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

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(SR/H--815)

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April 27, 1956

MEMORANDUM TO FILE

FROM: W. J. O'Leary

1. *J. Banick* AED Class Off 1/28/89

Name

Title

Date

NOTES ON SHEATH MEETING AT SRI

April 17-18, 1956

Name

Title

Date

Those present were:

AECL

U.S. AEC

Du Pont

G. C. Laurence
H. S. Milne
W. M. Barss
E.C.W. Perryman (AlCan)

N. J. Donahue
P. J. Hagelston
T. B. Niland
E. W. Stark
N. Stetson
R. C. Dalzell (Wash.)

J. C. Woodhouse, Wilm.
J. P. Maloney
P. H. Permar
N. F. Spraggins, Wilm.
R. R. Herries, Wilm.
B. L. Richards
B. W. Dunnington
R. T. Huntoon
G. L. Tuer
M. L. Holzworth
V. I. Montenyohl
W. R. McDonell
C. C. McBride
C. W. J. Wende
W. J. O'Leary, Wilm.
M. H. Wahl

Canada

Bureau of Mines

DOES NOT CONTAIN

UNCLASSIFIED CONTROLLED
NUCLEAR INFORMATION

J. A. Perry
J. S. Nelles
M. J. Lavigne
N. S. Spence

Reviewing
Official

J. Banick
C. J. Banick, AED Class Officer

Date

1/28/89

Dr. Laurence opened the discussion by saying that AECL is concentrating its interest on fuel rods for NRU to be ready at the end of the year; these will be unbonded, based on NRX experience. Chalk River, however, is prepared to go to bonded fuel elements, and now has in extrusion cladding at AlCan an alternate process. AECL is putting its trust in extrusion clad flat plates for the immediate future. General Electric Co. of Canada is now making UO₂ fuel rods; these are UO₂ pellets machined and threaded into a sheath. They are hoped to be useful for higher temperature operation.

Mr. Perry described extrusion cladding research at the Canada Bureau of Mines. He secured two more dies, die E159A and E159B. The latter was designed to give more self-propulsion than the former; the cladding thickness on both was meant to be 30 mils. He ran two bars through the latter, and broke the die; the extrusion conditions were as follows:

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Bar	Unit Die Load	Temperature of		Extrusion Speed
		Tools	Core	
9008D	56 tons	450°C (842°F)	450°C (842°F)	0.3 ft/min. to 8 ft/min
9008E	32 tons	450°C (842°F)	525°C (977°F)	

Bar 9008D had bond strengths from 5700 to 13,300 psi on the first half; the last half was flash copper-plated, but the bonding on this was poorer than on the nickel plate and ran from 2900 to 3600 psi. Bar 9008E had no bond. Another bar was started with integral end plugs of aluminum, 2% nickel alloy at 67 tons, with the core at 525°C (977°F) and the tools at 450°C (842°F); after 18 inches were clad the temperature of the core dropped to 450°C (842°F), and the extrusion stopped.

It is believed that die design is a major factor influencing self-propulsion. The clearance between mandrel and core is kept at 7-1/2 mils. A bow of 1/16" in 20" in a bar does not prevent extrusion cladding, but more bow than this causes sticking.

The Bureau of Mines has made coextrusions of uranium-aluminum alloy rod 5/16" in diameter, following the SRL technique. Flat slab castings are now being made in order to achieve homogeneity in the alloy; it is desired that a 30-mil sheath be coextruded. The Bureau of Mines is trying to copy the ORNL MTR-type flat plates by extrusion cladding, and expects to adapt this technique to Pu-U alloys for spiking rods. Al-Si end plugs will be used. Flat plates 48" long have been coextruded with a Mg shell as lubricant; the shell reacted with the aluminum sheath and spoiled its surface. The flat plates have been pulled through a die to make a tube, but the tubing has not yet been seam-welded. The extrusions so far have had fish-tails at the ends.

