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NONDESTRUCTIVE TESTS OF COMPONENTS OF EBR-I, CORE IV

by

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INTRODUCTION

The extensive nondestructive tests which were required for various components of Core IV of EBR-I were performed by ultrasonic and eddy current methods especially adapted to each particular test problem. These tests included:

1. ultrasonic tests of Zircaloy-2 and zirconium rod stock for rod tip, fuel connector, and filler plug components;
2. ultrasonic tests of zirconium rod stock used in the fabrication of part of the spacer-rib wire;
3. eddy current tests of Zircaloy-2 core and blanket jacket tubing;
4. eddy current tests of Zircaloy-2 instrument tubing;
5. eddy current tests of zirconium spacer-rib wire;
6. eddy current tests of stainless steel tubing used in components for the breeding gain experiments;
7. eddy current tests of assembled blanket elements for the quality of the NaK bond.

Details of these tests and the results follow.

I. ULTRASONIC TESTS OF ZIRCALOY-2 AND ZIRCONIUM ROD STOCK

A. Introduction

The rod tip, fuel connector, and filler plug components for EBR-I Mark IV were fabricated from Zircaloy-2 rod stock, 0.299 in. in diameter. This stock was converted from forged bar stock by rolling at 850°C to a 0.347-in. diameter, cold swaging to straighten and round the rod, and centerless grinding to size.

To insure the integrity of the components for EBR-I Mark IV, an ultrasonic through-transmission system was used to inspect the Zircaloy-2 stock before subsequent machining operations. The inspection system was primarily concerned with the detection of internal voids produced during the rolling and swaging.

The ultrasonic system was employed, also, to examine 0.250- to 0.300-in.-diameter zirconium rod stock used in the fabrication of spacer-rib wire. Addition of this stock to the testing program was required after internal voids, 0.005 to 0.010 in. in diameter, were detected in wire stock by an eddy current technique. No modification of the test system was necessary.

B. Discussion of Test Technique

Ultrasonic through-transmission techniques have been applied to the inspection of various materials of assorted sizes and configurations.[1-4] Flaws such as cracks, voids, non-bonds, laminations, and grain-size variations can be readily detected by a transmission technique.

A transmission technique employs two transducers (mounted crystals) for the transmitting and receiving of ultrasonic energy. In a test system primarily concerned with the detection of internal voids in rod stock, the ultrasonic beam is directed along a diameter through the rod. Discontinuities interrupt or "block" this beam in varying degrees. The amount of interruption depends primarily on the ratio of defect area to beam size and on the separation between defect and transducers.[5]

Several techniques can be employed to improve defect detectibility. Among these are the use of focused transducers, lenses, beam reduction by means of masks or collimators, and small-diameter crystals. Although such techniques improve a testing system's ability to "see" smaller defects, inherent disadvantages must be considered before adoption of any one technique. In a system utilizing focused transducers or lenses, considerable time is needed for positioning the transducer holders. Collimation reduces the amplitude of the ultrasonic energy, whereas small-diameter crystals produce diverging beams at lower frequencies.

In this particular application, a favorable ratio of defect area to beam size was obtained by masking the transducers with Teflon collimators containing holes tapered from $\frac{5}{8}$ in. to $\frac{1}{8}$ in. at the exit. A cross section of the receiver collimator is shown in Figure 1. The $\frac{5}{8}$-in. opening permitted the $\frac{1}{2}$-in.-diameter crystal to vibrate freely in the collimator. Masking of the receive transducer reduced the signal fluctuations produced by scattered energy.

C. Description of Equipment

A Sperry Reflectoscope, type UR, was used to generate, detect, and visually display short pulses of ultrasonic energy. This instrument by itself

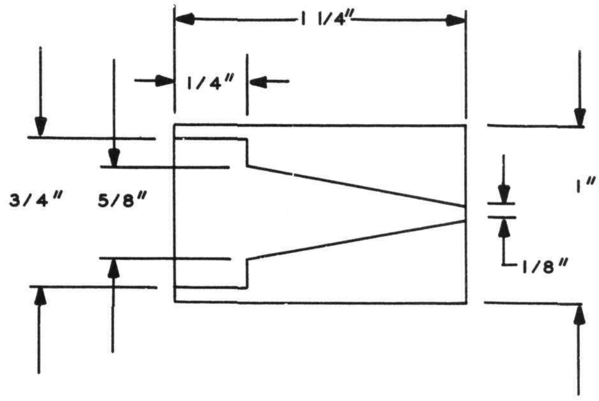

Figure 1. Cross section of receiver collimator

has no provisions for recording or alarm circuits as required by a semi-automatic or automatic inspection system. To meet this need, the reflectoscope was modified to work in conjunction with a Sperry Monitor, type RA. The monitor interprets the information gathered by the reflectoscope and provides outputs which can be used by audio alarms, marking devices, or oscillographs. An oscillograph was used in this case since permanent recordings were desired. Testing a reference standard at regular intervals yields oscillographic recordings that make it possible to check the sensitivity of the system quickly.

A roller lead assembly conveyed the rods past stationary transducers mounted on milling attachments of a lathe. The rotational and translational movements, imparted to the rods by the roller assembly, provided a helical or spiral scan whose pitch could be varied to allow sufficient overlapping of the ultrasonic beam.(6) By rotating and translating the rods at 340 rpm and 2ft/min, respectively, an approximate pitch of $\frac{1}{16}$ in. was attained and used throughout the test.

Branson Z-K transducers served as transmitter and receiver of the ultrasonic vibrations. A frequency of 5 Mc was chosen after preliminary tests at different frequencies (from 1-5 Mc) disclosed this to be more sensitive than the lower frequencies to the void areas typically encountered. Possibly a higher frequency would have been even more sensitive, but none was tried, for no transducers above 5 Mc were on hand and the sensitivity achieved at 5 Mc was adequate. The pulse repetition rate was set at 600 cycles/sec to insure complete circumferential coverage. The test facility is shown in Figure 2.

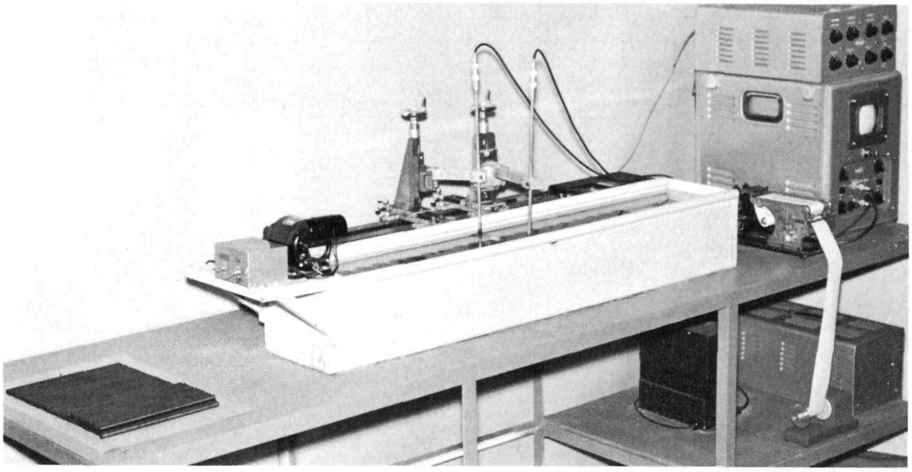

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Figure 2. Overall view of through-transmission test system

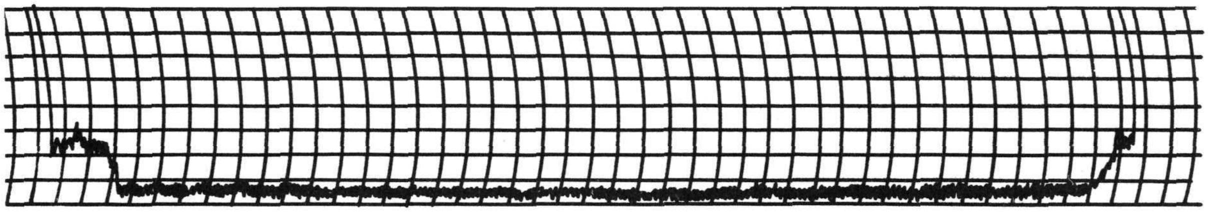
D. Inspection Procedure

1. Reference Standards

Prior to actual testing, reference standards were fabricated for each diameter and type of rod stock. Each standard length, 15-20 in. long, was taken from regular production stock. To simulate void-type defects common to this material, $\frac{1}{32}$ -in.-diameter, flat-bottomed holes were drilled axially $\frac{1}{4}$ in. up the center of one end and $\frac{1}{2}$ in. up the other.

