ANL-6216
Reactors - General
(TID-4500, 15th Ed.)
AEC Research and
Development Report

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois

REMOVAL OF EBWR FUEL ELEMENT SCALE
BY SLURRY HONING

by

Ira Charak

Reactor Engineering Division

September 1960

Operated by The University of Chicago
under
Contract W-31-109-eng-38

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, 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. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	4
I. INTRODUCTION.	4
II. EQUIPMENT	4
A. Gun and Carrier.	5
B. Plate Support and Table.	6
C. Cover.	6
D. Mixing Apparatus	8
III. ABRASIVES.	9
IV. AIR SUPPLY	10
V. SAMPLES	10
VI. SCOPE OF THE TEST.	10
VII. TEST PROCEDURE	11
VIII. RESULTS	12
IX. CONCLUSIONS.	16
X. RECOMMENDATIONS	16
REFERENCES	18
ACKNOWLEDGMENT	18

LIST OF TABLES

<u>No.</u>	<u>Title</u>	<u>Page</u>
1.	Summary of Data of Slurry Honing Test	12

LIST OF FIGURES

<u>No.</u>	<u>Title</u>	<u>Page</u>
1.	Gun and Carrier Assembly.	5
2.	Plate Support and Table.	7
3.	Complete Slurry Honing Assembly.	8
4.	Slurry Mixing Apparatus	9
5.	Plate HT-10 before Blasting.	13
6.	Plate HT-10 after 10 Seconds of Blasting	13
7.	Plate HT-10 after 40 Seconds of Blasting	13
8a.	Unscaled, Unblasted Portion of Plate 28-B (13X)	14
8b.	Spot 28-B2 after Blasting (13X).	15
9.	Spot 813-D1 after Blasting Showing Scale Surface Demarcation (13X)	15
10.	Spot 21-D2 after Blasting (13X).	15

REMOVAL OF EBWR FUEL ELEMENT SCALE BY SLURRY HONING

by

Ira Charak

ABSTRACT

The scale deposit on the EBWR fuel plates can be removed by slurry honing the plates with an abrasive-water mixture. Problems inherent in any production operation of this type are discussed. Areas of continued investigation of the method are suggested.

I. INTRODUCTION

The problem of aluminum oxide monohydrate ($\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$) scale deposition on the EBWR fuel plates has been described in detail elsewhere.⁽¹⁾ Efforts to remove the scale by chemical and heating methods were fraught with frustration. Due to the extremely good bond between the scale and the Zircaloy-2 cladding, it was felt that ultrasonic cleaning would also prove to be fruitless.

Although the decision to try to attain 100-Mw operation of the reactor with the scaled fuel elements had been made, it was nevertheless of interest to develop some means of cleaning the fuel plates, if only to give an assist to the technology if such a corrosion problem should ever occur again, either in EBWR or elsewhere. The cleaning method described in this report is known as slurry honing. It consists of directing a stream of water-abrasive mixture, under air pressure, at the surface to be cleaned. Depending upon the abrasive used, the action will be either a cutting or a peening one on the surface. The surface of the abrasive is either irregular or spherical, respectively.

The samples used to test this method of scale removal were obtained from the destructive testing of an EBWR fuel element by the Metallurgy Division. All the work was performed in the hot cell facilities of Argonne National Laboratory.

II. EQUIPMENT

The equipment used consisted chiefly of four items: the gun and carrier, the plate support and table, the cover and the mixing apparatus.

A. Gun and Carrier

The business end of the slurryhoning process was a gun through which the air and abrasive mixture flowed, and which directed the high-velocity stream at the area to be cleaned. The slurry was drawn from the mixing drum (see Section II-D below) by the aspirator action of the air at the gun. The air stream mixed with the slurry and the mixture was then ejected from the nozzle of the gun. A positive slurry feed was more desirable, but the associated equipment would have added both to the complexity and cost of the setup.

In order to manipulate the gun remotely, it was necessary to mount it on a carrier so that a specimen could be traversed laterally or vertically. Lateral movement of the gun was accomplished by a block which slid on roller bearings and to which the gun was connected by a vertical shaft. Vertical movement of the gun was achieved by loosening a spring-loaded plunger which rode against the vertical shaft. A hex wrench was welded to the plunger for easy handling.

