corrosion tests at the Savannah River Laboratory. Corrosion tests of Aeroprojects' folded-over ultrasonically soldered rib gave poor results at Savannah. Aeroprojects requested the return of all remaining specimens of this type. By contrast with the Savannah results, Battelle experienced no failure in a six-months' test period with similar samples. In view of this evidence that exact corrosion test conditions appear highly important and that various obscure factors may be causing ultrasonically soldered aluminum corrosion failures, attention to this method of attaching ribs to aluminum sheaths is being greatly decreased.

2. Ultrasonic Welding of Aluminum

In contrast with the corrosion results on aluminum pieces fastened by ultrasonic soldering, all corrosion results on pieces fastened by ultrasonic welding have been excellent. The initial difficulties experienced by Aeroprojects in making satisfactory and reproducible welds with the high-power ultrasonic unit required for metal thicknesses and dimensions of the ribs and sheaths have been largely overcome. Initial samples indicate that the welding of ribs to relatively thick gauge composites, such as the clad fuel elements, is feasible.

III. BONDING

The success to date of hot-press bonding and, particularly, the favorable results in step-pressing making possible the bonding of long plates without unwieldy, impractical dies and presses cause this method to be preferred for initial fabrication of the full length pieces for pile use. Although the securing of equipment has prevented attainment of further results on the extrusion ("cable cladding") process of uranium cladding at Battelle during this report period, they will make tests on actual widths and thicknesses of plate in the next month. The method continues to appear attractive as a long-range economical means of providing ribbed and unribbed aluminum claddings for uranium plate.

Quantitative bond strength tests are being run on wrought uranium hot-press clad plates, using a stud welder to attach tensile grips to the clad specimen (see Development of Testing Methods). Preliminary results indicate that bond strengths vary widely from 0 to 35,000 psi. The average value for the U-Ni-Al bonds is about 10,000 psi.

Preliminary evaluation of hot-pressing tests indicate that the use of methanol or similar drying agents in the cleaning procedure for aluminum components is not necessary for obtaining good bonding.

The step-pressing die has been installed with a temporary power source, and has been operated. A preliminary temperature survey using an aluminum blank indicated temperature gradients as high as 100°C from the end to center of the die. The die was dismantled and reassembled to eliminate cam galling.

IV. DEVELOPMENT OF TESTING METHODS

A. Bond Strength Test by Stud Welder Technique

Development of quantitative bonding strength tensile test is proceeding. A stud welder for attaching a pulling stud to a clad surface has been installed, and reproducible welding technique has nearly been achieved. The test results are adequate to start preliminary studies (see Bonding).

B. Grain Size Determination of Wrought Uranium

A pulse-echo type ultrasonic test was developed to determine grain size of wrought uranium. The test, based upon a count of the number of back reflections obtained with 10 megacycle sound using a Sperry

Reflectoscope, is a semi-quantitative one. Although it is influenced by test variables such as temperature, specimen thickness, coupling medium, and the pressure with which the transducer is applied to the metal surface, the test allows one to distinguish easily wrought metal which has been alpha-rolled from the same metal after beta-treatment. This precision is not great enough, however, to allow detection of the surface layers of large grains in as-rolled plate, mentioned earlier.

V. FLAT FUEL ELEMENTS BY POWDER METALLURGY TECHINQUES

A group of twenty powder metallurgy plates, prepared by Sylvania Electric Products, Inc., by hot-press cladding of powder uranium "preforms" is undergoing a schedule of non-destructive and destructive testing.

A. Non-Destructive Tests

Radiography of the plates in the as-received condition indicates the plates are more uniform than the first group of Sylvania plates tested in December and January. The edges of the cores have some small irregularities, up to 10-15 mils in size. The ends of the cores are deformed slightly, and nearly half exhibited corners which were somewhat chipped. In five cases there was a slight non-uniformity in core width. Only three plates had "fish-tail" or "dog-bone" ends, measuring as much as 1/32". While none of the cores was completely straight, only three showed as much as 10 mils camber. Edge cladding thickness varied somewhat, and five plates have inclusions at the end plug-sheath interface.