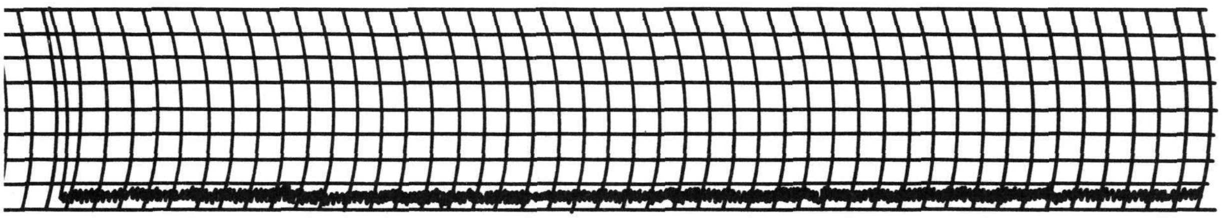
2. Correlation Studies

As is usual in most nondestructive tests, it was necessary to correlate the response produced by the reference standard with the response produced by actual defects. After scanning the standard and noting the indications of the artifical defect on the pen recording, random lengths of pre-production Zircaloy-2 stock were inspected. A comparison of normal and standard rod indications is shown in Figure 3. Several pieces produced defect indications, and representative examples of these are shown in Figure 4.



1/32-in. diameter (F.B.H.) x 1/2-in. long and 1/4-in. long holes

Standard



Normal Trace - Acceptable Rod

Figure 3. Pen recordings of the reference standard and acceptable rod

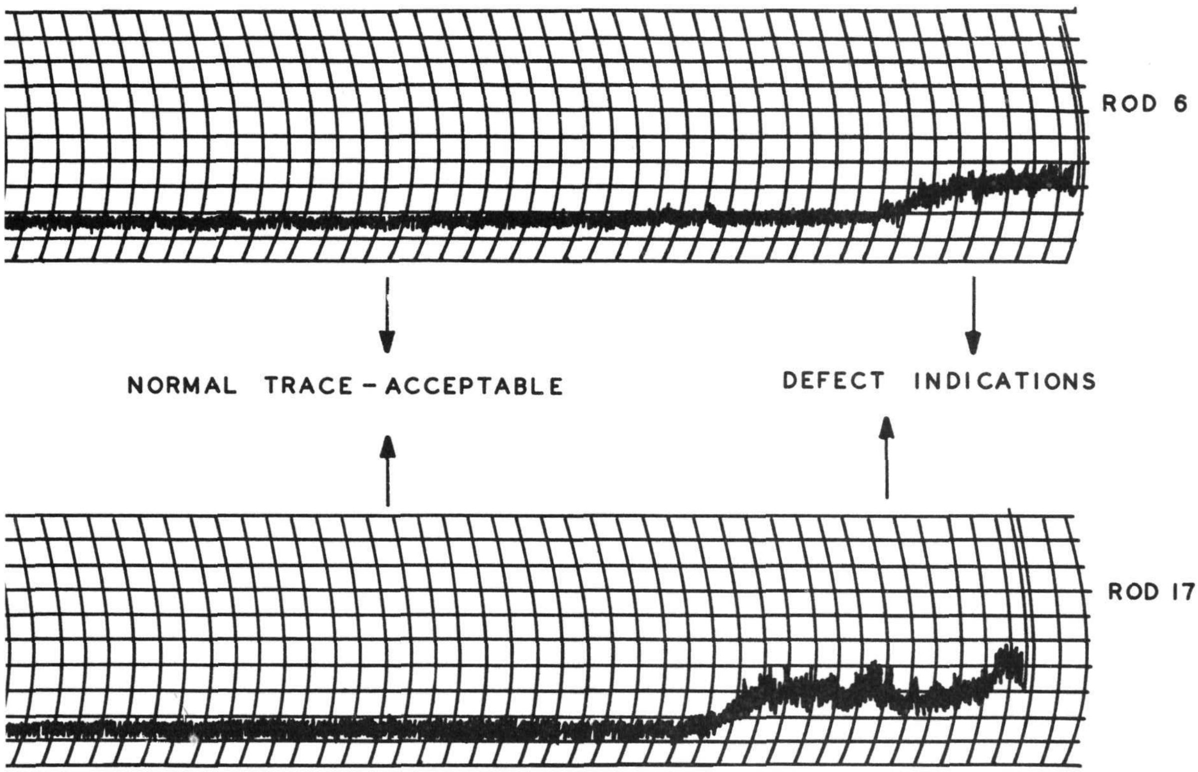
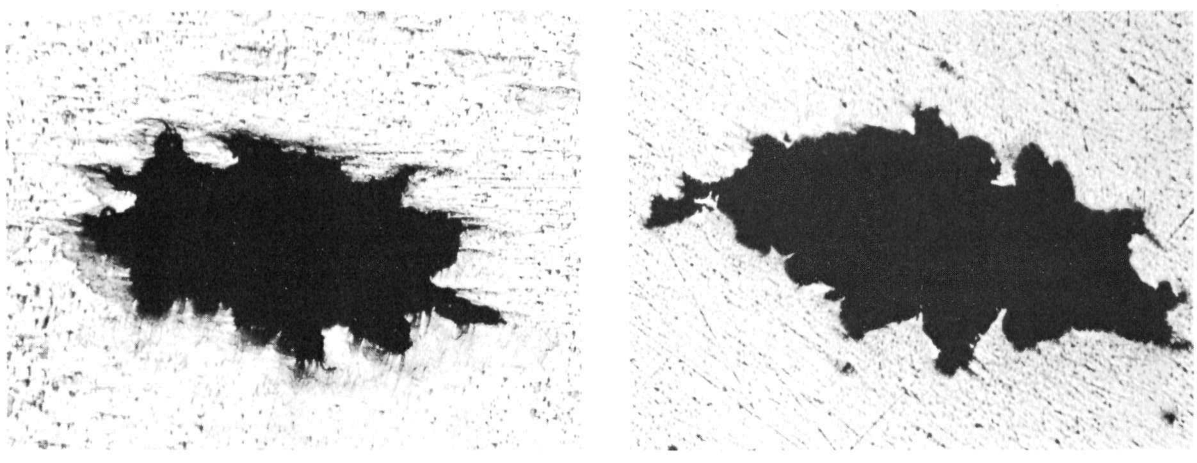


Figure 4. Pen recordings of void areas detected in Rods Nos. 6 and 17 of Zircaloy-2 rod stock

Subsequent metallographic examination of transverse sections from defect areas revealed void areas (see Figure 5) which tended to be greater in diameter at the ends of the rods. The voids ranged in diameter from 22 to 52 mils.



28190 100X 28191 100X

Figure 5. Transverse sections of void areas detected in Zircaloy-2 Rods Nos. 6 and 17

Although the standard served mainly as a "go-no-go" gage, fairly accurate predictions as to defect diameter could be made by comparison of defect and standard indications, i.e., a 14-mm pen deflection for both the standard defect and an unknown flaw would indicate a flaw approximately $\frac{1}{32}$ in. in diameter. This correlation held true for void-type defects only. Diameter measurements were taken along the major axis of the voids.

3. Transducer Alignment and Final Instrument Settings

During the developmental stage of this program, transducer alignment proved a critical operation. Slight deviations from center resulted in significant amplitude losses as well as decreased sensitivity to the centrally located voids. In order to speed up the alignment procedure and still maintain optimum performance, a special collimator was fabricated.

As mentioned earlier in the report, the collimators contained tapered holes. Any provision for maintaining the exit hole along a diameter during an alignment process would substantially reduce set-up time. With this thought in mind, a groove having the radius of a rod to be tested was machined into the end of a collimator at the centerline of the exit hole. One such collimator is shown in Figure 6.

