Hw-65579

**Cover Sheet for a Hanford
Historical Document
Released for Public Availability**

Released 1994

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

DISCLAIMER

This is a **historical document** that is being released for public availability. This was made from the best available copy. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes any **warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.** The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

DOCUMENT NO.

HW-65579

SERIES AND COPY NO

DATE _____

June 14, 1960

XX

XX [REDACTED] **RESTRICTED**

THIS DOCUMENT CONTAINS UNCLASSIFIED DATA
EXCLUDED IN THE ATOMIC ENERGY ACT OF 1946.
IT IS TRANSMITTED IN THIS MANNER TO AVOID DISCLOSURE OF ITS
CONTENTS IN ANY MANNER TO AN UNAUTHORIZED
PERSON IS PROHIBITED.

TITLE

MEASUREMENT OF FUEL ELEMENT BOND

STRENGTH

7

OTHER OFFICIAL CLASSIFIED INFORMATION

THIS MATERIAL CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U. S. C., SECS. 793 AND 794, THE TRANSMISSION OR REVELATION OF WHICH IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

AUTHOR

C. A. Strand
Process Engineering
FPD

ISSUING FILE COPY
HALL 2ND FLOOR AREA

JUN 24 1960

RETURN TO

~~TECHNICAL INFORMATION FILE~~

THIS DOCUMENT MUST NOT BE LEFT UNATTENDED OR WHERE AN UNAUTHORIZED PERSON MAY HAVE ACCESS TO IT. WHEN NOT IN USE, IT MUST BE STORED IN AN APPROVED LOCKED REPOSITORY WITH AN APPROVED GUARDIAN AREA. WHILE IT IS IN YOUR POSSESSION AND UNTIL YOU HAVE OBTAINED A RETURNED RECEIPT FOR QUALIFIED FILES, IT IS YOUR RESPONSIBILITY TO KEEP IT AND ITS CONTENTS WITHIN THE LIMITS OF THIS PROJECT AND TO PREVENT ANY UNAUTHORIZED DISCLOSURE. ITS TRANSMITTAL AND STORAGE AT YOUR PLACE OF RESIDENCE IS PROHIBITED. IT IS NOT TO BE DUPLICATED. IF ADDITIONAL COPIES ARE REQUIRED, OBTAIN THEM FROM THE RELATED WORKING FILE. ALL PERSONS RECEIVING THIS DOCUMENT ARE REQUESTED TO SIGN IN THE SPACE PROVIDED BELOW.

[illegible]

DECLASSIFIED

DECLASSIFIED

HW-65579

This document consists
of 11 pages, [REDACTED]

June 14, 1960

MEASUREMENT OF FUEL ELEMENT BOND STRENGTH

C. A. Strand
Engineer, Process Engineering
Fuels Preparation Department

DISTRIBUTION

1. WA Blanton
2. AG Blasewitz
3. CA Burgess
4. FW Grubb
5. LT Hagie
6. GB Hansen
7. JL Jaech
8. HP Kraemer
9. WM Mathis
10. HC Money
11. TD Naylor
12. CA Strand
13. JT Stringer
14. JW Talbott
15. JC Tverberg
16. EA Weakley
17. Record Center
18. 300 Files
- 19-21. Extra

Classification Cancelled and Changed To

DECLASSIFIED

By Authority of RM - Iten

CG-PR-2, 1-27-94

By J E Saurly 2-25-94

Verified By Gerri M. Aley, 3-5-94

MASTER

DECLASSIFIED

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DECLASSIFIED

HW-65579

MEASUREMENT OF FUEL ELEMENT BOND STRENGTH

Introduction

Until recently, bond adherence between the Al-Si braze layer and the uranium core was estimated by a method known as the "chisel test". Fuel element jackets were removed from the core using a hammer and chisel, and the relative bond strength was estimated on a comparison basis. Bonds were classified as normal, below normal, or better than normal, depending upon the ease with which the jacket was removed. The weakest bonds were usually found one-to-two inches below the fuel element cap, but on occasions extended as far as five inches below the cap prior to making process changes in the duplex canning bath to improve bonding.

After duplex furnace conditions were changed (silicon concentration, core submersion depth, and temperature) during September, 1958, the weak bond area was reduced to a band 1/4 inch to 1 inch below the cap end of the piece.

