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EXPLOSIVES DEPARTMENT

October 17, 1956

Mr. P. J. Hagelston
Savannah River Operations Office
U. S. Atomic Energy Commission
P. O. Box A
Aiken, South Carolina

Dear Mr. Hagelston:

In line with your request, attached is a summary of the material I presented at the Sheath Meeting at Chalk River on September 25-26, 1956. As you realize, my presentation was not written out and not prepared with an idea of there being a request on your part for the provision of the material presented. However, I believe the attached summary corresponds closely to what I actually said.

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NUCLEAR INFORMATION

Very truly yours,
ATOMIC ENERGY DIVISION

J. Bonick
AED Class Officer
1/28/59

William J. O'Leary
Technical Division

WJO'L/jss

- 1 - P. J. Hagelston
- 2 - E. Worthington
- 3 - J. C. Woodhouse
- 4 - ~~File~~
- 5 - M. H. Wahl
- 6 - TIS File

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MASTER

PRESENTATION ON EXTRUSION CLADDING AT SHEATH MEETING,
CHALK RIVER, SEPTEMBER 25-26, 1956

~~This document consists of 5 pages.~~

Cladding Plates

No. 1 of 6 Copies, Series A

The progress in developing extrusion cladding for flat plates was reviewed. Battelle had run a series of 2-foot long natural uranium plates extrusion clad at controlled exit speeds, and these were evaluated at SRL for bond strength, with the following results:

<u>Exit Speed of Plate, (Inches/min.)</u>	<u>Extrusion Pressure on Ram, (psi)</u>	<u>Stud Weld Bond Strength, (Average psi)</u>
7	26 - 31,000	12,500
12	31 - 34,000	15,700
20	33 - 40,000	19,800
28	40 - 51,000	5,000
33	43 - 51,000	20,400

The above plates were clad at a billet temperature and core temperature of 1050°F (566°C), with Battelle's new mandrel tip, with a shear die, with a mandrel-to-die distance of 70 mils, and without end plugs. Thirty-three inches per minute is the highest controlled speed the Battelle press can use; above this the speed is fast with poor control.

By comparison with the above data, the earlier plates were clad with a 45-degree conical entry die, where at 6 inches per minute cladding speed the ram pressure was 35,000 psi, and bond strength averaged 24,000 psi.

In evaluating the latest series of plates, the bond strength values are an average for 80 studs pulled. It was noted that the surface appearance of the plates improved with increasing extrusion speed. Metallographic examination of the plate run at 28 inches per minute, which was out of line for increasing pressure and bond strength with increasing speed, showed that the core was poor, and that there were concentrations of foreign material (oxide or hydride) at the core-to-clad interface. A detailed examination of this series of plates is in progress.

End Plugs for Plates

Since Battelle is unable to start a plate into a flowing stream of aluminum, and therefore cannot presently make an integrally extruded leading end plug, effort has been concentrated on employing preformed, attached end plugs. At the July meeting the trouble that had been encountered with conventional aluminum alloy end plugs pinching off was discussed. At that time the only material that could be used as a leading attached end plug was the APV¹²

composition M-355 (19 w/o Al_2O_3 in Al) at a cladding speed of 6 inches per minute, using the conical entry die.

Our latest results with a 7-degree modified swage die show that M-355 as leading end plug can be used at cladding speeds up to 12 inches per minute, while M-276 (12 w/o Al_2O_3 in Al) is marginal in resistance to pinching off at 6 inches per minute. But with trailing end plugs there is seldom any difficulty at speeds up to 30 inches per minute.

With a shear die, however, M-276 can be used as leading end plug up to 30 inches per minute extrusion speed.

No data are yet available on the hot strength under extrusion conditions of M-257 (5 w/o Al_2O_3 in Al).

A number of end designs for these preformed end plugs have been tried out; these include pinned overlap joints and various modifications of dovetails. A T-slot milled into the uranium with a correspondingly machined end plug has been found the most satisfactory joint to date.

A few tests have been made to verify the strength of the bond between M-355 end plugs and 2S aluminum extrusion-clad over them. When the M-355 was nickel plated with 0.5 mils of nickel, the average of stud-weld tests was 7000 psi; on unplated plugs, however, the bond strength averaged 22,000 psi.

The supply of APMP with which we have been working consisted of three small experimental lots furnished by ALCOA. We understand that it will be impossible to obtain additional quantities of these materials for the indefinite future. Consequently, we have been looking for alternatives, and have on order some Hiduminium 100, made by High Duty Alloys, Ltd., Slough, Bucks, England. From descriptive literature, this material should be comparable to M-276.

The different die designs employed in the end plug studies, and speed versus bond strength tests showed up also some differences in dimensional control of the extruded aluminum. As long as the core or end plug was passing through the dies, there is sufficient flow of aluminum through Battelle's portholes to fill the dies adequately irrespective of die design, so dimensional control of clad core and of clad end plugs is good. But when the end plug has completely passed through the die, and billet aluminum is extruded after the trailing plug, the cross-section of the trailing aluminum is smaller than that of the clad core or plug in all dimensions (1) by 1 to 2 mils with the 45-degree conical entry die; (2) by 2 to 5 mils with the modified swage die; and (3) by up to 10 mils with the shear die. Part of this shrinkage is the result of the higher thermal expansion of aluminum with respect to that of uranium; in the case of the shear die, however, it is speculated that slippage occurs through the die without filling, and that this can perhaps be corrected by restraining the extruding aluminum.

