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TITLE

FEASIBILITY OF THE USE OF INDUCTION HEATING EQUIPMENT FOR PILOT PLANT DEVELOPMENT WORK

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August 28, 1963

FEASIBILITY OF THE USE OF INDUCTION HEATING EQUIPMENT
FOR PILOT PLANT DEVELOPMENT WORK

INTRODUCTION

The "F" process utilizes the molten AlSi canning furnace to preheat the can sleeve assembly prior to dip brazing to the uranium core. Optimum preheat time with this method does not allow the can to reach bath temperature prior to brazing. Preheating in the bath results in visible outgassing of the sleeve coating into the molten AlSi. Inadequate preheat results in AlSi solidification, braze porosity, assembly difficulty, and some can non-wetting. The preheat time cannot be increased because additional time alters the aluminum surface condition and causes gross nonwetting. A solution to this problem is to preheat outside of the bath and to increase the heating rate with the use of induction heating equipment.

SUMMARY

The fuel element braze process capability is not within specified product acceptance criteria. As a result, cap and base closure welding and 100 per cent braze testing and weld inspection of fuel elements is required. The annual production cost resulting from these operations and braze and weld defects is about \$355,000. The procurement and installation of a 50 KW, high frequency induction heating unit for can-sleeve preheating is proposed for the following reasons:

1. To develop technology which will be applied to improving the braze process capability.
2. To provide increased flexibility for future Pilot Plant development work, such as new product quality optimization, and the evaluation of shorter canning cycles.

The increased heating rate obtained from this equipment will provide the flexibility for a reduction of at least ten seconds in the canning furnace cycle time.

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DISCUSSION

The fuel element braze process capability is not within specified product acceptance criteria. As a result, cap and base closure welding and 100 per cent braze testing and weld inspection of fuel elements is required. Improvement in brazing process capability to provide acceptable braze and closure quality would result in:

1. Discontinuing closure welding and weld inspection.
2. A yield increase.
3. Conversion of the bond and end closure tests to a statistical sampling basis instead of screening.

The resultant annual savings is estimated below:

- | | <u>Annual
Savings</u> |
|--|---------------------------|
| 1. Cost of production rejected because of braze defects during the past twelve months.
(Potential yield increase resulting from improved braze process capability.) | |
| a. Bond test rejects (UE-1 test) | \$20,700.00 |
| 0.6 per cent @ \$1.50 per reject | |
| Estimated annual production = 2,300,000.00 | |
| b. Braze closure rejects (UT-4 test) | \$79,350.00 |
| 2.3 per cent @ \$1.50 per reject | |
| 2. Conversion of bond (UE-1) and end closure (UT-4) tests from screening to sampling. | |

Assumptions:

1. Sampling could be accomplished with two UE-1 testers and two UT-4 testers operational.
2. Screening costs resulting from out-of-control braze process conditions would not be more than ten per cent of the present direct operating and maintenance costs
3. Development and calibration efforts would not be appreciably affected by conversion.

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	Screening Costs Which Could be Reduced By Sampling	Sampling Cost
Operating Labor	\$82,500/Yr. Eleven Operators @ \$7,500/Yr.	\$30,000/Yr. Four Operators @ \$7,500/Yr.
Maintenance and Fabrication* (UE-1 Test)	\$128,316/Yr. Four Testers Operational	\$64,158/Yr. Two Testers Operational
Screening Cost Resulting From Out-of-Control Brazing Process Conditions	-----	\$28,343/Yr. 10 % of present Operating Labor and Maintenance and Fabrication costs

* UT-4 tests not included since two testers must be operational for screening or sampling.

	<u>Screening</u>	<u>Sampling</u>
Total (Affected by Conversion)	\$210,816.00	\$122,501.00
Annual Savings	----	\$ 88,315.00

3. Closure Welding

a. Welding Labor

Six welder operators @ \$7,500 per year operator.

Annual
Savings
\$45,000.00

Two mandrel operators @ \$7,500 per year per operator.

\$15,000.00

b. Weld Inspection Labor

Six inspectors @ \$7,500 per year per inspector.

\$45,000.00

c. Shielding Gas

2,000 cylinders helium per year @ \$16.66 per cylinder.

\$33,320.00

700 cylinders argon per year @ \$8.72 per cylinder.

\$ 6,104.00

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Annual
Savings

d. Direct Maintenance Labor

2,366 hours per year @ \$3.80 per hour based \$ 8,981.00
upon maintenance required during first six months
of CY 1963.