Ordinary air hose was used for the air line and plastic tubing for the slurry line. Each was attached to the gun through quick-disconnect fittings so that remote changing of the lines could be simply accomplished.

The gun and carrier assembly is shown in Fig. 1.

FIG. 1
GUN AND CARRIER SUPPORT

B. Plate Support and Table

In order to support a specimen during the blasting operation, it was necessary to construct a holder which could be adjusted for any size plate. The plate rested in a groove at the base of the support structure. The top edge of the plate fitted in a similar groove which was part of a clamping device used to keep the plate rigid. This clamp was lowered by means of a handwheel and was spring loaded to release the plate when the handwheel screw was raised. Both grooves were tapered to accommodate either the thick (0.7112 cm) or the thin (0.5385 cm) fuel plate samples.

The upper bar to which the clamp was attached could be raised or lowered as the plate size warranted. This bar was held in place by one clamp on each side of the structure. Each clamp was operated by a handwheel.

The entire support structure was screwed to a table. Angles were welded around the outside of the table to prevent water leakage. Directly under the plate support, a drain hole was cut in the table. A drain pipe was welded to the underside of the table and a flexible rubber hose was attached to the pipe. The hose ran to a waste bucket under the table.

Since the waste bucket could not be easily disposed of in the event it had a high activity level, it was necessary to try to minimize the amount of solids carried into the bucket. This was accomplished by stuffing the hose with fiberglass filter material. If activity became trapped in the filter material, the hose could be easily removed from the cell in a cylindrical tube for which a lead coffin was available.

The plate support and table are shown in Fig. 2. Note that the support was held together entirely by hex head cap screws. This would have facilitated disassembly and removal of the apparatus from the hot cell in the event it would have become highly contaminated.

C. Cover

During the blasting operation, it was necessary to contain the vapor stream so that the hot cell did not get splattered with contamination, leading to a difficult cleanup job. Hence, the apparatus was enclosed in a clear plastic cover so that the operation might be observed, while the spread of radioactivity was reduced to zero.

The front of the cover was cut out to accommodate the gun and carrier and a plastic door was lowered to the top of the gun. Since this cut-out was the only major escape for the air entering the cover, it was necessary to provide an exhaust during operation. One side of the cover contained

a filter box with an extension to which was attached the exhaust hose. The filter was used to remove the water from the air stream before it was exhausted. Construction of the filter box was such as to afford rapid, remote replacement of the filter.

FIG. 2

PLATE SUPPORT AND TABLE

A water spray jet was provided on one side of the cover to wash down that side in the event it became cloudy from the slurry spray. It was thought that this side would be used for observations and would have to be clean. The water tube was joined to the jet inlet by a quick-disconnect fitting.

A large screw eye was inserted in the top of the cover so that the crane located in the cell could be used to remove and replace the cover quite easily. The entire apparatus is shown assembled in Fig. 3.

FIG. 3
COMPLETE SLURRY HONING ASSEMBLY

D. Mixing Apparatus

The last of the major items of equipment is by no means the least. If everything else works according to plan, the slurry honing process will fail unless the slurry can be well-mixed and distributed to the gun before the abrasive settles out. In any commercially available unit, the mixing and feed devices constitute the major capital investment in a slurry honing setup. Since we did not think that this test would warrant such an expenditure if it could be avoided, we devised a mixing apparatus which proved exceedingly effective.

The chief component of the mixing device was a commercially available portable cement mixer. This unit consisted of an 18.925-liter drum which was rotated through two pairs of reduction drives at a speed of about 50 revolutions per minute. Abrasive and water were introduced into the drum, but the rotation of the drum was not adequate for good mixing. A kitchen-type mixer was used to stir the slurry during rotation of the drum. The combination of the rotation and the mixer resulted in an extremely good mix.

One end of a copper feed tube extended into the drum and the other was joined to a length of plastic tubing which was attached to the gun as described above. In operation, the mixer was run at full speed. The mixing apparatus is shown in Fig. 4.

