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RESULTS OF PRODUCTION TEST IP-206-CE
IN PILE TESTS OF BORON STAINLESS STEEL SPLINES

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RESULTS OF PRODUCTION TEST IP-206-CE IN-PILE TESTS OF BORON STAINLESS STEEL SPLINES

INTRODUCTION

A solid spline made of 430 boron stainless steel was tested in tube 2451 at D Reactor. The test was conducted to compare the boron carbide filled hollow aluminum spline presently used with a solid steel spline which is being considered as a substitute. Usage of hollow splines has shown that a solid rugged spline would be highly desirable. Comparisons of spline radiation and reactivity effect were obtained both in-pile and in out-of-pile test facilities.

Results of the production test are reported in this document. Production Test IP-206-CE⁽¹⁾ is closed by this report.

SUMMARY

The use of stainless steel splines with boron added for nuclear poisoning appears practical if certain limitations are placed on their use. Long irradiations of the stainless steel splines will saturate the splines so that the decay rate will be dangerously slow. The slow decay can be particularly serious if there is a malfunction of the equipment. The stainless steel splines can best be used for startup where they are left in the reactor a maximum of 24 hours.

Unless large quantities of Boron-10 are used the stainless splines will be less effective than the presently used boron-aluminum splines. A stainless steel spline alloyed with 1½ percent boron will be only 60 percent as effective as the boron-aluminum spline.

(1) HW-58496, "Production Test IP-206-CE, In-Pile Tests of Boron Stainless Steel Splines," P. B. McCarthy and W. S. Nechodom, 9-17-59. (Confidential)

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Radiation received during removal of stainless steel splines will be less than that received while removing aluminum-boron splines. For the first 17 minutes the stainless steel spline is considerably "cooler" than the aluminum-boron spline.

DISCUSSION

The presently used aluminum clad boron carbide splines have many drawbacks which a solid spline would eliminate. The best contender for a solid spline material is boron stainless steel. The boron stainless steel spline cuts easily in the present choppers prior to disposal and being solid, does not swell; however, radiation involved may be a problem.

Radiation from Splines

Figure I and Tables I and II show the results of irradiation tests on the boron steel material. Tests to obtain data for these curves were run at 105-F by the Irradiations Testing Group. Figure I⁽²⁾ also shows a comparison between the aluminum and boron steel spline on a gram weight basis. Figures II and Tables III and IV show a radiation comparison between the steel and aluminum boron spline as they come out of a reactor. Review of these curves and data will show that:

1. The length of exposure is very critical to the stainless steel spline. For long exposure slow decay occurs which can increase disposal problems as well as prohibit corrective action if equipment failures occur.
2. Seventeen minutes after removal from the reactor, the aluminum spline and the steel spline have the same radioactivity.
3. Beyond 17 minutes out of pile the steel spline is always more radioactive than the aluminum spline, and sooner than 17 minutes the aluminum spline is much "hotter."

Although few problems are anticipated using the spline chopper with the steel spline, problems which are encountered will be greatly magnified because of the slow decay rate on the steel. Blade dulling problems, kinking, and small aluminum chips hanging up in the chopper shield will have no counterpart when stainless steel splines are used.

In a recent case at 105-D a piece of spline hung up in the spline chopper and after 24 hours read 200 mr/hr at 2 feet through 1/2 inch of lead. If this incident had happened to a boron stainless steel spline which had been in the reactor 9 days it would have read 2 r/hr at 2 feet.

During the removal of the splines from tube 2451 a radiation detector was placed 11 inches away from the spline on the nozzle above the tube that the spline was being pulled from. For the boron steel spline the maximum reading was 120 r/hr while for the aluminum B₄C spline the reading was an estimated 8300 r/hr. Exposure on the elevator will be much less for the steel spline than for the aluminum B₄C spline for the first 15 minutes which is the time when most of the personnel exposure occurs.

(2) Letter, J. C. Johannesen to P. B. McCarthy, 10-23-56, HAP0 155, Poison Spline Activation Studies.

DECLASSIFIEDReactivity Effect of Splines

Table V shows the effect on the rods and outlet water temperature of inserting a spline into tube 2451D. Using rods to determine the difference in reactivity between the two splines produced surprisingly close results compared to calculations and 305 pile tests. The rods showed steel splines to be between 50 and 70 percent as effective as the aluminum B₄C splines. The calculations and 305 pile tests shows the effectiveness to be about 60 percent. The predicted effectiveness and 305 pile measured effectiveness of stainless steel splines with three different boron contents are shown in Table VI. Based on the values in this table and the effectiveness formula steel splines with at least 70 percent effectiveness have been ordered.