NPD prototype rods are being made by NMI. Before NMI began this work, it had been planned to sink a zirconium or zircalloy sheath on uranium bars. This worked very well with a rubber base-titania pigment wall paint as lubricant (suggested by NMI). Some of the uranium rods were nickel-plated before sheathing, and alpha heat treated after sheathing in an attempt to bond the sheath, with indifferent success.

It has been noticed at the Bureau of Mines that wire brushing or rubbing with steel wool a nickel-electroplated specimen that has been in storage for some time, does a remarkably good job of "reactivating" the nickel for bonding purposes. No data were presented to illustrate this.

Mr. Milne showed slides of the AlCan equipment and process for extrusion cladding flat plates. AlCan have found that the spacing between mandrel tip and die with their design is critical, and must be kept between 40 and 45 mils. The land of the die should be 80 to 90 mils long, and the entry angle 15 degrees. The die and billet

temperature should be around 530°C (986°F), and the core temperature is kept at 200° to 250°C (392° - 482°F). The extrusion speed is now 5 to 10 feet per minute, and the extrusion pressure is 40,000 psi.

Chalk River has assembled and autoclaved one set of full-length, extrusion-clad flat plates, made up of 3 sizes, for 24 hours without failure.

The machining tolerances on a full-length core are ± 2 mils. The flat plates are rolled individually instead of in a wide strip as for SRL, and are machined individually by pulling between cutters, 3 passes per side, so as to take off a total of about 15 mils per side. Chalk River can machine 30 flat plates per 2 men in 8 hours.

For cladding an unplated core for the unbonded condition, heating the bare cores in air excessively causes oxidation and sticking of the core in the guides. The sticking permits back extrusion, which is bad. Oxidation of the cores at low temperature (200°C) protects them during further heating for 30 minutes; thereafter the hard oxide becomes fluffy and flakes off. If heating and oxidation are done at higher temperatures (250° to 275°C), the length of time during which the plates can be further heated is greatly shortened, because the oxide earlier becomes fluffy and flakes off. The oxide produced by low temperature heating is harder and more protective than the oxide formed above 200°C .

Dr. Perryman ran some bond strength tests by stud-weld on 4 extrusion-clad specimens from each of the following groups:

- 1 - Surface-machined, followed by light etch, then nickel-plated.
- 2 - Surface-machined, followed by heavy etch, then nickel-plated.
- 3 - Surface-machined, sandblasted, light etch, then nickel-plated.
- 4 - As-rolled, sandblasted, heavy etch, then nickel-plated.

The temperature of the cores for extrusion cladding was 200° - 250°C (392° - 482°F); the billet temperature was 530°C (986°F); the extrusion speed was 8 feet per minute. The bond strength was initially good, but fell off rapidly to a low value, as indicated by the graph.

The conditions for bonding evidently changed progressively up to the 14 inches of cladding, perhaps because of heat removal from the billet by the core. When the core is first started through, the flow resistance of the aluminum momentarily increases, so pressure and time at pressure have been greatest at the lead end of the core.

AECL proposes to run some additional cores at a higher temperature to see if the shape of the curve changes.

The effect of core preparation had little or no effect on bond strength; the data for group 4 above showed more scatter of results than for the other 3 conditions. One bar was annealed at 500°C for 5 minutes, and another at the same temperature for 20 minutes after extrusion cladding to determine the effect on bond strength; there was no marked difference, but any blisters that originally were present increased in size. Another extrusion-clad core was step-pressed at 8000 psi, 1-1/2 minutes per step at 525°C; this treatment raised the slope of the falling curve between the 10-inch and 14-inch marks. In the stud-weld tests, most fractures occurred at the Al-Ni interface.