Recently, the stud-pull method for determining bond strength was developed providing a better method for measuring bond quality. Bond strength measured by the stud-pull method provides actual tensile strength measurements, which are valuable for test purposes and detecting in-process variations. This report summarizes tests made using the Instron Tensile Strength Machine for determining fuel element bond strength.

Summary

The stud-pull method for determining fuel element bond strength has been developed sufficiently to serve as an additional measurement of bond quality. The test is capable of detecting variation in bond strength produced by changing process variables which affect bonding. Average production fuel element bond strength has been determined to be over 13,500 psi tensile strength with actual values varying from 4000 psi to 20,000 psi.

Bond strength measurements are made by welding 1/4 in. diameter studs to the fuel element jacket by the Graham Stud Welding Process. The Instron Tensile Strength Machine is then used to pull the stud and measure the force required to break the bond.

Although only limited data is available on fuel elements preheated with horizontal agitation, the stud-pull method for determining bond strength has been demonstrated to be capable of detecting variations in bond

DECLASSIFIED

HW-65579

strength of fuel elements preheated in the sixty-degree duplex basket. Measurement of bond strength of cores preheated in the horizontal basket is continuing.

It is recommended that Quality Control use this test in the Quality Certification program as an added means for measuring, controlling, and/or predicting fuel element quality.

Discussion

Comparative fuel element bond strengths were previously determined using the "chisel test". As implied, this test was performed by removing the fuel element cap and base ends and stripping the jacket from the core with a hammer and chisel. Bond strengths were estimated by comparing the difference in manual force required to remove the jacket, the sound of the breaking bond, and the appearance of both the core and can surfaces after jacket removal. Generally, bond strengths fell into three categories of normal, below normal, and better than normal.

Although the "chisel test" was subjective in nature, it served as a valuable tool. During earlier tests for improving fuel element bonding, the "chisel test" was the only convenient method available for estimating the effect of process changes on bond strength. Initial applications of the stud-pulling technique⁽¹⁾ offered a direct method for measuring bond tensile strength. Through use of this test, it will be feasible to design better tests for improving bond quality and measure the resulting changes in bond strength.

Bond strength is measured by welding an 1100-H18 alloy aluminum stud to the fuel element jacket, and pulling the stud with an Instron Tensile Strength Machine. The aluminum stud is made according to a patent held by the Graham Stud Welding Company. (See Drawing No. H-3-7993.) Studs are welded to the fuel element jacket using a Graham Stud Welder set as follows: amperage - 115; pressure - 75 psig. The fuel element with attached studs is placed in the carriage of the Instron Tensile Strength Machine and secured in line with the jaws on the crosshead. A large number of crosshead speeds and chart speeds are available on the present test equipment. A combination of crosshead speed of 0.02 inch per minute, a chart speed of 0.5 inch per minute, and a chart range of 0 to 2000 pounds has been found to be satisfactory for measuring fuel element bond tensile strength.

Recently a controlled test was made to determine whether the "stud-pull method" could detect the variation in bond strength normally observed by the "chisel test". Fuel elements were fabricated using three different

1. Tverberg, J. C., "Bond Strength Evaluation of the Brittle Bond Problem in Production Fuel Elements". November 10, 1958. (Confidential-Undocumented)

DECLASSIFIED

7
HW-65549

levels of duplex furnace Al-Si silicon content (8.5%, 9.5%, and 10.5%) to produce varying amounts of weak (brittle) bonds. As in the past, the higher the silicon concentration, the larger the area of weak bonding. This was verified by pulling four studs on each of thirty (30) fuel elements. Bond strengths as measured by the stud-pull test are shown in Fig. 1. Note that as the silicon content decreases, the area of strong bonding increases as if by pushing the weaker bond up and off the top end of the piece. Statistical analysis⁽²⁾ of the test data indicates that there is a very strong difference between bond strength measured at the top end of the pieces and that measured at the center and base, which is essentially the same. Due to the small sample size at varying duplex furnace temperatures, there was no significant temperature effect upon bond strength detected. However, the effect of duplex Al-Si silicon content was significant. Results of the statistical analysis of these data are shown in Fig. 2, where bond strengths are plotted against duplex furnace Al-Si silicon content. The bond strength data are summarized by showing a comparison of average strength, minimum strength, and maximum minus minimum strength. Note in these curves that average bond strength maximizes at a silicon content of about 9.5%. There are two reasons for this increased strength at 9.5% silicon using the sixty-degree preheat basket. At higher silicon concentrations, increased amounts of the brittle laminar compound layer are formed at the top of the core. At lower concentrations, a considerably thicker UAl_3 -type compound is formed at the base end of the core, which is slightly weaker than that formed at 9.5% silicon content. Average minimum strength decreases as the silicon content increases because of the pronounced "brittle bonding" produced with the sixty-degree preheat basket at higher silicon levels. A third line has been added to show the relationship between the maximum and minimum bond strengths. This line is straight and shows a difference of 375 pounds force at 10.5% silicon, decreasing to 230 pounds force at 8.5% silicon. The general reduction in difference is due to less "brittle bonding" at the top end of core as the Al-Si silicon content is reduced. A slight decrease in middle and base end bond strength at the low silicon level also contributed to the reduction in the difference between maximum and minimum values.