B. Destructive Testing

A program of destructive testing including metallographic examination of control bonding regions, tensile and fatigue testing of plate assembly complete with welded end fittings, bond strength determination, and determination of core metal density, chemistry, and mechanical properties is under way. Only the results of metallographic examination of a single plate are available, revealing the following features:

1. Porous end-fitting welds (these are Savannah River Laboratory welds).

2. Negligible bonding between sheath and end plug.

3. Core-end plug interface broken and ragged, with jagged edges nearly penetrating the sheath at this point.

[redacted]

4. Core uranium grains are randomly oriented and of 10-15 microns in size.

5. Within the core uranium are large inclusions of foreign material - possibly uranium-nickel or uranium-iron compounds. Spot tests did not indicate the presence of nickel or iron in these places, however, and their true composition is uncertain.

6. Bonding layers of nickel and nickel-uranium between core and sheath vary markedly in thickness, suggesting imprecise temperature control during pressing.

7. Cracks at the uranium-nickel interface are observed.

8. The nickel layer is ruptured in spots, especially at the ragged core-end plug interface, permitting the formation of uranium-aluminum compounds.

C. MTR Irradiation Test

Further irradiation at MTR of the single Sylvania powder metallurgy uranium plate, previously reported as having been discharged after an integrated exposure of 750 MWD/ton, has been deferred until it can be inserted with some of the above pieces to provide a full charge of five plates.

VI. FLAT ELEMENTS PRODUCED FROM WROUGHT URANIUM CORES

A. Fabrication

The fabrication of a group of flat fuel elements with as-alpha-rolled uranium cores was completed and the plates are being tested preliminary to selection of candidates for MTR irradiation.

The plates were fabricated from as-alpha-rolled uranium cores of good quality metal. Eighteen plates of grain size nominally less than 100 microns were selected using the pulse-echo grain size test (see Development of Testing Methods). This test was, however, not sensitive enough to detect the "hot spots" of large size surface layer grains, which have been observed metallographically in as-rolled uranium, and the possibility of the presence of such large grain size regions could not be excluded.

Following nickel plating and detailed dimensional and surface inspection the uranium plates were clad by hot-pressing according to standard procedure previously described, using a pressing schedule [redacted] psi and [redacted] and [redacted]

[redacted]

Difficulty was experienced in welding the end fittings to the clad plates because poor thermal contact between the sheath and the end plug resulted in the sheath "rolling back" during welding.

Detailed results of the testing of the fabricated plates are not yet available. In general, however, radiography and ultrasonic tests indicate the plates are of quality comparable to previous MTR plates fabricated at the Savannah River Laboratory.

B. MTR Irradiation of Beta-Transformed Wrought Uranium

Three beta-transformed wrought uranium plates (so-called Group I plates) had accumulated a total exposure of 400 MWD/ton early in March without evidence of change in dimension or other damage. Irradiation of the plates is continuing.

DISTRIBUTION LIST

Copies 1 thru 10 - Winston Davis, AEC, Augusta, Georgia

11 - R. M. Evans - B. H. Mackey

12 - L. Squires - H. Worthington - J. E. Cole

13 - W. C. Kay - J. B. Tinker

14 - D. F. Babcock

15 - W. J. O'Leary - K. G. Jones

16 - J. C. Woodhouse

17 - W File

18 - M. H. Wahl, SRL

19 - C. W. J. Wende - P. H. Permar, SRL

20 - W. P. Overbeck - T. C. Evans

21 thru 26 - TIS File

27 - H. W. Russell, BMI

28 - Charles A. Priode, Hanford

29 - G. E. McCullough, Hanford

30 - R. L. Kirk, AEC, NYOO

31 - D. S. Webster, NRTS

32 - G. W. Wunder, National Lead Co., Cincinnati

33 - C. D. Harrington, Mallinckrodt Chemical Works, St. Louis

34 - D. G. Sturges, AEC, Hanford

35 - F. K. Pittman, AEC, Washington

36 - A. J. Vander Weyden, AEC, Washington

[redacted]