FIG. 4
SLURRY MIXING APPARATUS

III. ABRASIVES

Abrasives for use in this test were made available to us by the Metallurgy Division. Two types were used: aluminum oxide and smooth silica crystals. The former is an irregularly shaped crystal of 400 mesh particle size and the latter is a blend of very smooth, spherical silica crystal of between 100 and 325 mesh. The alumina is used where a cutting action is desired and the silica where cleaning can be effected by a peening action. The silica is also known as "Brite Shot."

The density of each abrasive was measured for a lightly compacted powder and found to be 1.81 and 1.47 gm/cm³ for the alumina and silica, respectively. Based on these densities, and assuming an optimum 35 wt-% abrasive-water mixture, the water-abrasive volume ratio was 3.36 and 2.73, respectively. These ratios were not strictly observed, but rather used as a guide to obtain a usable slurry.

IV. AIR SUPPLY

The recommended air supply for use with a gun of the type used in this test is about 30 liters/sec at 6.4 to 7.1 atmospheres. When the air is used to pump as well as eject the slurry, as was the case in this test, a higher pressure would be very desirable. Actually, the air available in the hot cell facility was delivered at a maximum pressure of about 4.7 atmospheres.

While the suction on the slurry feed line left much to be desired, it was nevertheless possible to deliver the slurry to the gun by making use of the static head of the slurry in helping to overcome the large pressure drop of the system. Any production operation of this type would require a positive slurry feed.

V. SAMPLES

The samples used in this test consisted of coupons which had been cut from the fuel plates of EBWR fuel assembly ET-51. The thickness of the plates from this element prior to irradiation is given as $0.5385^{+0.000}_{-0.015}$ cm.⁽²⁾ All the coupons were full width (9.208 cm⁽²⁾) and were either about 5.08 cm or 15.24 cm in length. Although there were about 15 such coupons to work with, it was felt that enough information could be gleaned from experimenting with only a handful, to make qualitative analysis of the test possible.

VI. SCOPE OF THE TEST

The main reason for performing this experiment was not to develop a method or process of descaling the EBWR fuel plates from the Mark I Core, but rather to show that they could be descaled if and when it was decided to do so. In addition, if a similar scale deposition problem should occur in any other reactor, we felt that such a method of scale removal should be made available to the reactor operators.

There are many arguments pro and con with regard to slurry honing as applied to an EBWR-type fuel assembly. The strongest pro argument merely states that if all else fails, what then? In other words, if scaling on a reactor fuel plate will tend to limit its performance and no other means of scale removal is available, one has no choice but to resort to slurry honing if that method can be shown to work.

On the other side of the ledger, one can argue that once the abrasive gets through the scale (which presumably is not uniformly distributed), it is difficult to prevent removal of cladding material. While this problem would surely exist, it is believed that an adequate development program

could resolve the question. Various points of possible investigation are discussed in Section X below.

Another negative argument considers that the fuel plate, having been descaled, must now be pickled in nitric-hydrofluoric acid solution in order to restore the corrosion resistance of the cladding, at least in the case of Zircaloy-2.⁽³⁾ This process results in the removal of 0.0025 to 0.0076 cm of Zircaloy-2. In addition, the solution must be completely removed from all Zircaloy-2 surfaces in order to inhibit corrosion. It is suggested that it would be extremely difficult to remove all the pickling solution from certain regions such as crevices. Possible resolution of this question is also discussed in Section X below. Of course, this pickling problem would not be present in the case of stainless steel or aluminum cladding.

Again, the purpose of this experiment was to prove the effectiveness of slurry honing on scale removal. Adaptation of the method to actual production processes involving any large number of fuel elements is left to future study.

VII. TEST PROCEDURE

Initially, the 400 mesh alumina was used on one of the large coupons just to see whether the abrasive would remove scale. Positive results were noted. Then another large plate was blasted with the same abrasive. Measurements of the target spot thickness were made before blasting, after 10 seconds of blasting, after an additional 30 seconds of blasting, and after a final 10 seconds of blasting. Photographs of the plate were taken before blasting and after each of the first two blasting operations.

Since we believed that the Brite Shot would cause less removal of the Zircaloy-2 than the alumina, we decided to investigate this abrasive from the standpoint of scale removal and effect on the Zircaloy-2 surface. In order to photograph the surfaces, a stereo camera permanently mounted in one of the hot cells was used. The large plates could not be transferred to this cell, so we used the small plates in our tests.