Bond strengths of two-hundred (200) I & E fuel elements produced in the 313 Building were determined and the raw data was statistically⁽³⁾ analyzed. These data show that there was no difference between bond strengths taken one inch from each end and in the center of the fuel element. No differences were observed because the area of weak "brittle bonding" when using the sixty-degree basket is just above the spot where the upper stud is welded. (This typical cap-end brittle area has since been eliminated by use of the horizontal duplex basket.)

2. Jaech, J. L. Personal Communication. May 5, 1960.

3. op. cit., J. L. Jaech, reference 2.

DECLASSIFIED

HW-65579

Average bond strength by canning line and lot for the production fuel elements was determined by pulling studs from six pieces per line per lot. The average of these pieces was found to be 15,040 psi tensile strength, corresponding to 737 pounds force, the direct chart reading which is a more convenient method for expressing bond strength. Data from these tests are shown in Fig. 3 and 4. Fig. 3 is a control chart with three sigma limits showing the average bond strength by line. Fig. 4 shows the average bond strength and range per lot.

It is recommended that the control chart method for showing bond strength be adopted by Quality Control for the Quality Certification Program. Since large changes in bond strength are of major concern, it is suggested that average bond strength and range be recorded for each canning line and production lot, to express the bond strength of outgoing fuel elements. By pulling three studs from each of five pieces per line shift, it will be possible to detect both line variation and lot/or shift variation in bond strength. There is a probability of 93% for detecting a line variation of 200 pounds force in five samples. Since the lot/or shift sample will be larger, the possibility of detecting smaller changes will increase as shown in Fig. 5. Probability for detecting changes in average bond strength ranging from 25 to 300 pounds force for a given sample size is given in Fig. 5.⁽⁴⁾ Expressing the lot average and range will also be a valuable development tool for use in measuring future improvements in fuel element bonding. It appears that it would be desirable to maintain the present average bond strength, but to produce greater uniformity within each piece and lot.

C. A. Strand

C. A. Strand, Engineer
Process Engineering
Fuels Preparation Department

CAS:gab

4. op. cit., J. L. Jaech, Page 4.

REFERENCES

1. Tverberg, J. C., "Bond Strength Evaluation of the Brittle Bond Problem in Production Fuel Elements". November 10, 1958. (Confidential-Undocumented)
2. Jaech, J. L. Personal Communication. May 5, 1960.
3. Jaech, J. L. Personal Communication. May 5, 1960.
4. Jaech, J. L. Personal Communication. May 5, 1960.

DECLASSIFIED

DECLASSIFIED

Fig. 1

AVERAGE FUEL ELEMENT BOND STRENGTH ACCORDING TO LOCATION MEASURED ON CORES PREHEATED IN THE SIXTY DEGREE DUPLEX BASKET AND BRAZED WITH VARYING SILICON CONTENT Al-Si

DECLASSIFIED

HW-65579

Fig. 2

EFFECT OF DUPLEX FURNACE AL-Si SILICON CONTENT UPON FUEL ELEMENT BOND STRENGTH

DECLASSIFIED

HW-65579

Fig. 3

Control chart showing average bond strength by line. Each point is the average bond strength for six fuel elements. Three sigma limits are shown.

DECLASSIFIED

Fig. 4

Control chart showing average bond strength and range per fuel element lot.

**FIGURE 5 - PROBABILITY FOR DETECTING
CHANGES IN AVERAGE BOND STRENGTH FOR A
GIVEN SAMPLE SIZE**

UNCLASSIFIED

DATE

FILMED

6 / 14 / 94

END