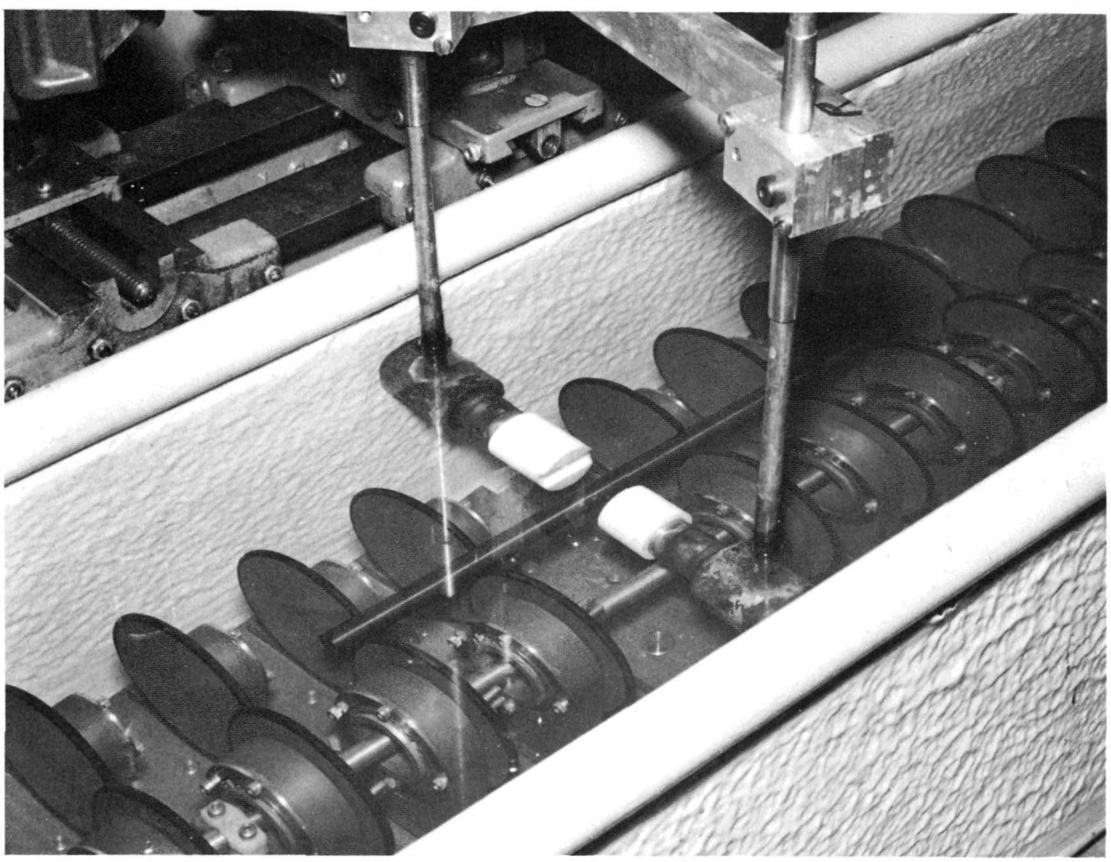


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Figure 6. Top view of conveyor and collimated transducers

With a special collimator attached to the transmit transducer, the following procedure was developed:

1. Adjust horizontal, angular, and vertical positions of transmitter until collimator radius fits snugly against rod.

2. Adjust receiver position until maximum amplitude of first transmitted pulse is observed on reflectoscope screen.

3. Re-adjust horizontal positions of both transmitter and receiver until maximum sensitivity is achieved for a standard defect.

Upon completion of transducer alignment, final adjustments of the transmitted pulse amplitude and of the gating circuitry were necessary. The amplitude of the first transmitted pulse was set at three relative units by means of the reject control. The position and length of the gate were varied until the system was sensitive only to the first pulse transmitted through the rod. This made the system ready for production testing.

E. Test Results

Approximately 700 ft of Zircaloy-2 and zirconium rod stock were inspected with the through-transmission system. The length of rod scrapped for defects amounted to less than 20 ft. Scrap material included 62 defective areas and 8 entire rods. Without the 8 reject rods, which contained large particles, the scrap length would have been less than 9 ft.

No difficulties were encountered in this test until one batch of zirconium stock produced wide, as well as normal, base-line fluctuations on the pen recordings. An example of such a pen recording is shown in Figure 7. Metallographic examination of rods exhibiting normal and wide base-line fluctuations revealed a great difference in microstructure, as shown in Figure 8. The large particles in rod EO are thought to be a result of improper annealing or quenching processes. X-ray diffraction studies on samples from rod EO were unsuccessful in determining the exact nature of these particles. Although a definite zirconium pattern could be seen, other lines were weak and diffuse.

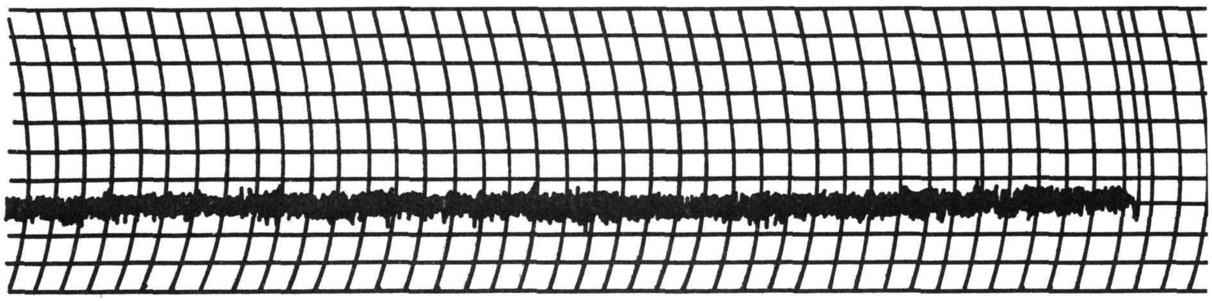
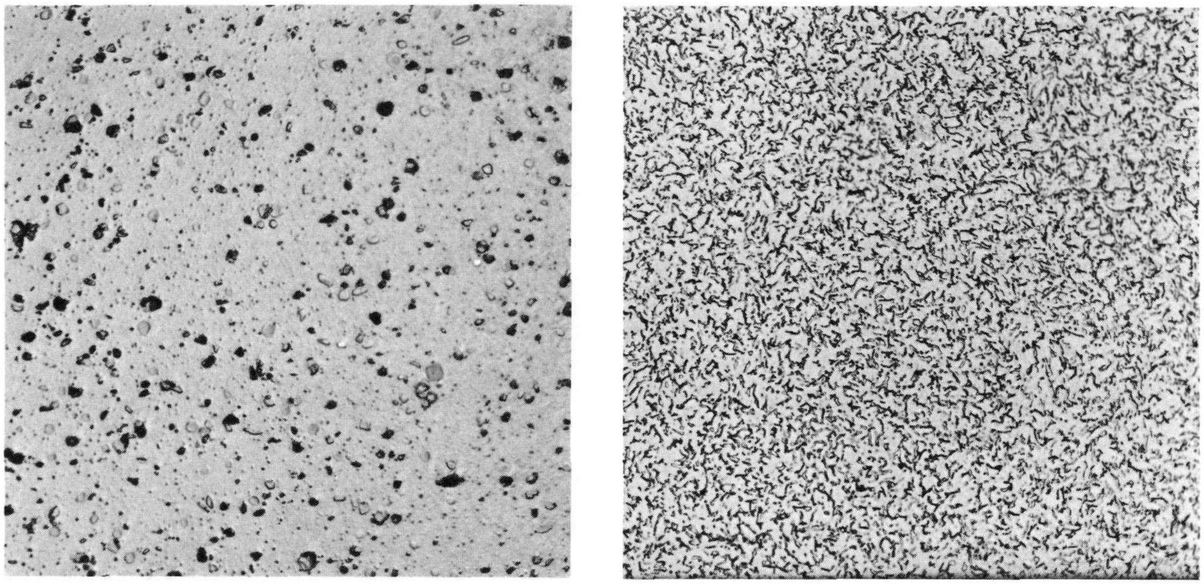


Figure 7. Typical pen recording of zirconium stock with abnormal microstructure



34968 Rod EO 200X

Etch - 5% $AgNO_3$, 2% HF

34969 Rod ET 200X

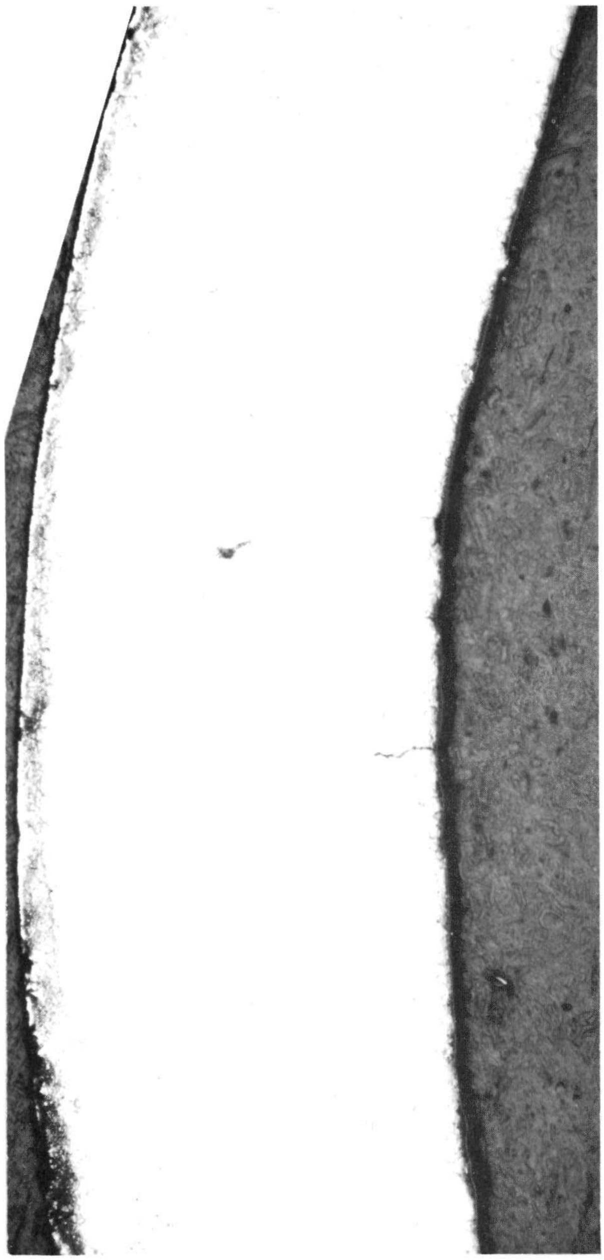
Etch - 5% $AgNO_3$, 2% HF

Figure 8. Transverse sections of zirconium rods EO and ET. Rod EO contains large particles while ET is normal stock.