Spline Material

The stainless steel used in the test was Type 430 alloyed with 1½ percent boron. As more boron is added the steel becomes more difficult to work. Samples with up to 2½ percent boron were fabricated with difficulty. A stainless with about 2 percent boron appears to be about the limit but to obtain the desired "blackness" and thickness some enrichment (Boron 10) would have to be added. Since Boron 10 costs about \$3.30 per gram it is not economically possible to add very many grams to each spline. However, the Boron 10 with a cross section of 4020 barns is much more effective than natural boron with a cross section of 755 barns, so it may not be necessary to add very much Boron 10.

ACKNOWLEDGEMENTS

Through the cooperation of D Processing Operation it was possible to run the test and obtain decay curves on test splines.

Paul B. McCarthy

Engineer, Mechanical Development "B"
Equipment Development
IRRADIATION PROCESSING DEPARTMENT

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FIGURE 1

DECAY CURVES

Samples tested by Irradiation Testing

1.5% Boron in 430 stainless steel

2.003 days in-pile (— — — —)

1.5% Boron in 430 stainless steel

8.948 days in-pile (————)

Aluminum (type 6063) and B_4C

33 days in-pile (-----)

mr/hr/gram
at
1 foot
in air
at
 10^{13}
flux

DECAY CURVES

Tube 2451-D - 11-7-58 to 11-25-58

Boron-Steel (----)
 1.5% Boron
 430-Stainless Steel
 13½ feet in active zone
 18 hours exposure at
 full pile power
 9 inch probe to spline in
 a can

Boron-Aluminum (-----)
 Boron carbide powder
 6063S-T4 aluminum cover
 13½ feet in active zone
 6 days exposure at full
 pile power
 9 inch probe to spline in
 a can

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FIGURE II

r/hr
 in
 air
 at
 9 inch

DECLASSIFIEDTABLE I

PIECE 1-A

 ΔT -51.6.

Operating Time-8.948 days

Boron Steel with Graphite Carrier FLOW-32.2W.T. 1.1766 gm.

<u>Time</u>	<u>Reading</u>	<u>R/hr</u>	<u>R/hr/gm</u>
2 minutes	1.52×10^{-10}	.596	.506
3 minutes	1.49×10^{-10}	.584	.496
4 minutes	1.47×10^{-10}	.576	.490
5 minutes	1.43×10^{-10}	.561	.477
10 minutes	1.38×10^{-10}	.541	.460
15 minutes	1.36×10^{-10}	.533	.453
30 minutes	1.28×10^{-10}	.502	.427
1 hour	1.14×10^{-10}	.447	.380
2 hours	$.92 \times 10^{-10}$	.361	.306
3 hours	$.79 \times 10^{-10}$	.310	.263
4 hours	$.68 \times 10^{-10}$	.267	.227
5 hours	$.6 \times 10^{-10}$	.235	.199
6 hours	$.54 \times 10^{-10}$	.212	.180
7 hours	$.49 \times 10^{-10}$	.192	.163
8 hours	$.45 \times 10^{-10}$	.176	.150
9 hours	$.41 \times 10^{-10}$	.161	.137
10 hours	3.95×10^{-11}	.155	.132
11 hours	3.8×10^{-11}	.149	.127
12 hours	3.7×10^{-11}	.145	.123
13 hours	3.6×10^{-11}	.141	.120
14 hours	3.45×10^{-11}	.135	.115
15 hours	3.38×10^{-11}	.132	.112
16 hours	3.32×10^{-11}	.130	.110
17 hours	3.28×10^{-11}	.129	.109
18 hours	3.22×10^{-11}	.126	.107
19 hours	3.18×10^{-11}	.124	.105
20 hours	3.12×10^{-11}	.122	.104
30 hours	2.8×10^{-11}	.110	.093
40 hours	2.7×10^{-11}	.106	.090
50 hours	2.6×10^{-11}	.102	.087
60 hours	2.5×10^{-11}	.098	.083

DECLASSIFIEDTABLE II

PIECE NO. 30

-T 52.5

Operating Time 2.003 days

Stainless Steel with Boron -Flow 39.3W.T. 1.6415 gm.