Each of four of these small plates was blasted with the silica in two areas, with the time of blasting varied. Measurements of thickness were made before and after blasting and then each spot was photographed at a magnification of 13X, the highest available. The gun nozzle was about 1.27 cm from the surfaces during all the tests.

VIII. RESULTS

The changes in thickness of the various plates used in this test are listed in Table 1. The data for coupon HT-10 are given for repeated blasting on one spot, while the data for each of the other sections corresponds to two different spots.

Table 1

SUMMARY OF DATA OF SLURRY HONING TEST

Plate or Spot Designation	Total Blasting Time (sec)	Thickness (cm)		Abrasive Used
		Before Blasting	After Blasting	
HT-10	10	0.554	0.544	Alumina
HT-10	40	0.544	0.541	Alumina
HT-10	50	0.541	0.540	Alumina
28-B1	-	0.551	0.546	Silica (Brite Shot)
28-B2	120*	0.554	0.549	Silica (Brite Shot)
21-D1	15	0.549	0.538	Silica (Brite Shot)
21-D2	45	0.551	0.541	Silica (Brite Shot)
29-D1	10	0.546	0.533	Silica (Brite Shot)
29-D2	30	0.546	0.531	Silica (Brite Shot)
813-D1	20	0.554	0.538	Silica (Brite Shot)
813-D2	60	0.559	0.541	Silica (Brite Shot)

*This spot was on a descaled section of the coupon.

Photos taken of plate HT-10 are shown in Figs. 5-7. Figure 5 shows the plate before blasting with a mark over the spot to be worked on, and Fig. 6 and 7 show that same spot after 10 and 40 seconds of total blasting with alumina, respectively. Note that after only 10 seconds the spot was descaled and the zirconium oxide corrosion film had been removed. Blasting the spot for 30 more seconds resulted in the removal of 0.003 cm of Zircaloy-2 (see Table 1). It was difficult to estimate the scale thickness since the cladding had separated from the meat at several locations during the machining operation. However, the author believes the thickness to be about 0.00762 cm, which is certainly within the realm of expected values from previous experience.

From the data of Table 1 for specimen HT-10, it appears that, for this particular setup, the rate of removal of Zircaloy-2 is about 0.0001 cm/sec. There is no doubt that this number could be reduced if some development work is done on this process. For example, one might try using a more dilute slurry.

FIG. 5.
PLATE HT-10 BEFORE BLASTING

FIG. 6.
PLATE HT-10 AFTER 10 SEC-
ONDS BLASTING

FIG. 7.
PLATE HT-10 AFTER 40 SEC-
ONDS BLASTING

The results of using the Brite Shot on the four small coupons indicate that the rate of removal of the Zircaloy-2 with this grit is greater than for the alumina. This is to be expected since the average particle size is greater for the Brite Shot than for the alumina.

Again assuming a scale thickness of 0.00762 cm, although this is probably high for coupons 29-D and 21-D, the rates of Zircaloy-2 removal ranged from 0.00004 to 0.0005 cm/sec. The data for plate 28-B are not significant, since the feed line became plugged during the blasting, and so the 120-second time of blasting should be reduced.

Figures 8 through 10 are photomicrographs of the small plates taken at a magnification of 13X. Figure 8a illustrates a descaled portion of plate 28-B which was not blasted, and Fig. 8b shows spot 28-B2 which was blasted to determine the effect on unscaled Zircaloy-2 of the Brite Shot. It can be seen that the effect of blasting, in spite of Zircaloy-2 removal, is to polish the plate.

Figure 9 shows the demarcation between the scaled and descaled portions of spot 813-D1. Figure 10 shows the center of spot 21-D2, which was also descaled with Brite Shot. Again, a polishing action can be noted on the Zircaloy-2. Additional photographs of the other spots listed in Table 1 do not add to the information presented above and hence are not included in this report.

FIG. 8a

UNSCALED UNBLASTED PORTION OF PLATE 28-B (13X)

FIG. 8b
SPOT 28-B2 AFTER
BLASTING (13X)

FIG. 9
SPOT 813-D1 AFTER
BLASTING SHOWING
SCALE SURFACE
DEMARCATON (13X)

FIG. 10
SPOT 21-D2 AFTER
BLASTING (13X)

IX. CONCLUSIONS

The scale which has deposited on the EBWR fuel plates can be removed by the slurry honing process. Brite Shot abrasive is as effective as alumina in removing scale and was more effective in removing Zircaloy-2 in this test.