Folds were also detected by the system but, as they could be discerned by the naked eye, were not considered an important part of the test. However, rods containing such a defect were set aside and brought to the attention of foundry personnel.

II. NONDESTRUCTIVE TESTING OF THE EBR-I MARK-IV CORE AND BLANKET JACKET TUBING

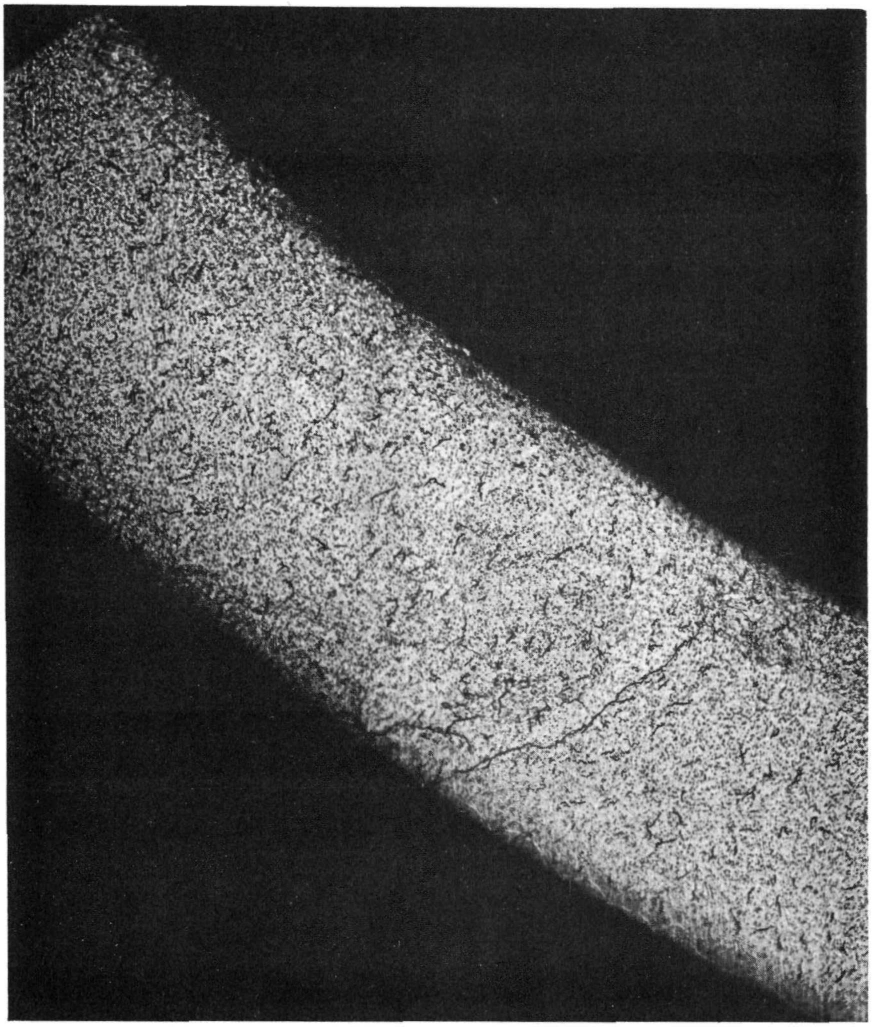
The jacket tubing for the Core IV was made of Zircaloy-2, with a nominal ID of 0.257 in. and a wall thickness of 0.021 in. Previous experience with small-diameter Zircaloy-2 tubing had indicated that high-quality tubing of this size was difficult to obtain, so it was decided from the outset to subject this tubing to nondestructive tests to insure that only tubing of the best quality obtainable was used in the assembly of the components. The first shipment of 2912 ft obtained from a commercial supplier was tested in lengths of about 6 ft by a dual-frequency eddy current test system. Seven hundred and twelve feet were rejected as containing wall cracks deeper than 0.005 in. starting from the inner circumference. A typical small crack is shown in Figure 9. Three hundred and eighty-one feet were accepted as suitable for blanket components. The rest of the tubing was retested with a much improved model of the dual-frequency test system which had just become available.(7) This equipment was capable of much higher sensitivity than the older test equipment.(8) The remaining 1819 ft were tested at a reject level equivalent to a 0.003-in. crack starting from the ID. About 800 ft more were rejected, not all of them for radial cracks. Some of these defects were of the type shown in Figure 10. This type of defect was definitely not detected by the older test equipment used for the 2912 ft of tubing first received. Any one of these defects which produced a defect signal equivalent to a 0.003-in.-deep radial crack more than $\frac{1}{16}$ in. long caused the rejection of the tube, although it was never definitely determined what these defects



30499 100X

Figure 9. A typical small crack on the inner circumference detected by the eddy current test equipment.

were or whether they were in fact deleterious. Transverse sections showed defects of this type running parallel to the tube wall as well as normal to it, and at all angles in between.



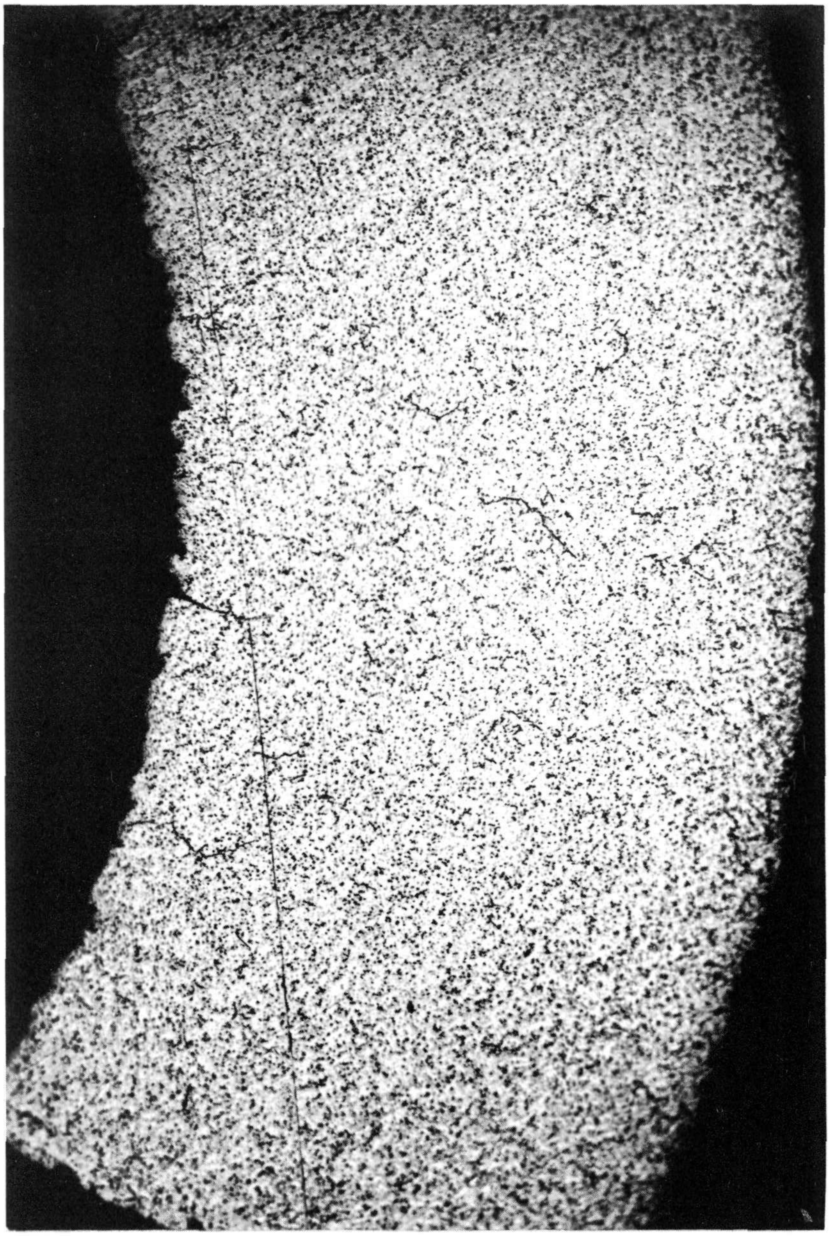
30500 100X

Figure 10. A defect in the wall detected by the eddy current test equipment.

