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PROPOSED TEST FOR USING
ALSI MADE FROM 8001 SCRAP

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INTRODUCTION

An arbitrary limit of 0.5 per cent maximum nickel content in the canning and duplex AlSi baths was established in 1958 when large quantities of 8001 aluminum caps and cans began to be used. Prior to that date, most of the scrap generated at the facing lathes and the reject components was melted down, alloyed with silicon, and used for additions to the canning baths. Since the 8001 alloy contains approximately one per cent nickel, only about one-half of the scrap generated in the AlSi Shop can now be used for making reclaimed AlSi. It is estimated that an annual saving of \$37,000 could be expected on a eight-line shifts per day basis if only scrap was used.

One small, inconclusive test was conducted in the pilot plant in 1959 using 1.2 per cent nickel in the canning baths.^(1, 2) This test level was higher than the estimated 0.89 per cent average nickel content that would occur if only reclaimed AlSi made from 8001 alloy were used.

SUMMARY

It is proposed that an approximate 40-day canning test (10,000 pounds of high nickel AlSi) be run in which one canning line has only AlSi of 0.78 to 1.1 per cent Ni added as makeup. The other canning lines would be operated as usual. Under these conditions, it would take about 17 days to reach a level of 95 per cent of the ultimate average 0.89 per cent nickel content. The uranium cores canned in the test line should be only normal ingot uranium that has been fabricated using the standard process. This would amount to 1/3 of the normal production for about 40 canning days. The test material would be identified by the normal line identification stamped near the base end O.D.

Besides monitoring the nickel content and other impurities in the test and control lines, attributes, variables, and destructive fuel element data would be collected and analyzed. Attributes data includes per cent rejects by canning line for braze layer contamination, bad welds, pinholes, bond layer integrity, penetrations, and braze layer integrity. Variables data includes UT-4 total count and total bad discs, UE-1 total bond count, and canned reactivity. Destructive data will include bonding layer and weld mixing examination.

If only 8001 scrap AlSi were used for bath additions, it is estimated that an annual savings of \$36,500, \$41,500, and \$46,100 would result based on an 8, 9, or 10-line shifts per day basis, respectively.

DISCUSSION

The present and proposed monthly material balance for AlSi, aluminum, and silicon in the 313 Building canning lines on an eight-line shifts per day basis are shown in Figure 1. This material balance was calculated using:

- (1) HW-63115, "Effect of Increased Nickel Content in Canning Baths," C. A. Strand, February 2, 1960.
- (2) HW-63138, "The Influence of the Nickel Content of the Brazing on Fuel Element Weld Quality," G. R. Hanson, December 21, 1959.

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- 1) Average usage rates of virgin AlSi, elemental silicon, and aluminum caps and cans.
- 2) Average amount of aluminum scrap sold (skimmings, cups, and turnings).
- 3) Measurement of residual can wall thickness, thickness of AlSi layer, and decanned jacket weight.
- 4) Measurement of the amount of AlSi on the cups and in the can bases that is removed by the facing lathes.

The estimated annual savings of using no virgin AlSi are as follows:

Eight Line-Shifts/Day

Savings in Virgin AlSi @ 23¢/lb.	\$70,400
Cost of Additional Si @ 21¢/lb.	- 5,500
Scrap Value of Cups and Trimmings Used for Remelt @ 10¢/lb.	-28,000
TOTAL ANNUAL SAVINGS	\$36,900

Nine Line-Shifts/Day

TOTAL ANNUAL SAVINGS	\$41,500
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Ten Line-Shifts/Day

TOTAL ANNUAL SAVINGS	\$46,100
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For this test, it is proposed that only 8001 alloy diluted with the proper silicon concentration be added to one particular canning line duplex and canning bath. On this basis, the average buildup of nickel in a duplex and canning bath was calculated as outlined in the Appendix. The results are shown in Figures 2 and 3, assuming an initial nickel content of 0.35 and 0.40 per cent in the duplex and canning bath AlSi. The ultimate nickel concentration obtained in the AlSi under these ideal conditions would average about 0.89 per cent with a range of 0.8 to 1.1 per cent nickel. The percentage of the ultimate nickel content by days canned is also shown in Figures 2 and 3. It will take about 17 days of adding only 8001 AlSi to reach a level of 95 per cent of the ultimate average nickel content.