Electroplating Techniques

Since differences in equipment and techniques between Savannah River, Chalk River, and Battelle in electroplating cores for extrusion cladding may result in differences in bonding, it may be advisable for the three sites to standardize as much as possible on plating procedures in order to compare results.

Equipment to Extrusion Clad Full Length Plates at SRL

It had been expected that some results of extrusion cladding full length plates at SRL would be available for this meeting, but the container has just been received at Savannah, and is now being installed on the press. This item completes the experimental equipment designed for these tests. The container is 36 inches in diameter by 30 inches long, with a 6-3/4 inch bore to take a billet about 6-5/8 inches in diameter by about 9 inches long. It is heated by embedded bayonet-type calrods with a 56 KW capacity, which are expected to hold the container at 1100°F.

Attached to the container is a pusher mechanism designed to grip and push the cores as close to the container-die assembly as possible, in order to minimize bending the core. In the pusher, two pneumatic cylinders actuate two 3-inch by 4-inch flat shoes. One cylinder clamps the shoes on the core with up to 5000 psi pressure; the second cylinder pushes or pulls the core with a 1-1/2 inch stroke. At the end of the stroke in either direction, the shoes touch a limit switch that opens them to release the core. In order to avoid a cold spot on the core, the pusher has 5 KW built-in heating coils. It is hoped with the pusher to be able to extrude integral end plugs.

Ahead of the pusher is a 50 KW furnace about 15 feet long. This is built as 3 independent units each 5 feet long, for preheating part or all of the cores. The furnace is muffle lined and equipped for argon flushing. The pusher is also equipped for argon flushing. A run-out table is provided on the other side of the assembly. A sketch of the pusher is attached.

This equipment should soon be in operation, and information on the results obtained will be available for the next meeting.

Progress on Extrusion Cladding the Inside of Tubes

The experimental program has been continued at Moczik Tool and Die Corp. in Detroit to extrusion clad the inside surface of tubular shapes. A number of steel tubular sections 1-3/4 inches, 2-1/2 inches, and 3 inches in diameter have been successfully clad on the inside only with a 30-mil thickness of 2S aluminum over a length of about 2 feet. The bond strength obtained with these has ranged from 10,000 to 26,000 psi.

Seven uranium tubes 2-1/2 inches in diameter by about 20 inches long have also been extrusion clad on their inside surface. Four of these were more or less oxidized, so were not extensively evaluated. Of the remaining three, the bond strength on two ranged from 1000 to 6000 psi, and the third had an average bond strength of 5000 psi with no non-bonds.

The conditions that to date appear best for internally extrusion cladding are:

Temperature of container, die, billet, and tube	1100°F (590°C)
Exit speed of internally clad tube	6 to 12 inches per minute.
Die design	7° modified swage.
Extrusion pressure resulting from the above	35,000 psi.
Clearance between tube I.D. and container O.D.	25 to 40 mils.
Atmosphere	Argon.

With present equipment under these conditions, all of the extrusions have been self-propelled.

Using steel tubes, it has been found that the extrusion pressure at about 1100°F reached 27,000 psi at a tube exit speed of 1/2 inch per minute, and increased to 35,000 psi at a tube exit speed of 12 inches per minute.

No work has yet been done on end plugs for tubular elements, so there are no data.

Program for Future Work on Extrusion Cladding

This includes the following:

Electroplating of flat and tubular cores, to make the plate a more constant factor in bond strength;

Reducing extrusion pressure and temperature, particularly for externally cladding tubular elements;

Increasing extrusion speeds to make present laboratory processes more economical;

Investigating the effects on extrusion cladding of employing cladding alloys of various compositions, from high purity aluminum to such an alloy as 6063.

Miscellaneous

The speaker was asked to comment on his observations after looking at a UO_2 slug that had failed under irradiation, and that was believed to have in part melted. A companion slug never irradiated looked on the surface too black to be UO_2 ; it looked as if it had been reduced somewhat, and might correspond in composition to UO_{2-x} .

The failed UO_2 slug had been sectioned across its length to show the central cavity that corresponded with the long axis of the slug. As far as the depth of focus of the microscope permitted, no evidence could be seen of rounding, free surface, frozen droplets, stalactites, or the like commonly associated with melting. A better examination for melting could be made on a vertical cross-section of the bottom of the cavity, which should have been a reservoir for molten material.

The section examined showed marked recrystallization, such as accompanies solid state reactions and solid-vapor reactions. The section looked like a typical area where vaporization had occurred in a hot central region at some temperature below the melting point, and as if the vapor had migrated to and condensed in outer, cooler layers, with consequent grain growth of the pre-situated solid.

WJD'L/jss

10/17/56

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10/12/94

END