After this inspection was completed, it became necessary to scrap some of the fuel tubes when weld defects were discovered below the rib wires. An additional 500 ft of 0.257-in.-ID tubing was ordered from a different tubing manufacturer. This new batch of tubing proved to be of much higher quality than any tubing previously obtained in this size. Three hundred and thirty feet were inspected with the dual-frequency equipment at a reject level equivalent to a 0.0015-in. crack $\frac{1}{16}$ in. long. Only a few feet of this tubing was rejected.

III. INSPECTION OF THE 0.080-IN.-OD x 0.015-IN.-WALL ZIRCALOY-2 THERMOCOUPLE TUBING USED IN THE THERMOCOUPLE FUEL AND BLANKET RODS OF CORE IV

Fabrication of high-quality tubing of this size from Zircaloy-2 is difficult, so careful nondestructive tests were performed with this tubing in order to see that material of the highest quality obtainable was used in the fabrication of the thermocouple rods. The flaws most likely to occur in this material seemed to be narrow radial cracks starting from the inner circumference. Figure 11 shows some of these cracks which were detected



34157 250X

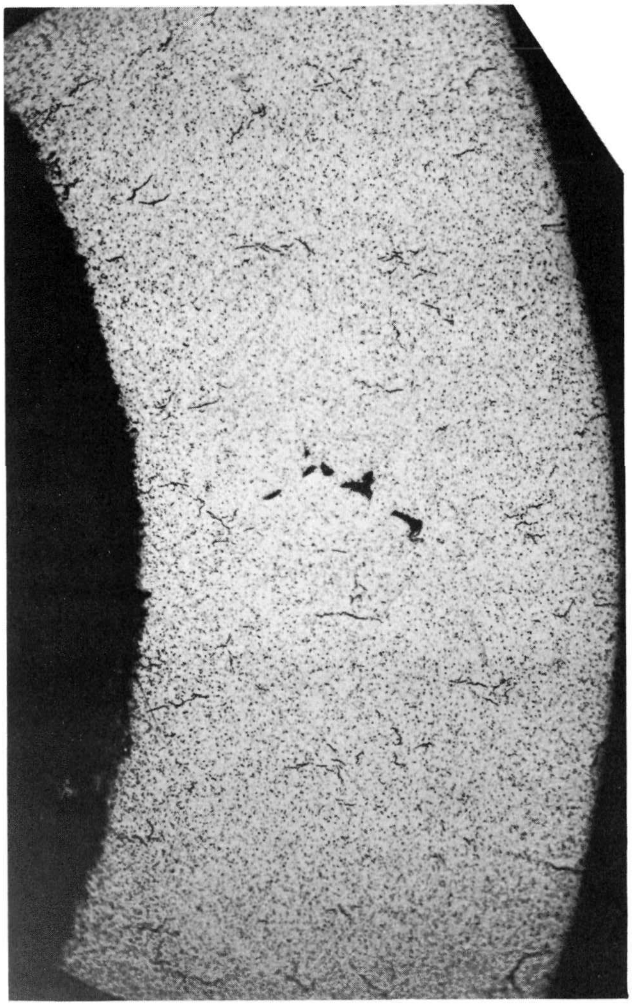
Figure 11. Defects located in the 0.080-in. Zircaloy-2 thermocouple tubing by the eddy current test equipment. This figure shows a small transverse crack starting from the ID.

by the test equipment. The tightness of these cracks makes their radiographic detection very difficult. Nor could these tubes be tested by the sinusoidal test equipment and point probes which were used, for instance, to test the fuel element tubing and breeding gain experiment tubing, because this equipment cannot efficiently test tubes of only 0.080-in. OD. It was necessary to develop equipment especially adapted for this inspection problem.

The result of this effort was a pulsed system using a differential encircling coil. The encircling coil was formed of three windings: a center winding which generated the field, and two pickup windings located on each side. The pickups were connected to a mixing transformer which provided null output when conditions in the metal were identical on each side of the center coil. Any metallic discontinuity on one side of the coil produced a change in the normal reflections picked up by the associated pickup coil and a change in the resultant voltage normally produced. The total width of the three coils along the tube axis was 0.1 in. The center coil was driven with pulses approximately 6 μsec in duration and shaped like a half sinusoid. The inspection was carried out at a linear tube velocity of about 2 in./sec. The circuit filtering was designed to provide the proper pass band for this inspection speed.

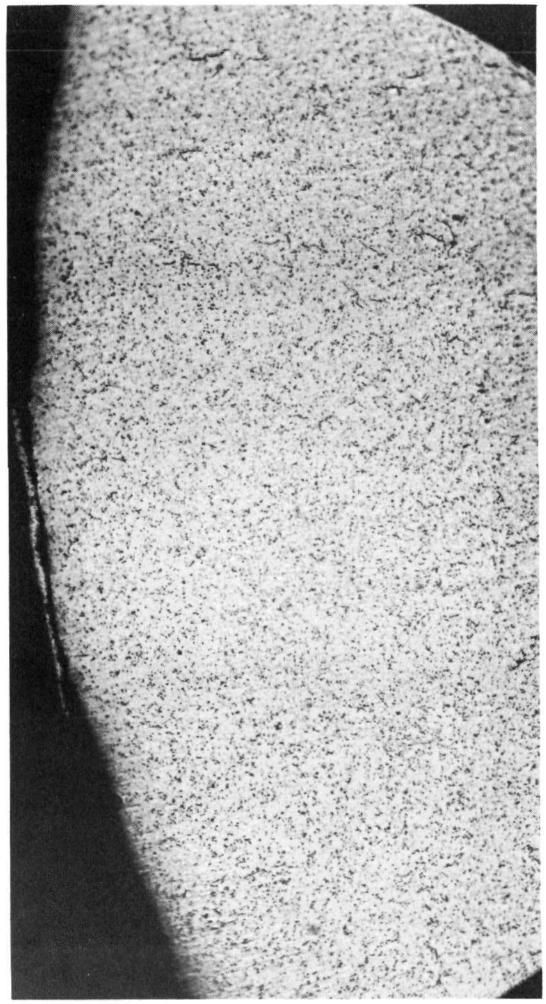
A differential test system by its very nature discards some of the information detected by the coil - information which relates to absolute defect depth, among other things - and it adds ambiguity regarding the rate of change of defect depth. It also appeared that radial cracks starting from the ID could not be eliminated entirely, and so it was necessary to select enough tubes for both core and blanket which had the smallest cracks of all those which were available. This meant that the eddy current test had to be quantitative and roughly calibrated at least for the smaller cracks. On the other hand, although an infinite variety of defects are theoretically imaginable in a tube wall, a certain fabrication process generally produces only a limited number of different types of defects, and the problem of quantitative measurement is not as hopeless as it first appears.

The fabrication process which was used to produce these tubes generally caused defects of the type shown in Figure 11. The lengths of these defects which were examined metallographically always were between $\frac{1}{16}$ in. and $\frac{1}{8}$ in. Occasionally other defects were encountered, such as the inclusions in Figure 12 and the very shallow surface lap in Figure 13. These were judged to be less serious than the radial cracks and were certainly easier to detect. They were more or less automatically eliminated once the lower limit on crack depth was set.



34147 200X

Figure 12. Defects located in the 0.080-in. Zircaloy-2 thermocouple tubing by the eddy current test equipment. This figure shows wall inclusions.



34155 200X

Figure 13. Defects located in the 0.080-in. Zircaloy-2 thermocouple tubing by the eddy current test equipment. This figure shows a shallow surface lap.

An extensive program of correlation between the eddy current test system defect indications and metallographic sections showed that a reasonable correlation between the amplitude of the defect signal and the crack depth existed. (This correlation became a reality only after numerous changes in the test system had been made.) The instrument in its final form had sufficient sensitivity to detect cracks under 0.002 in. in depth emanating from the inner circumference. All detectable defects were assumed to be cracks, since small cracks did in fact prove to be the preponderant defect type. On the basis of this calibration it appeared highly unlikely that this select group of tubes contained cracks extending deeper than 0.003 in. from the inner circumference, except for one tube, which may have contained cracks up to 0.005 in. Most of the cracks were probably shallower than 0.003 in., and some of these tubes were for all practical purposes perfect.