The high nickel content AlSi for this test could be obtained by (1) melting down reject 8001 components and alloying with silicon at HA^{20} and/or (2) purchasing 12.5 per cent silicon AlSi containing 0.78 to 1.1 per cent nickel and 0.40 to .60 per cent iron. Aluminum scrap from the facing lathes should not be used for making AlSi for this test since the nickel content would be lower than required due to dilution with AlSi from the canning baths. Elemental nickel should not be used for adjusting the nickel content in scrap AlSi due to the danger of introducing undissolved nickel particles into the canning

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bath which may collect in the induction channels. Since the quantity of reject 8001 components on hand and available for remelt is very small, it is proposed that a 10,000 pound lot (the smallest quantity that the suppliers will cast) of 8001 AlSi ingots be purchased for this test. The price of approximately 26.5¢/pound is only about 3¢/pound higher than for regular AlSi ingots or about \$300 more for a 10,000 pound order.

It is suggested that this test be run until the 10,000 pounds of 8001 AlSi are used up, which would be about 40 operating days. The uranium cores canned in the test line should be only normal ingot uranium that has been fabricated using the standard process. The canning line used for the high nickel test would be identified by the normal line identification stamp now being used on the base end O.D. If desired, the material from this test canning line could be segregated at final into separate pallets.

Canning bath behavior and fuel quality will be monitored during the time the nickel content is increasing to equilibrium and for the duration of the test. The AlSi in the canning and duplex bath in the test line will be sampled each day for nickel content as well as other impurities. The other canning lines will be sampled twice a week as usual. Any unusual furnace problems in the test line will be noted.

Comparison of the high nickel AlSi canning line fuel elements with the other normal uranium canning line fuel elements having less than 0.5 per cent nickel will be as follows:

1) Attributes data by canning line.

- a) Per cent braze layer contamination (BLC) rejects.
- b) Per cent weld rejects (WR).
- c) Per cent pin hole (PH) rejects.
- d) Per cent bond layer integrity (BLI) rejects.
- e) Per cent thin wall (TW) rejects.
- f) Per cent braze layer integrity (UT-4) rejects.

2) Variables data by canning line.

- a) UT-4 Data - Collect ten samples per line per shift per day before UT-4 testing in the 313 Building and transfer these samples to the Pilot Plant at the end of a product model run for UT-4 testing. Record and analyze total internal and external count and total bad discs (TBD) by canning line. This sampling technique should total approximately 2,400 fuel elements.
- b) Total Bond Count - Bond test the above UT-4 samples in the Pilot Plant and record and analyze the total internal and external bond count by canning line. In addition, the Quality Certification external total bond count data should be analyzed by canning line. The Quality Certification sample size is 20 pieces per line per lot and approximately five Quality Certification lots are canned per week, or about a total of 2,400 fuel elements.

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- c) Reactivity Test - A test stringer of eleven fuel elements should be taken from the pieces canned in the high nickel test line and submitted to the 305 Test Reactor for reactivity measurements. Eleven pieces from one of the control canning lines should also be submitted for comparison. Since the ingot chemistry and density has such a major effect on reactivity, the Quality Certification samples should be used for the comparison. If care is taken in handling the elements, they should still be suitable for Quality Certification charges.

3) Destructive Examination

- a) Bonding Layer - Collect three samples per line per week and transfer them to the Metallography Laboratory for compound layer examination.
- b) Weld Mixing - Collect at least five samples per line per shift per day (150 per week) and section them in the Process Control Laboratory or Metallography Laboratory for examination of weld mixing, cracking, stringers, etc. These samples can be obtained from reject fuel elements other than weld rejects.

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APPENDIX

Calculation of Ni Buildup in the Duplex and Canning Bath AlSi

A = 100 lbs/day of makeup AlSi (50 lbs of 10% Si and 50 lbs of 12.5% Si). Makeup AlSi is made from 8001 alloy scrap with average Ni content of 1.0% plus Si.

a = 0.8875% Ni (10% Si metal @ 0.90% Ni and 12.5% Si metal at 0.875% Ni).

B = Average amount of AlSi in duplex bath is 640 lbs.

c = Per cent Ni in duplex AlSi (varies with time).

H = Estimated weight of 50 lbs of AlSi lost per day (eight lbs of thermal samples and 42 lbs of skimmings).

Y = A-H = 50 lbs/day of AlSi carried over into the canning bath from the duplex bath.

T = 150 lbs/day of makeup AlSi (75 lbs of 12.5% Si and 75 lbs of 13.5% Si). Makeup AlSi is made from 8001 alloy with average Ni content of 1.0% plus Si.

v = 0.870% Ni (12.5% Si metal at 0.375% Ni and 13.5% Si metal at 0.865% Ni).