It is known that alumina-cleaned Zircaloy-2 must be pickled prior to hot water exposure to prevent corrosion. Use of Brite Shot may preclude the need for pickling the fuel plates after cleaning. However, the scope of this test did not include autoclaving a Brite Shot-cleaned Zircaloy-2 specimen to determine its corrosion resistance.

X. RECOMMENDATIONS

In order to assess completely the potential of slurry honing in cleaning the scale off an EBWR-type fuel plate, an extensive program would have to be initiated. Among the variables that must be investigated are:

1. slurry concentration,
2. distance of gun from plate,
3. air pressure and flow rate,
4. variation of particle size for both alumina and Brite Shot, and
5. angle of approach of the slurry.

These variables should then be used in determining optimum conditions for minimum Zircaloy-2 removal, since we have shown that the scale removal is no problem.

Corrosion of Brite Shot-cleaned Zircaloy-2 should be investigated. If pickling is still necessary in order to create a corrosion-resistant surface, then a possible solution to the problem would be to blast with an inert gas such as argon or helium. The lack of nitrogen will probably be a big factor in eliminating the need for pickling. Of course, this would lead to an expensive operation.

If and when the decision to clean a number of EBWR-type fuel elements by slurry honing is made, the problems outlined above will seem trivial. In the case of the EBWR, the fuel elements would presumably be cleaned in the fuel storage pit. This would require a bell-jar-type of enclosure for the fuel element from which the water could be ejected by air pressure or other means. A gun would have to be developed which would traverse the space between adjacent fuel plates. This is not believed to be too serious a development problem. Two of the most formidable problems, however, are those of observation and waste removal.

It will be necessary to monitor the channel width in order to regulate the traversing speed of the gun so that as little metal as possible is removed. At present, the Metallurgy Division is developing an eddy current device to monitor scale buildup on the present EBWR plate-type assemblies. It is possible that this method could be adapted to the needs of a remote slurry honing operation as envisioned here.

Once the slurry is ejected from the gun, the solid and liquid separate. It is not possible to recirculate the slurry unless the used abrasive is somehow fed into some mixing apparatus located in the pit. It would appear that this would be a major problem to be solved. If it is solved, then one is faced with the additional problem of recirculating a radioactive slurry.

If it is decided to make the slurry honing a once-through operation, in other words, the slurry will be used only once, then the expense of the abrasive will rapidly mount. In addition, there will be the need to dispose of large quantities of solid active waste.

Finally, some means of inspection of the cleaned fuel element would have to be devised. It would be necessary to know exactly how much Zircaloy-2 was removed, since channel width alone is not a good indicator of cladding thickness.

Although the inherent problems of slurry honing on a production basis are indeed numerous, they are by no means insoluble. However, the solutions will probably be very expensive. In fact, it is quite possible that the cost involved would be greater than the value of the core itself.

In summary, we have shown that fuel element scale can be removed by slurry honing. If such a method can be avoided, it would be a blessing. If, on the other hand, scale removal is imperative, and all else fails, then one has no choice and slurry honing must be employed.

.

REFERENCES

1. Breden, C. R., Ira Charak and R. H. Leyse, Water Chemistry and Fuel Element Scale in EBWR, ANL-6136 (to be published).
2. ANL-5607, The EBWR Experimental Boiling Water Reactor, p. 184.
3. Macherey, R. E., to B. I. Spinrad, ANL, Personal Communication, August 5, 1960.

ACKNOWLEDGMENT

The author wishes to express his appreciation to each of the following who contributed to the inception and completion of this experiment:

Mr. W. D. Jackson, Remote Control Division
Mr. R. C. Wolz, Remote Control Division
Mr. N. J. Peters, Reactor Engineering Division
Dr. C. R. Breden, Reactor Engineering Division
Mr. C. F. Reinke, Metallurgy Division
Mr. R. Carlander, Metallurgy Division
Mr. C. H. Bean, Metallurgy Division
Mr. W. C. Kettman, Metallurgy Division