IV. NONDESTRUCTIVE INSPECTION OF RIB WIRE FOR THE CORE-IV FUEL AND BLANKET ELEMENTS

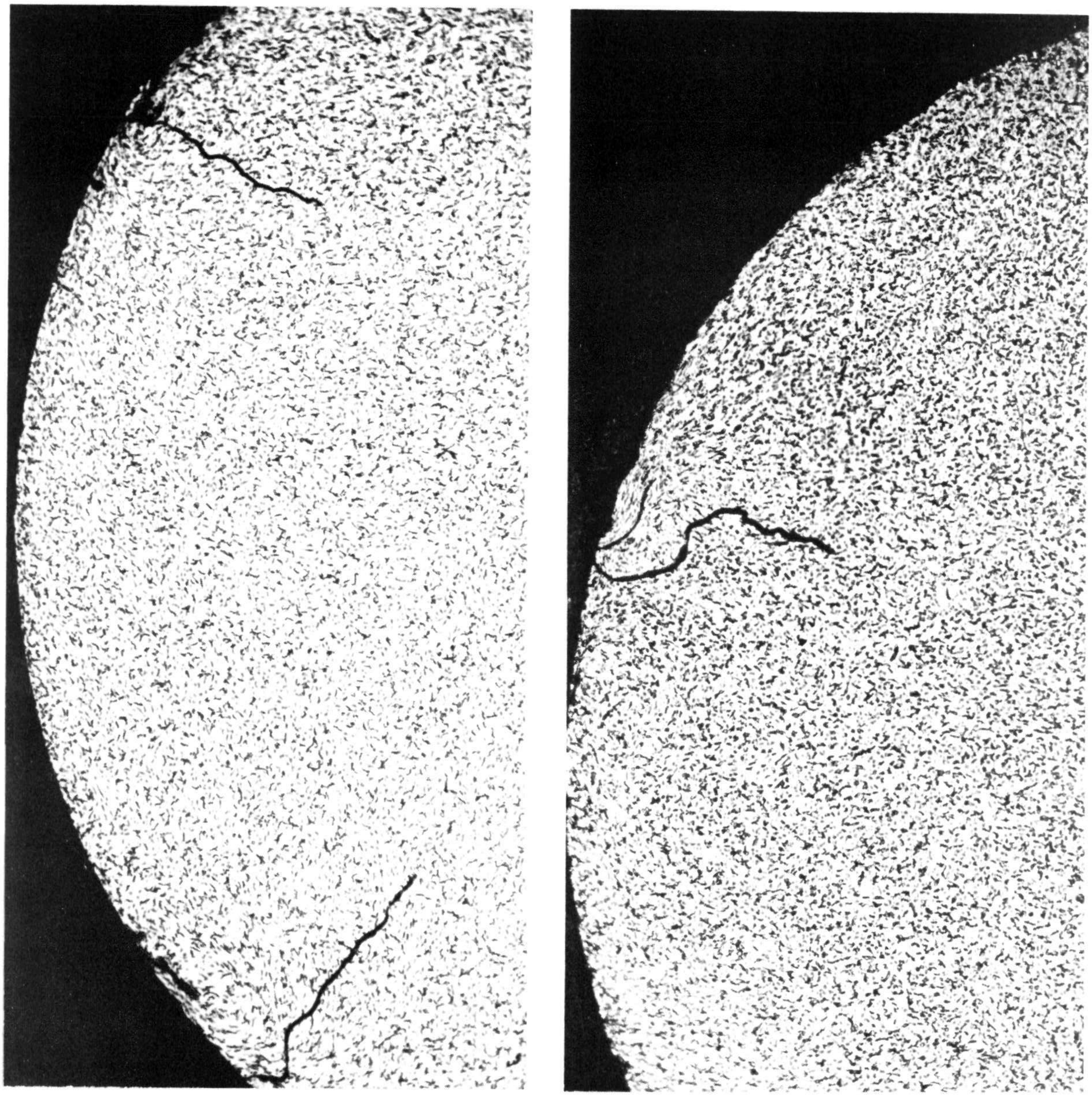
The 0.048-in.-diameter Zircaloy-2 and zirconium rib wires used as fuel and blanket element spacers in Core IV were inspected by an improved version of an eddy current test instrument described in another report.(9) This section of this report deals with the inspection of 566 ft of zirconium wire which was fabricated and inspected early in 1962. It does not apply to the tests undertaken on an earlier lot of Zircaloy-2 wire fabricated in the spring of 1961.

Before the inspection of this second lot of wire began, the defect indications and metallographic evidence were carefully correlated with a considerable number of defect locations. Some transverse sections showing cracks starting from the surface are shown in Figures 14a and b. These cracks were not considered important since they would have had little effect on the quality of the weld which held the wire to the jacket, as contrasted, for instance, with the effect of a large internal void such as often occurred in the first lot of wire. No evidence was found of any internal voids in this batch of wire.

In the 566 ft inspected, 19 defective areas were detected. The length of wire scrapped for defects amounted to less than 3 ft.

V. INSPECTION OF STAINLESS STEEL TUBING USED FOR COMPONENTS INTENDED FOR USE IN BREEDING GAIN EXPERIMENTS

Stainless steel (Type 304) tubing of two sizes, nominally 0.413-in. OD x 0.0165-in. wall, and 0.297-in. OD x 0.0175-in. wall, was used in the construction of hardware for breeding gain experiments in Core IV. This tubing was tested in 10-ft lengths by a dual-frequency system at a reject level equivalent to a 0.0015-in. crack starting from the ID. Of the 28 larger size tubes tested, 22 were found acceptable; 32 of the 36 smaller tubes passed the test. Microphotographs of transverse sections showing some of the defects located by the test system are shown in Figures 15a and b.



33574 (a) 150X 33575 (b) 150X

Figure 14. Transverse sections showing cracks in zirconium wire located by the nondestructive test equipment.

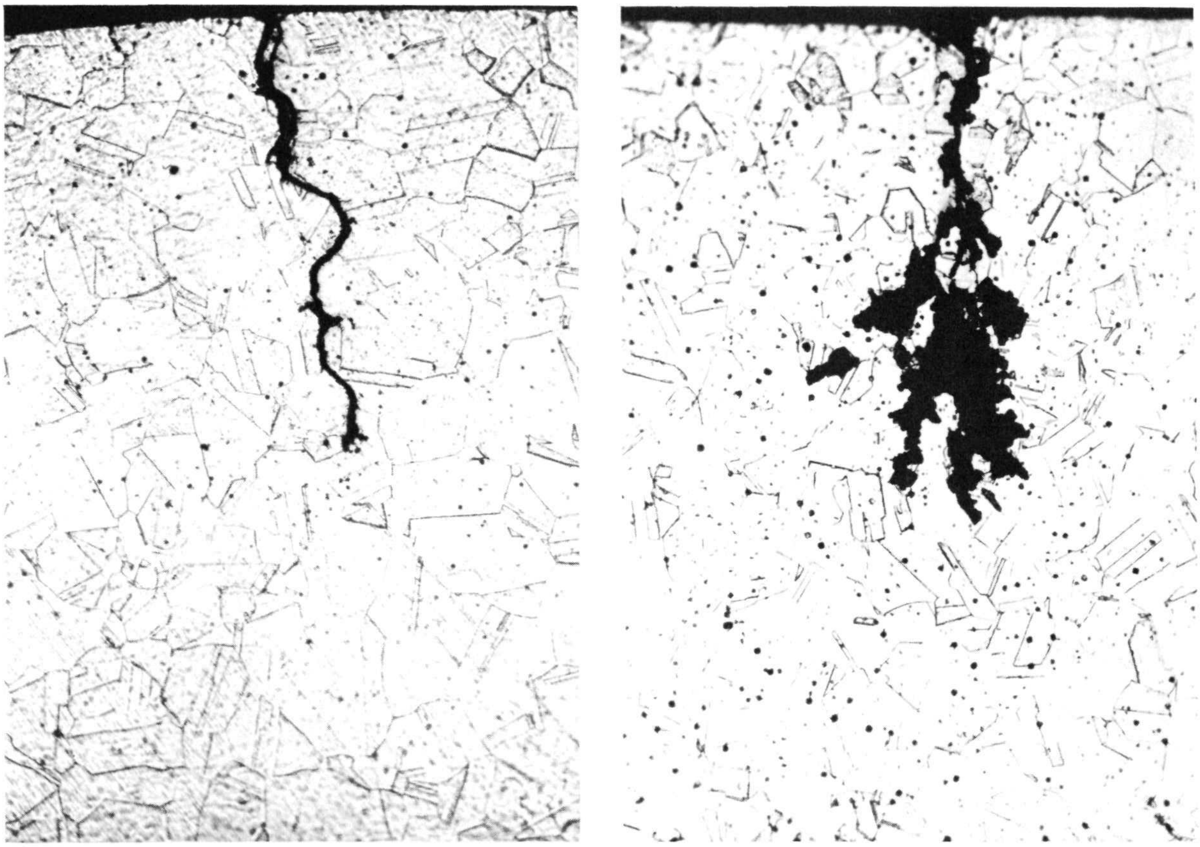


Figure 15. Transverse cracks discovered by the eddy current test system in stainless steel tubing which was to be used for components of the EBR-I Mark-IV breeding gain experiments.

