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August 11, 1953

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FROM: GEORGE W. BECKMAN

TRIP REPORT--BMI
AUGUST 7, 1953

SUMMARY

1. A program for the pressure bonding group was discussed and found mutually agreeable.
2. A BMI letter report summarizing corrosion test results of pressure bonded systems will be in Wilmington the week of August 10, 1953.
3. In roll cladding of copper plated uranium with aluminum, the percent pack reduction required for good bonding increases rapidly with decreasing temperature.
4. The effect of increased core thickness in roll cladding is to permit increased reduction of sheath before significant deformation of core.
5. Alpha phase heat treatment of nickel plated uranium shows promise of increasing corrosion resistance.
6. For AlSi dipped uranium, it has been established that there is no minimum quantity of uranium in the bath necessary for successful cladding. Dipping rate has been correlated with successful AlSi coatings.

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7. Weight change during oven drying of uranium samples prior to AlSi dipping has shown an anomalous decrease in weight.

8. A critical extrusion experiment making use of a steel mandrel between core and aluminum billet will be completed in two weeks.

9. Nickel bonded as well as AlSi bonded samples have been on test by the corrosion group for two weeks without visible degradation. Copper failed after 24 hours.

PRESSURE BONDING

At a meeting with D. Martin and R. Carlson, the pressure bonding program for August was discussed.

Samples for all the tests to be described are currently being fabricated. They are "half dollar" specimens made in the metallographic die by the picture frame technique with the following barrier layers between uranium and aluminum:

1. .1 mil copper
2. .3 mil copper
3. .5 mil copper
4. .1 mil nickel
5. .2 mil nickel
6. .3 mil nickel
7. AlSi dipped (to study growth of intermetallics with time and temperature).
8. Nickel and copper in combination (dimensions not yet firmly decided).

Recent results have established that copper despite its excellent bonding characteristics is unsatisfactory from the standpoint of corrosion resistance. Nickel, however, has proved to have desirable corrosion properties, particularly in the heat-treated condition. Emphasis is now being placed on the nickel plated uranium system, particularly with respect to developing minimum bonding conditions in terms of pressure and temperature.

In the event that bonding of nickel plated uranium to aluminum is unsatisfactory, it is thought that both the corrosion resistance of nickel and the bonding characteristics of copper could be retained by use of a flash coat of copper on nickel. It has previously been established that the presence of copper on nickel does not deleteriously influence corrosion resistance. Pressure bonding studies with a nickel and copper bimetal barrier layer will also be carried out to develop minimum bonding conditions. It is anticipated that the minimum conditions for successful bonding will be determined by August 25, 1953.

The effect of thickness of nickel and nickel-copper barrier layers on bonding characteristics will be determined. The obvious use for this information is related to lowering the cross section of the components. However, in addition, there may be an optimum thickness for bonding. This work is scheduled for completion on or about August 25, 1953.

Nickel and nickel-copper bonded samples for barrier effectiveness tests will be fabricated by August 14, 1953, and will be diffusion heat treated during the week of August 17, 1953. Evaluation by metallography is estimated for completion by August 25, 1953. This work will provide some measure of the interdiffusion of bond materials and uranium under temperature conditions comparable to those found in reactor application. Test coupons will be diffused for 50-100 hours at temperatures of 250°C and 400°C.

Determination of optimum thickness of aluminum picture frame to be used with 0.020" aluminum cover plates is also projected for August.

The die for producing bond strength test specimens has been completed, but the resistance furnace is not yet available. This project does not command the priority of the work listed above; it will be completed at a later date.

Essentially this program is in agreement with du Pont proposals. The single exception is that of developing the minimum percent reduction of aluminum for successful bonding. It was the expressed opinion of R. Carlson and D. Martin that this study should be deferred until the MTR plates are fabricated for two reasons:

1. The percent deformation of aluminum is fixed by dimensions of the extruded sheath already designed and in production. They feel that the sheath will provide sufficient deformation for good bonding. Since this is true, at least for MTR plates, the question becomes an academic one at this time. However, in designing a new sheath material for final production of flat plates, information of this nature should be available.

2. It was thought that the proposed study would seriously interfere with progress of other tests discussed above if undertaken at this time.