R = 32.3 lbs/day of 8001 alloy dissolved in the bath from spires and cans. Estimate is based on measuring residual aluminum can and spire wall thickness on K4N elements to obtain thickness of aluminum dissolved (2.65 mil on the can and 1.80 mil on the spire). That thickness times the area (can 43.36 sq. in., spire 20-32 sq. in.) times the density (0.098 lbs/in.³) times the canning rate per line (2176/day) gave 32.3 lbs per day average.

s = 1.0% average Ni content in 8001 alloy.

W = T + R = 182.3 lbs/day.

y = 0.893% Ni

X = Average amount of AlSi in the canning bath is 1350 lbs.

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b = % Ni in the canning bath (varies with time).

t = Time in days.

In calculating the concentration of Ni in the duplex (c) and canning baths (b) with time (t), it is assumed that:

- 1) Perfect mixing of Ni occurs in the duplex and canning bath AlSi.
- 2) The only variables are c, b, and t.
- 3) The initial concentrations, based on average analyses, are:

$$a) \quad c_o = 0.35\% \text{ Ni}$$

$$b) \quad b_o = 0.40\% \text{ Ni}$$

A Ni material balance was used to solve the relation of variation in Ni concentration with time. To establish the basic differential equation, the following form was used:

$$\text{Input} - \text{Output} = \text{Accumulation}$$

I. DUPLEX BATH ALSI

$$Aadt - \frac{A(c+c+dc)dt}{2} = B(c+dc-c)$$

$$(Aa-Ac)dt - \frac{Adc}{2} = Bdc$$

The term dcdt is dropped since it is insignificant.

$$\text{Therefore: } \int_{t_o}^t dt = \int_{c_o}^c \frac{Bdc}{Aa-Ac} = \frac{-B}{A} \ln(Aa-Ac) \Big|_{c_o}^c$$

$$\ln(Aa-Ac) = \frac{B}{A} \frac{\ln(Aa-Ac_o) - (t-t_o)}{B/A}$$

$$(Aa-Ac) = e^{\frac{B/A \ln(Aa-Ac_o) - (t-t_o)}{B/A}}$$

$$c = \frac{Aa}{A} - \frac{e^{\frac{B/A \ln(Aa-Ac_o) - (t-t_o)}{B/A}}}{A}$$

$$c = .008875 - \frac{e^{\frac{-3.975 - (t-t_o)}{6.4}}}{100}$$

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A plot of % Ni in the duplex bath with time is given in Figure 2. The average asymptotic Ni concentration in the duplex bath AlSi is 0.8875%. A curve showing the percentage of the asymptotic Ni concentration with time is also shown in Figure 2.

II. CANNING BATH ALSi

The method for deriving the equation for the Ni content in the canning bath AlSi is similar to that for the duplex bath AlSi, except it is complicated by the variation in the Ni content (c) in the carryover from the duplex bath.

$$(Yc+Wy)dt - (w+Y) \frac{(b+db+db)}{2} db = X(b+db-b)$$

$$b_2 = \frac{(Yc+Wy)}{W+Y} - e^{\frac{\frac{X}{W+Y} \ln[Yc+Wy - (W+Y)b_1] - (t_2-t_1)}{\frac{X}{W+Y}}}$$

$$b_2 = \frac{50c+1.628}{232.3} - e^{\frac{5.808 \ln(50c+1.628-232.3 b_1) - (t_2-t_1)}{5.808}}$$

To obtain a plot of Ni concentration with time in the canning bath, it was necessary to solve the equation in increments of one day for the first ten days and in increments of two days for the next 12 days. The average value of Ni content in the carryover from the duplex bath (c) for the time increment in question was used in solving the equation for each increment.

A plot of per cent Ni in the canning bath with time is given in Figure 3. The average asymptotic Ni concentration in the canning bath is 0.8915%. A curve showing the percentage of the asymptotic Ni concentration with time is also shown in Figure 3.

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A. PRESENT MATERIAL BALANCE

B. PROPOSED MATERIAL BALANCE

FIGURE 1. PRESENT AND PROPOSED Al-Si, Al, AND SI MATERIAL BALANCE ON AN 8-LINE SHIFTS/DAY. BASIS.

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FIGURE 2
CALCULATED BUILDUP OF NICKEL IN THE DUPLEX BATH WITH TIME

AVERAGE PER CENT NI IN CANNING BATH ALSI

FIGURE 3
CALCULATED BUILDUP OF NICKEL IN THE CANNING BATH WITH TIME

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