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DUPLEX BATH VARIABLES EXPERIMENTS

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DUPLEX BATH VARIABLES EXPERIMENTS

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July 20, 1960

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DUPLEX BATH VARIABLES EXPERIMENTSINTRODUCTION

The bond quality of an Al-Si brazed fuel element is considered to be influenced most significantly by the conditions in the duplex furnace where the initial U - Al-Si layers are first formed. The duplex bath consists of a furnace of molten lead with a layer of Al-Si floating on the lead. The bare uranium cores are immersed in the lead layer, agitated for a specified length of time, and removed from the duplex bath by raising through the Al-Si layer. The significant variables affecting the bond formation are the lead temperature, the degree of agitation of the uranium core in the lead (both frequency and displacement), and the time in the lead. This report presents the results of tests to investigate the effect of these variables on the bond quality of fuel elements as measured on the non-destructive bond tester by total bond count and supplemented by destructive examination.

SUMMARY

The effect of duplex bath canning variables on the bond quality of fuel elements has been investigated over a range of lead bath temperatures from 610 to 630 C, immersion time in the lead bath of 30-51 seconds, agitation frequency of 60-120 cycles per minute, and agitation displacement (60° basket) of 2.68 to 5.0 inches.

All of the variables have an effect on residual porosity. The strongest influence is associated with the time the fuel core is in the lead and the temperature of the lead bath.

Minimum porosity was associated with time in the lead bath of 44 seconds, lead temperatures in excess of 622 C, agitation displacement of 3.65 to 4.19 inches, and agitation frequency of 90-110 cycles per minute.

DISCUSSIONTemperature Effect

A series of three experiments was run with the following conditions:

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1. PWR 118-79

Five duplex lead temperatures, 610 C to 630 C, inclusive. Twenty fuel elements canned in each run. Test duplicated three times for a total of 60 elements at each temperature condition. Canning bath silicon 11 percent and 2 C above the primary arrest.

2. PWR 144-97

Five duplex lead temperatures evenly spaced 610 C to 630 C inclusive, ran two weeks after PWR 118-79. Twenty fuel elements canned in each run with the test duplicated five times for a total of a hundred (100) fuel elements at each temperature. Canning bath silicon 11 percent and 2 C above the primary arrest.

3. PWR 145-98

Five duplex lead temperatures evenly spaced, 610 C to 630 C. Thirty fuel elements canned per run with the test duplicated four times for a total of 120 fuel elements at each temperature. Canning bath silicon 9 percent and 2 C above the primary arrest.

A summary of the statistical analysis of the results of these tests demonstrated the following to be true and unique with each test:

Test	External Counts	Internal Counts
1	No significant effects but a wide variance and a tendency for temperature associated significance.	No significant effects.
2	Strong difference between temperature levels - quadratic in nature - results were very positive.	No significant results.
3	Strong difference between runs that may or may not have masked significant temperature association that appears to be present.	No significant results.

As indicated above, there were no significant differences between duplex temperatures in two sets of data. However,

[REDACTED]

tendencies toward significance of a general type did exist. In order to determine whether or not results from the three sets were comparable, the data were analyzed as a whole.

For external counts, the absence of a significant set X temperature interaction indicates that the results of the three sets are comparable and hence can be combined to give a more precise picture of the effect of duplex temperatures. The average log of the total external bond count +1 (un-weighted) based on these three sets of data are:

610 C - 1.15
615 C - 1.10
620 C - 1.01
625 C - 0.97
630 C - 0.98

These results are significantly different. The average values as such are probably not too meaningful since the experiments were conducted at widely spaced intervals and under varying conditions. However, the absence of the set X temperature interaction implies that the relative differences between these averages are meaningful and real.

In fitting these data, a linear fit is all that is required for a mathematical graphical interpretation (see Fig. 1).

Although the relative differences are not great, it should be recognized that these are differences of the average logs for a relatively large population.

Data were also combined for internal counts to determine if tendencies toward significance enforced one another to lead to overall significance. A look at the overall average of the log of the internal total bond count plus one shows that the lead temperature of the duplex bath does not affect internal porosity.

610 C - 1.62
615 C - 1.67
620 C - 1.66
625 C - 1.65
630 C - 1.65

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-4-

Hence, in summary, there is a strong tendency for the higher lead duplex temperatures to minimize external porosity but this had no influence on the internal porosity as it is being currently measured.

Lead Time and Agitation Rate Effect

The following lead times and agitation rates were investigated:

- a. Lead Time (30, 37, 44, 51 seconds).
- b. Agitation Rate (60, 80, 100, and 120 cycles per minute.

Assuming that there are no other time associated effects existing during the time of experimentation, significant effects were found to be consistent within all of the test. For external bond counts at lead times of 35 seconds and beyond, a significant interaction between the lead time and rate of agitation exists. In general, at lead times of 35 seconds and beyond there is a quadratic response due to agitation rates with the minimum external count occurring at 44 seconds lead time and agitation rates of 90 cycles per minute.

There is no apparent agitation rate effect at lead times less than 34 seconds for those times investigated.

Displacements

The angular stroke that the duplex basket makes during agitation is determined by a cam-pin combination setting of the duplex agitator. This stroke distance plus the agitation rate determines the distance of travel the fuel element experiences during the duplex cycle. This influences the heating rates and the washing action on the core. The displacement had a significant effect upon both the external and internal total bond counts when using a 60° basket on the agitator. The displacement investigated were: Position 1 - 2.68 inches; Position 2 - 3.65 inches; Position 3 - 4.19 inches, and Position 5 - 5.00 inches.

No work was conducted during this testing program on the horizontal type basket. The best results for minimum total counts, external and internal, were found at displacement position 2 and 3 (3.65 and 4.19 inches).

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HW-66054

Since this test was conducted, the agitator has been modified to conform to the 313 Building design and displacement position 3 (4.06 inches) most nearly simulates the best results obtained in this study.

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FIGURE 1 - DUPLEX FURNACE LEAD
TEMPERATURE VS LOG EXTERNAL
TOTAL BOND COUNT