Materials \$ 3,000.00

e. Reject Cost

0.3 per cent reject rate @ \$1.528 per reject \$10,540.00

0.3 per cent based upon a 1.5% weld reject
rate and an 80% reweld recovery yield.

Total \$355,310.00

There are several known sources of braze porosity, the major sources appear to be:

1. Entrapped air
2. Hydrogen outgassing from the uranium core
3. Hydrogen absorbed into the molten AlSi

The approximate composition of braze void gas based upon mass spectrometer analysis of gas from ten fuel elements containing voids is shown below:

<u>Gas</u>	<u>Approximate Volume Per Cent</u>
Hydrogen	60%
Air	27%
CO + CO ²	3%*
Other	1%

* About ten times that normally present in air.

The sleeve is coated prior to preheating, with soap and sodium-aluminate. Sodium-aluminate, being hygroscopic, contains moisture before preheating. At the beginning of preheat, a large amount of outgassing from the sleeve surface through the molten AlSi is visible. The soap and sodium-aluminate undoubtedly results in carbon contamination, hydrogen absorption into the surrounding AlSi and aluminum oxidation.

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Highly viscous or solidified AlSi resulting from poor preheating appears to be the primary source of entrapped air.

The uranium core presently contains about one part per million hydrogen which outgasses during assembly. Unfortunately, the percentage of hydrogen coming from the uranium core compared to that from the decomposition of the sleeve coating is unknown. However, based upon tests using vacuum outgassed cores, uranium outgassing is a significant contributor to the braze porosity problem, and it should be recognized that induction can-sleeve preheating will effect no control over this variable. The reduction and control of uranium hydrogen concentration appears feasible based upon past test work and progress is continuing in this area.

Attempts to reduce porosity and other braze defects resulting from the canning operation should also be made to effect the earliest realization of the potential savings resulting from high quality brazing. The greatest potential for reducing braze defects unrelated to core outgassing appears to be in the use of induction can-sleeve preheating. Equipment proposed for Pilot Plant test work is a 50 KW, high frequency, induction heating unit. The estimated cost is shown below:

Cost of Equipment

Electronic Generator	\$18,000.00
50 KW Output	
200-500 kilocycles per second	
Heating Station	\$ 9,000.00
Heat Exchanger	\$ 1,000.00
Freight and Shipping	\$ 1,000.00
Subtotal	<u>\$29,000.00</u>

Cost of Installation

Materials	\$ 2,500.00
Labor	\$ 1,700.00
Plant Forces IME	\$ 2,000.00
Subtotal	<u>\$ 6,200.00</u>
Contingency	<u>\$ 4,800.00</u>
Total	<u><u>\$40,000.00</u></u>

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The increased heating rate obtained with this equipment will provide the flexibility for a reduction of at least ten seconds in the canning furnace cycle time. Whether or not this flexibility is required for a shorter canning cycle would require the use of supplementary preheat baskets as an alternate to induction preheating. Cold sleeves freeze to the preheat basket and cannot be transferred in less than approximately 70 seconds. Preheat times of this magnitude result in gross nonwetting. There is a possibility of maintaining the 47-second preheat time by inserting the can in the sleeve about 23-seconds after the beginning of sleeve preheat. Potential problems or obstacles to be overcome using this approach are:

1. Material Handling

Sleeves and cans would be transferred directly to the furnace for mating during preheat.

2. Can Sleeve Assembly

Based upon a preliminary test, there may be difficulties in keeping AlSi out of the sleeve and possibly in completing the assembly.

3. Manpower Utilization

Manpower utilization resulting from relocation of the assembly operation should be evaluated.

This alternate, if successful, would provide for a reduction in the furnace time cycle only, and would not overcome the problems of outgassing of the sleeve coating into the molten AlSi and inadequate preheat temperature.

CONCLUSIONS

1. That a reduction in braze defects associated with the canning operation will be required to obtain the full potential savings of high quality brazing.

RECOMMENDATIONS

1. That a 50 KW, high frequency induction heating unit be installed in the 306 Pilot Plant for:
 - a. Evaluating the braze process capability improvement resulting from the elimination of outgassing of the sleeve coating into molten braze, and increasing the can temperature to that of the molten AlSi prior to brazing.

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- b. Increasing the flexibility of future Pilot Plant development work such as shorter canning cycles and new product quality optimization.

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Engineer,
Process Control Engineering Unit

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