<u>Time</u>	<u>Reading</u>	<u>R/hr</u>	<u>R/hr/gm</u>
2 minutes	1.78×10^{-10}	.698	.425
3 minutes	1.72×10^{-10}	.674	.411
4 minutes	1.68×10^{-10}	.659	.401
5 minutes	1.62×10^{-10}	.635	.387
10 minutes	1.55×10^{-10}	.608	.370
15 minutes	1.54×10^{-10}	.604	.368
20 minutes	1.54×10^{-10}	.604	.368
30 minutes	1.54×10^{-10}	.604	.368
1 hour	1.4×10^{-10}	.549	.334
2 hours	1.1×10^{-10}	.431	.263
3 hours	$.88 \times 10^{-10}$	.345	.210
4 hours	$.7 \times 10^{-10}$	.274	.167
5 hours	$.57 \times 10^{-10}$	.223	.136
6 hours	$.46 \times 10^{-10}$	.180	.110
7 hours	$.38 \times 10^{-10}$	.149	.091
8 hours	3.2×10^{-11}	.125	.076
9 hours	2.8×10^{-11}	.110	.067
10 hours	2.4×10^{-11}	.094	.057
11 hours	2.1×10^{-11}	.082	.050
12 hours	1.8×10^{-11}	.071	.043
13 hours	1.7×10^{-11}	.067	.041
14 hours	1.55×10^{-11}	.061	.037
15 hours	1.4×10^{-11}	.055	.034
16 hours	1.3×10^{-11}	.051	.031
17 hours	1.2×10^{-11}	.047	.029
18 hours	1.1×10^{-11}	.043	.026
19 hours	1.05×10^{-11}	.041	.025
20 hours	1.03×10^{-11}	.040	.024

DECLASSIFIEDTABLE IIIBORON-ALUMINUM SPLINE DECAY DATA

Spline presently in use (6063-T4 AL & B₄C)

Exposed in tube 2451D

Six days exposure at full pile power

Readings above 500 r/hr extrapolated from data previously run by
Irradiations Testing.

<u>Time</u>	<u>Reading R/Hr at 9 inch</u>
12 minutes	500
13.3 minutes	400
15.6 minutes	300
23.3 minutes	200
2 hours	150
4 hours	80
6 hours	43
7.8 hours	29
11.8 hours	14
15.8 hours	6
19.8 hours	4
27.8 hours	2.2
35.8 hours	1.0
55.8 hours	.490 (m rads/hr)
70.8 hours	.190 (m rads/hr)

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TABLE IVBORON STAINLESS STEEL SPLINE DECAY DATAMaterial

Heat	X895-3
Carbon	.09 percent
Manganese	.07 percent
Silicon	.16 percent
Chromium	16.45 percent
Boron	1.56 percent
Phosphorus	.005 percent
Sulphur	.006 percent
Iron	balance

Exposed in tube 2451D for 18 hours at full pile power level.

<u>Time</u> <u>Hours</u>	<u>Reading</u> <u>R/Hr at 9 inch</u>
0	320
2	180
4.6	100
5.4	70
9.9	26
13.9	14
18.0	8
22.0	7
26.0	6
30.0	4.8
38.0	3.9
54.0	2.8
65.9	2.5
70.0	2.4
240.0	1.5

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TABLE V
EFFECT OF INSERTING SPLINES
INTO TUBE 2451D WHILE
OPERATING AT FULL POWER LEVEL

	<u>Boron-Aluminum</u> <u>Standard .050" Thick</u> <u>Spline</u>	<u>1.5 percent Boron</u> <u>Stainless Steel</u> <u>Spline</u>
Distance Inserted, Feet	24	24
Distance in Active Zone (no Uranium In Tube), Feet	13½	13½
Temperature Drop in Tube Above and Below 2451, Average, °C	1.0	0.7
Temperature Before Inserting Spline, °C	72	72
In-hour Value as Determined by Rod Calibration	2	1+

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TABLE VI

305 PILE TESTING OF BORON STAINLESS STEEL SPLINE SAMPLES⁽¹⁾

Following are the results of relative reactivity tests on short boron stainless steel spline samples performed in the 305 Test pile on October 31, 1958. The materials tested and the results in percent relative effectiveness using the AL-B₄C spline as a standard are given below. Also the predicted values are given.

<u>Sample</u>	<u>% Effectiveness Measured</u>	<u>Average Thickness in.</u>	<u>Predicted Effectiveness</u>
AL-B ₄ C	100	- -	100
1.5 wt % boron in SS	60.3	.051	63
2.0 wt % boron in SS	71.7	.051	71.5
2.5 wt % boron in SS	77.4	.051	78

To calculate the effectiveness as a function of thickness the following relationships are adequate. (These values assume the standard B₄C spline has effectiveness of 1.0.)

$$\text{Eff.} = 1 - e^{-cx} \quad \text{where } x \text{ is thickness in inches}$$

c is constant for material

<u>Material</u>	<u>Value of c</u>
1.5 wt % boron in SS	18.1
2.0 wt % boron in SS	25.25
2.5 wt % boron in SS	29.16

These values of "c" were determined from the experiment and are standardized to .050 inch thickness. The effectiveness calculated for thinner splines will probably be slightly lower than the actual case, but by no more than an effectiveness of .04 - .05. For thickness of 30 mils or more the equation should yield a result conservative by no more than an effectiveness of .03.

⁽¹⁾ Letter from G. F. Owsley to P. B. McCarthy, same subject, dated 12-5-58.

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