ROLL CLADDING

Work with the copper plated uranium-aluminum system has been virtually completed. Results indicate good bonding at [REDACTED] with pack reduction greater than 12-1/2 percent. Bonding at [REDACTED]

lower temperatures, [REDACTED], requires relatively high percent deformation of pack. 70 percent reduction provided good bonds; 45 percent did not.

Results using 0.125" uranium as compared to 0.100" show the effect of increasing thickness is to allow higher deformation of the sheath before significant reduction of core takes place. Quantitatively, a 0.100" core does not deform more than 2 percent until the pack has been reduced 12 percent. By reducing the deformation per pass to .005", this figure is raised to 18 percent. With passes of .010" or more, the 0.125" core did not begin to deform until the reduction of pack was about 20 percent. The trend towards more sheath deformation for any given amount of core reduction with thicker uranium cores makes the possibility of roll cladding without working of the core more probable.

A pessimistic attitude towards the quantitative evaluation of bond strength of roll clad samples was obtained by BMI personnel on a recent trip to Metals and Controls Corporation. It was reported that M&C feels that no significant method of quantitative appraising bond strength of roll clad samples has yet been developed. They claim that the most satisfactory method to date is that of using a trained operator who can qualitatively evaluate bond strength by manually tearing the bond apart. On this basis, bond systems are listed in order of increasing strength based on AlSi with a value of unity.

AlSi	1
Chromium	6-7
Nickel	7
Copper	10

Roll cladding is anticipated to proceed at its current level of effort. The major consideration will be that of determining minimum rolling conditions for the U-Ni-Al system. Some exploratory work is being done with chromium as a bonding agent.

ELECTROPLATING

It has been demonstrated that corrosion resistance of nickel plated uranium is improved by an anneal at β temperature (700°C). Since the β temperature heat treatment is objectionable due to the pronounced grain growth encountered, work is now underway to find the minimum temperature at which improved corrosion resistance is obtained. Accordingly, samples of 5 different combinations of bonding materials have been prepared and heat treated at 500°F, 700°F, and 1000°F for three time periods of 24, 48, and 96 hours. Results to date are given as follows for all times at temperature:

[REDACTED]

Corrosion test results in boiling distilled water after 20 hours.*

	<u>R.T.</u>	<u>500°F</u>	<u>750°F</u>	<u>1000°F</u>
Ni	failed	ok	ok	ok
Ni-Cu	ok	ok	ok	ok
Ni-Cu-Sn	badly pitted	badly pitted	ok	ok
Cu-Sn	failed	failed	ok	ok
Cu	failed	failed	ok	ok

* These tests are being continued.

The question of Watts bath versus high sulfate bath for nickel plating was discussed. J. Beach feels that the Watts bath is faster and produces more ductile nickel than the high sulfate type. If desired, he can convert to the Watts bath with little difficulty. This decision will be dictated by results from evaluation tests now being made at SRL on samples plated at ANL.

DIPPED COATINGS

The satisfactory coating of uranium by hot dipping in AlSi has been demonstrated to be independent of uranium content of the bath. Spectrographic analysis indicates no uranium in a bath which coats well.

Another variable in the AlSi dipping of uranium has been shown to be the rate at which the sample is immersed in the bath. Plunging the sample into AlSi gives poor results, particularly at the top of the specimen. Dipping rates slow enough to allow 5 sec. for complete immersion of the 1" x 3" standard size sample were always associated with continuous coatings. The mechanism by which improvement is noted with slow dipping is not clear at this time. However, a low rate of immersion has several advantages:

1. The sample receives more preheat with better dehydration and degassing of the surface.
2. Slow rates do not tend to occlude gases. The molten bath acts like a squeegee displacing air pockets as it progressively moves towards the top of the sample.

Apparatus is being designed by which the dipping rate can be accurately measured. Future work will determine the maximum rate consistent with satisfactory coating.

Weight change measurements of uranium cores during preparation of the surface for dipping have been followed in the 50 percent HNO₃ etch and the drying oven at 110°C with the objective

of correlating surface preparation with coating characteristics. Preliminary results indicate anomalous behavior in the drying oven where samples were exposed for 5, 10 and 15 minute intervals at 110°C. An initial weight gain was followed by a measurable loss of .0009 to .0012 grams. It was anticipated that the formation of an oxide film would bring about weight increases. This work will be continued in an attempt to explain this anomaly.

When all operating variables are satisfactorily defined, it is planned to try beryllium and copper additions to the bath.

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