Corrosion tests were made on a series of aluminum alloys over a 4-week period at a pH of 7, using cold water; the alloys were:

1S with 0 -	2% Ni, 4% Cu
1S with	2% Ni, 0.5% Fe
1S with	0.5% Ni, 0.5% Fe
1S with	2% Ni, 2% Cu

The last composition was tested over a 10-week period and was found to be the most corrosion-resistant; the penetration of the first 3 was 3 mils per year. All of these were tested as wrought sheet. When tested in an autoclave, the corrosion was found to be uniform.

Corrosion tests were run also in a loop at a pH of 9.4 and at a flow rate of 3 feet per second; the results were about the same as above. A tube was made by welding the sheet, and was tested in-pile at a pH of 9.4, with a water flow of 18 feet per second at 250°C; the corrosion rate increased to about 50 mils penetration per year. In the tube, the corrosion rate immediately adjacent to the weld was higher than on the rest of the tube; there was evidence also that at the higher flow rate, oxide was scaling off.

Corrosion-wise, vacuum melted, as-cast 2S aluminum is good; air melted, as-cast 2S is good; but wrought 2S, whether air or vacuum melted, is poorer in corrosion resistance.

Dr. Barss discussed the inspection of an NRX rod de-sheathed in a cave after 1000 MWD/ton. The indication that the rod had reached a high temperature was formation of some uranium-aluminum compound on the uranium that had been unbonded.

Mr. Nelles discussed pressure welding and forge welding of end plugs to sheaths, welding for the stud-weld test, and pneumatic burst tests of welded aluminum components.

Dr. Lavigne reviewed the figures on the yield of flat plates from ingots. The yield was 60%, but has increased to 77% with the new process based on buying from Fernald billets cut to a specified length.

Dr. Perryman mentioned alternative fuel elements for small power reactors; these are UO_2 , and U or UO_2 co-extruded with zircalloy; work on the latter is being done by NMI. Diffusion layers are formed at the uranium-zircalloy interface by annealing after extrusion cladding; corrosion causes separation at the interface.

MISCELLANEOUS

A later discussion was held to review the information presented by both Canadian and U.S. participants, and to go more fully into some detail on a few points. The Canadians feel that mechanical pushing of flat plates for extrusion cladding is satisfactory, especially at high extrusion rates. There is, however, no information on ability to push plates and keep them straight if they are preheated above $250^\circ C$. As-rolled surfaces seem to clad as satisfactorily as machined surfaces.

The end plugs integrally extruded by AlCan are 40 mils thinner and 10 mils narrower than the clad core. The Canadians believe that their die is not filling with aluminum at current extrusion speeds. In other respects, however, the end plugs are satisfactory, with no large voids, and only occasional small voids between the core and end plug. The Canadians taper their cores to obtain end plug fill as shown:

Tensile tests on the strength of bond between end plug and core show a 1500 to 2000 pound pull.

At present, everyone lacks information on:

- (a) the pressure exerted on the plate during extrusion cladding;
- (b) the range of pressure required on the plate to effect bonding;
- (c) dimensional and structural changes undergone by a plate during extrusion cladding.
- (d) effect of hydrides and other core inclusions on extrusion cladding.

Dr. Laurence summed up the AECL program for future work. The Canadians will continue extrusion cladding at AlCan to achieve better bonding. They will install electroplating equipment at Chalk River. They will initiate extrusion cladding of NRX round rods; Perry and the Bureau of Mines staff will look into mandrel design, temperatures, and pressures for doing this.

Dr. Perryman will continue studies of the corrosion resistance of aluminum alloys. A comparison will be made between Atlas rolled and Superior rolled plates. They will investigate the effect that cold drawing and cold finishing has on uranium plate. They will look into sheathing aluminum alloy end plugs with aluminum. They will try to learn something about zirconium cladding, and sheathing UO_2 pellets in zirconium. They may have some information on forge welding aluminum end plugs.

Some extrusion clad, unbonded plates will go into NRX for test the week of April 23.

Since the Canadians would like to see the extrusion cladding work at BMI, they will plan for a visit there the week of May 14, and will confirm a date for this through SROO.

WJO'L/jss

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