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DPW-53-1307-DeI. Ver.

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October 15, 1953

TO: FILE

FROM: GEORGE W. BECKMAN

TRIP REPORT
BATTELLE MEMORIAL INSTITUTE
SEPT. 17 and 24, and OCT. 8, 1953

SUMMARY

1. Barrier effectiveness tests show that 0.2 mil nickel is a minimum for diffusion barrier application.
2. Successful bonds by roll cladding with an electrodeposited nickel bond layer have been produced without deformation of 1" x 1" x 0.180" cores. Deformation of core versus pack has been established for several conditions of core dimension and rolling schedule.
3. Apparatus for a critical extrusion test is being machined. The experiment is planned for late October.
4. Beryllium additions to the AlSi bath suppress drooping, but they have negligible effect on intermetallic compound formation.
5. Corrosion test failures of soldered ribs sprayed with zinc took place in 6 days regardless of solder used. The same ribs sprayed with aluminum are still intact after two weeks.
6. Solder bonding with a flash coating of copper on both core and sheath has been satisfactorily completed with [redacted] and [redacted].

Reviewing
Official

H. Coughlin
9/28/53

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MASTER

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Pressure Bonding

Progress in pressure bonding was retarded during the last period in that both men responsible for the work have been on vacation.

It has been established however, that 0.2 mil nickel and 0.1 mil copper respectively provide good bonding characteristics. In addition, barrier effectiveness tests at 300°C for 100 hours indicate that 0.2 mil nickel and 0.3 mil copper respectively were not penetrated by diffusion.

A critical test was made to determine the effect of zero aluminum flow on bonding. A sandwich using 0.5 mil nickel as a barrier layer was made up in such a way as to provide no aluminum deformation. Bonding was attained but some deformation was noted where the core and picture frame were not exactly fitted. Therefore, the test only indicates that the critical flow, if any, is small.

By plant request, an attempt was made to bond AlSi dipped aluminum to bare uranium by hot pressing. Poor bonding resulted from rapid oxidation of uranium.

Bond strength of the U-Ni-Al system is currently being evaluated in terms of fabricating variables, temperature and pressure. Tensile samples are made by pressing a 1/4" diameter nickel plated uranium wafer between two 1/4" diameter aluminum rods in a cylindrical die. Tensile strength will be measured by applying uniaxial tension normal to the bond interface. Bonding characteristics will be studied as a function of pressure for three isotherms spread equally over the range of temperature considered practical for production. These data will be valid for flat plate fuel element application since it is BMI opinion that dimension of pack components has negligible effect on bonding by pressure bonding methods.

Another problem being studied concurrently is that of rate of crevice corrosion attack at uranium-nickel interface in hot pressed samples. It has been demonstrated that nickel is superior to both AlSi and copper in resisting attack by boiling demineralized water. However, since all three systems eventually fail in the same manner, it is not clear whether the difference is in incubation period or if the corrosion rates are actually different. If the former is true, less confidence can be placed in corrosion resistance of the barrier layer because incubation period is apt to be non-reproducible. A series of "half dollar" samples will be corrosion tested so as to measure both the incubation period and the rate at which attack proceeds after the incubation period.

Further clarification of the mechanism by which corrosive attack progresses in electroplated cores with and without a bonded aluminum sheath is considered desirable. Electroplated samples corrode predominantly by pit formation whereas bonded samples deteriorate at the uranium barrier layer interface by crevice type corrosion. Some insight into this problem may be provided by corrosion tests with samples in which the sheath alone is penetrated by a hole.

Scale-up to larger size specimens is anticipated after the work previously outlined. Dies and heated platens are now completed and ready for use. The larger size samples will be used for making bend tests with which to compare the strength of roll clad and pressure bonded assemblies. Bend tests were chosen because they can more nearly duplicate the most severe handling conditions to be anticipated with a 14 foot element and because they can be readily made from both pressure bonded and roll clad samples.

Roll Cladding

Developmental work on roll cladding has been continued with 1" x 1" x 0.180" (approx.) cores. Since bonding without deformation of the core is considered to be requisite for a successful cladding process, the relationship between core and pack reduction has been established for varying conditions of core thickness and pass schedule. For one-inch square samples intercepts on the curves (Figure 1) on the abscissa indicate that the pack can be reduced 12 to 22 percent before core reduction takes place. For future convenience the value of percent pack reduction corresponding to zero core reduction for any given combination of conditions is called the critical pack reduction.

Conditions of temperature and percent pack deformation for satisfactory bonding of aluminum to uranium with intermediate barrier layers of several different materials are shown in Figure 2. It is recognized that these conditions are not necessarily minimum ones and that further improvement may be expected by such expedients as post-rolling diffusion treatments. It can be concluded from the results shown in Figures 1 and 2 on 1" x 1" x 0.180" (approx.) cores that bonding with nickel and/or copper plated uranium is possible without deformation of the core.