VI. NONDESTRUCTIVE TESTS OF THE NaK ANNULUS OF THE ASSEMBLED BLANKET ELEMENTS

A. Introduction

EBR-I Mark-IV fuel and blanket elements contained NaK distributed in an annulus between blanket slugs and the Zircaloy-2 jacket. The NaK level in the elements extended $\frac{3}{8} \pm \frac{1}{8}$ in. above the end of the upper slug at room temperature, as shown in Figure 16. The ID of the jacket tube was 0.257 ± 0.005 in. and the slug diameter was 0.235 ± 0.001 in., leaving a NaK-filled annulus of 0.011 ± 0.003 in. The blanket slugs had four spacer ribs at each end, 90° apart, of 0.006-in. height. The fuel slugs had similar ribs which aided in centering the slugs in the jacket. To maintain good heat transfer between the fissionable material and the jacket the NaK annulus had to be free of large voids.

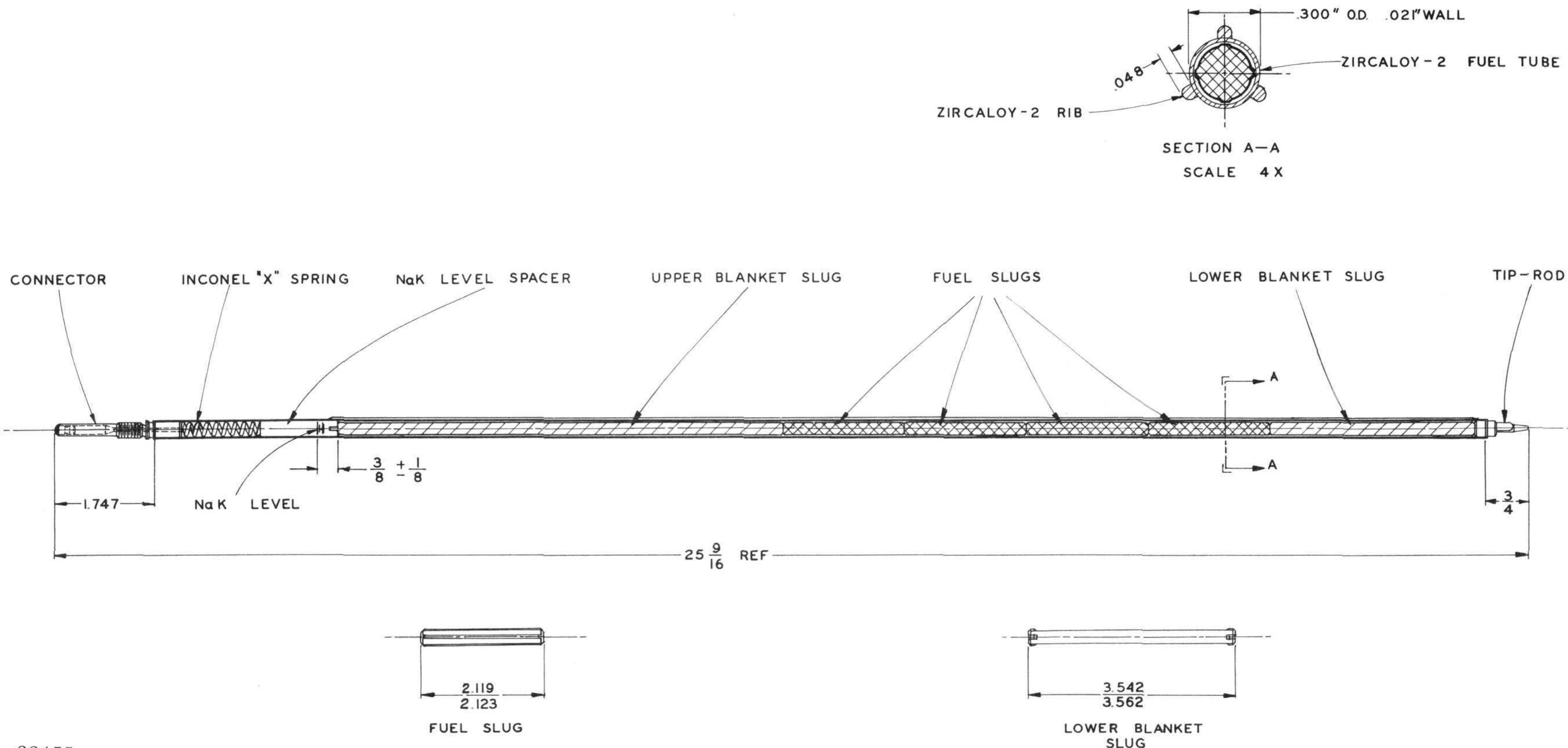


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Figure 16. EBR-I Core-IV fuel element.

B. Eddy Current Tests for Voids in the NaK Annulus

A $\frac{1}{16}$-in.-diameter probe consisting of two layers of No. 40 copper wire wound on ferrite was used to locate voids in the NaK annulus. The eddy current instrument was an AC bridge type operated at a frequency of 50 kc with the probe in a parallel resonant circuit. The instrument was similar to an instrument for measuring coating thickness used by Brenner and Garcia-Rivera(10) of the National Bureau of Standards. The AC bridge in the instrument was balanced to minimize the effect of probe-to-specimen spacing under actual testing conditions. The output voltage which was displayed on a strip chart recorder was then proportional to the resistivity of the specimen, with a minimum effect due to spacing.

Specially prepared blanket elements, with simulated voids of adhesive tape applied to the uranium slugs before NaK filling, indicated that voids of $\frac{1}{16}$-in. diameter or larger could be detected. On testing a number of blanket elements it was found that some of the traces were difficult to interpret. Six blanket elements were selected for destructive evaluation to permit direct correlation of the eddy current trace to the condition of the NaK annulus. The following points were particularly of interest:

1. The effect of heat treating elements on the presence or absence of NaK in the spaces between the slug ends and in the spaces provided by chamfers on the slug ends was compared.

2. The nature of defects indicated by the eddy current test at the bottom of a number of rods.

3. NaK wetting of the uranium slugs and Zircaloy tubing in the heat-treated compared with non heat-treated elements.

4. Condition of the oxidized area on the jacket under the rib welds.

5. Correlation between void size and location with their eddy current trace.

C. Experimental Procedure for Destructive Evaluation

The blanket elements that were stripped had to be cooled below the melting point of NaK, -12°C, and kept below this temperature long enough to permit removal of the jacket. The elements were cooled by immersion in liquid nitrogen and stripped in a glovebox with a dry nitrogen atmosphere to prevent frost formation on the element. The Zircaloy-2 jacket was removed in two halves in sections of 2- to 3-in. length with a small abrasive wheel cutter. The NaK was kept frozen during stripping by intermittent immersion in the liquid nitrogen container. The uranium slug and the inside surface of the jacket tubing were photographed and the results were compared to the eddy current trace. Of the six blanket elements selected for evaluation, two were used to develop the technique for stripping. The remaining four were successfully stripped and photographed. The blanket elements that were stripped and photographed were:

Number	Condition	Number	Condition
748	not heat-treated	715	heat-treated
709	heat-treated	854	heat-treated.

D. Stripping Results

1. Blanket Element No. 748

The eddy current test trace (see Figure 17a) for blanket element No. 748 indicated a large void at the top of the upper blanket slug. On removing part of the jacket in this location a number of closely spaced voids were found, as shown in Figure 17b. Figure 18a shows that the NaK easily pulled away from the slug and the jacket, as this element had not

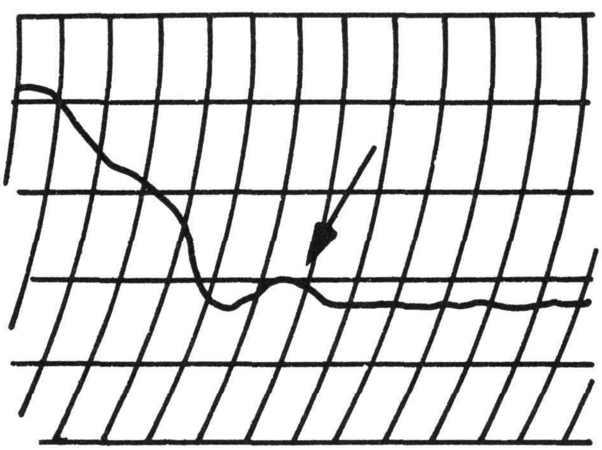

Figure 17a. Defect shown by the recording of the eddy current test obtained before Rod No. 748 was stripped.