However, scale-up of sample size 1" x 3" x 0.180" (approx.) cores revealed (Figure 1) a less desirable relationship between percent reduction of core and pack. The critical pack reduction is reduced to approximately 3%. This unfavorable lowering of critical pack deformation is obviously associated with "end effects" encountered in rolling of composites where individual components have different flow characteristics. Since it has been shown that the critical pack reduction is dependent on sample dimensions, specimens of projected MTR cross-sections by 9 inches and longer are being rolled to establish the relationship between pack and core reduction as well as minimum conditions for bonding.

In addition, post-rolling diffusion heat treatments will be explored as a means of increasing the bond strength at minimum pack deformation where the core is not deformed.

Additional effort will be diverted to increasing critical pack deformation by variations in rolling technique such as roll size and speed, lubrication, pass schedule, as well as intermediate heat treatments between passes.

A letter report summarizing roll cladding information to date will be available from BMI the week of October 19, 1953.

Extrusion

Preliminary attempts to extrude aluminum over a steel core were unsuccessful. Radial forces in the upset aluminum billet caused seizing and subsequent tensile failure of the core. A critical experiment in which a protective mandral is used between core and aluminum billet is scheduled for late October. Equipment has been designed and is now being machined.

Much helpful information on die design and extrusion of aluminum was received by the BMI extrusion group from consultation with ALCOA. The fact that ALCOA is currently experimenting with a cable sheathing method similar to that proposed by BMI indicates their feeling concerning the possibilities of the process. ALCOA's opinion is that if the extrusion can be made, bonding will not be a problem.

Dipped Coatings

The original purpose of the dipped coating study was to provide a workable method for coating uranium uniformly with AlSi. To this end, the pertinent variables have been discovered and optimum conditions evaluated. The current work is concerned with improvement in the end product mostly by additions to the bath.

Additions of [redacted] to the AlSi bath in the order of [redacted] to [redacted] have significantly reduced drossing. For promoting cleanliness in the bath, however, beryllium is of marginal value for a careful skimming operation does equally well.

The effect of [redacted] additions on formation of intermetallic compounds was found to be negligible at dipping temperatures from [redacted] and for dipping times up to [redacted].

It was observed that a hypoeutectic bath containing [REDACTED] silicon significantly increased the volume of intermetallic compound formation, particularly at low operating temperatures near [REDACTED]. The effect of hypereutectic composition on compound formation is projected for future study.

It is also known that the final structure of AlSi coating obtained from a eutectic bath is composed of primary dendrites of aluminum surrounded by a eutectic matrix. There is some evidence that silicon is lost to reaction with uranium, and that adjusting silicon concentration upwards may result in a more uniform eutectic structure. This coating will be evaluated from the standpoint of strength, intermetallic compound formation, and corrosion resistance.

A series of bend test samples are currently being produced under optimum conditions in the eutectic bath. By selectively exposing various zones of the composite to maximum tensile fiber stresses it is hoped that some comparison of their strength can be effected.

Solder Bonding

Recent success with solder bonding copper plated aluminum and uranium with an 80:20 Pb-Sn solder has increased interest in the possibilities of solder bonding. Bonding was accomplished at [REDACTED] with pressures from [REDACTED]. Due to the demonstrated poor corrosion resistance of copper alone in pressure bonding systems, current emphasis is on a nickel bond layer on the core and a flash of copper on aluminum. Corrosion tests will be made in boiling demineralized water.

Electroplating

The effect of heat treatment on corrosion resistance of electroplated uranium is appreciable. A series of 1" x 3" samples nickel-plated to a depth of 0.5 mil have been heat treated in vacuo to 500°F, 750°F, 1000°F for 24, 48, and 96 hours for each temperature studied. Corrosion tests were made in boiling demineralized water. Criterion for failure is 50 mg/45 cm² weight loss.

Temp. °F	Time at Temp. hours	Time to Failure hours
R.T.	--	3-5
500	48-96	30-100
750	48-96	30-100
1000	24	30-100
1300	2	100-200
1375	0.16	100-200

This study demonstrates that inter-diffusion of nickel and uranium is directly associated with increased corrosion resistance.

A comparable study was made with 0.5 mil copper plates uranium. No significant effect of heat treatment on corrosion resistance was noted in the uranium-copper system.

Testing of the uranium -0.3 nickel -0.3 copper system proved that the presence of copper on nickel did not impair corrosion resistance.

The electroplating group is also currently concerned with evaluation of nickel plating baths of greater potential productivity than the present high sulfate solution which takes 40 minutes for 0.5 mil deposition. Several possibilities are:

1. (a) strike coating in a high sulfate bath with sodium sulfate (1 to 10 minutes)
- (b) Watts bath up to 0.5 mil (15 minutes)
2. Nickel fluoroborate which is said to need no strike bath.

GWB/g

FIGURE 2 - CONDITIONS OF % REDUCTION OF PACK AND TEMPERATURE FOR SATISFACTORY BONDING