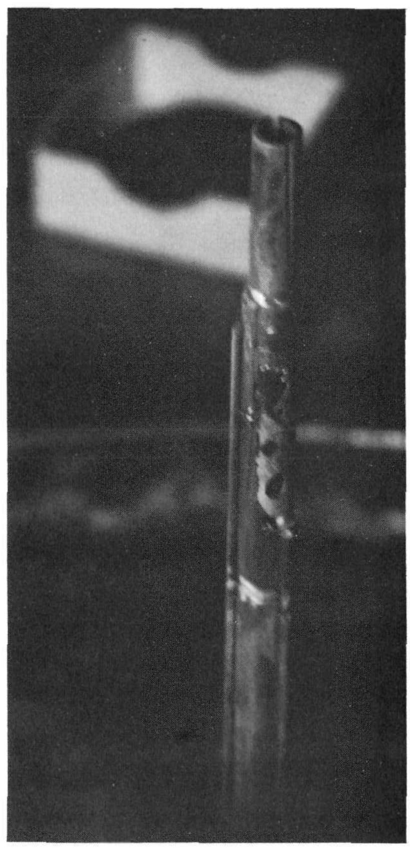

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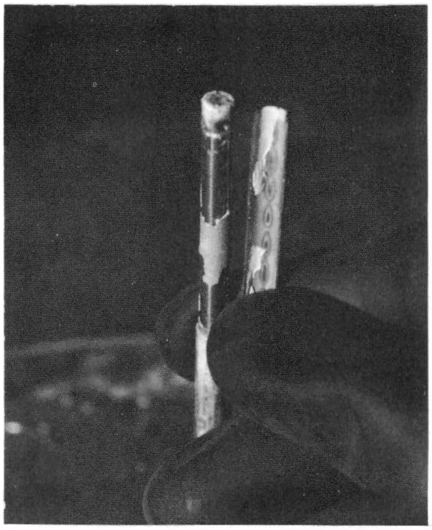
Figure 17b. Appearance of the slug portion on stripping. Note the voids in the frozen NaK sticking to the slug.

been heat treated and no wetting is evident. Note also that the end of the slug has only a thin layer of NaK. Before heat treatment the ends of the slugs could easily be located on the eddy current test trace by the large signal developed at this point, as shown in Figure 18b. Evidence that the space between the chamfered ends of adjacent slugs was filled with NaK was given by the ridge of frozen NaK that can be seen on the jacket at the bottom of Figure 19.



32852

Figure 18a. Appearance of one-half of the Zircaloy-2 jacket immediately after stripping. Weld areas are seen on the jacket.

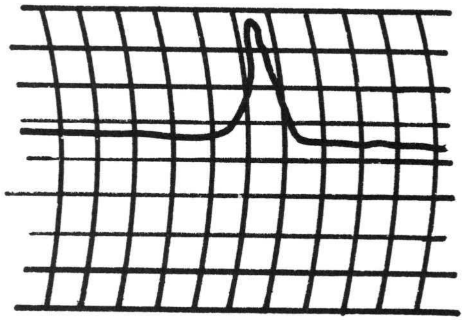
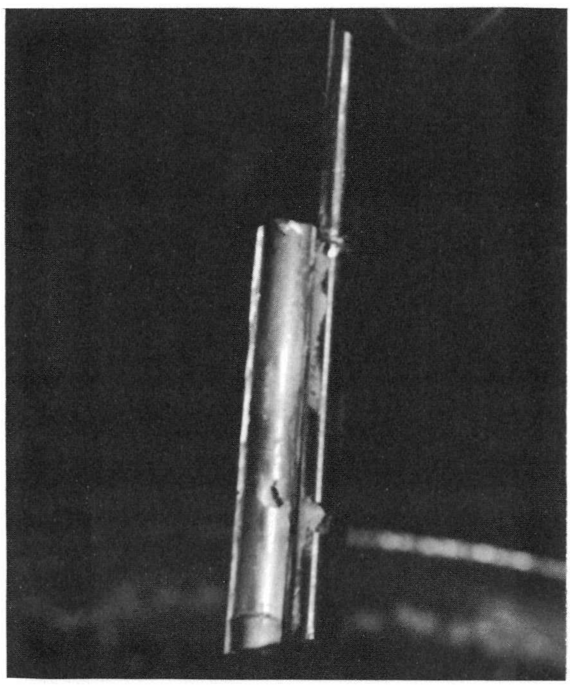


Figure 18b. Top of the second uranium slug of Rod No. 748.



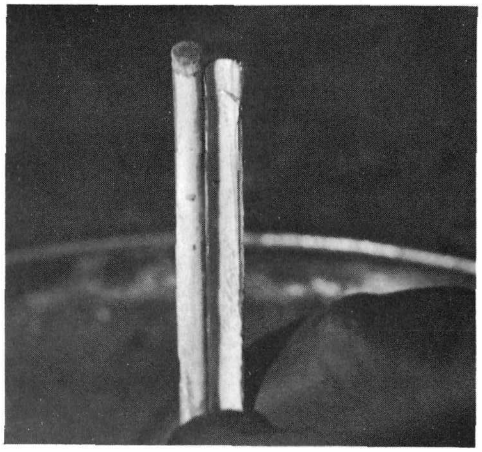
32829

Figure 19

The long object on the right is the second slug of Rod No. 748. To the left is part of the Zircaloy-2 jacket. Note the ridge of NaK on its bottom portion.

2. Blanket Element No. 709

It was evident from Figure 20a that the NaK level in blanket element No. 709 was below the top of the upper slug. An indication of the low NaK level was given on the trace shown in Figure 20b. The dotted line in the figure indicates the trace for a correct NaK level. This element had been heat treated, and the NaK appears to have wet both the uranium slugs and the jacket tubing. The small voids in a vertical line in Figure 20a were directly underneath the rib wire and were not detected by the eddy current instrument.



32833

Figure 20a. Rod No. 709. Note the absence of NaK near the top of the slug and on the Zircaloy-2 jacket.

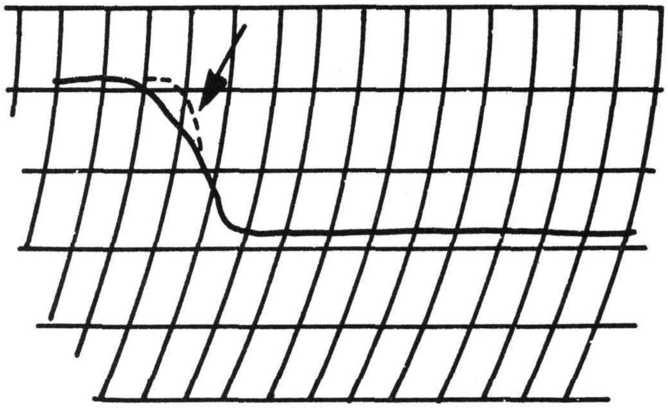
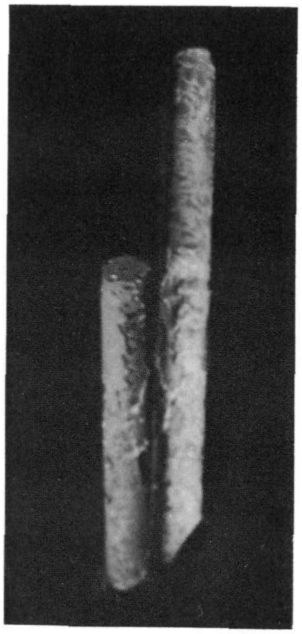


Figure 20b. Part of the trace obtained on testing Rod No. 709. Low level of NaK could be noticed by the deviation of the trace from the dotted line which indicates normal level.

The upper end of the fourth or bottom slug of blanket element No. 709 appeared to have an area of poor wetting, for most of the NaK had pulled away with the jacket, as shown in Figure 21a. This corresponds with position A of the trace shown in Figure 21b. A similar condition appeared at the bottom of the same slug shown at the top of Figure 22, corresponding to position B of the trace in Figure 21b.



32843

Figure 21a

The appearance of the top portion of the fourth slug soon after stripping. Note the presence of voids near the top.

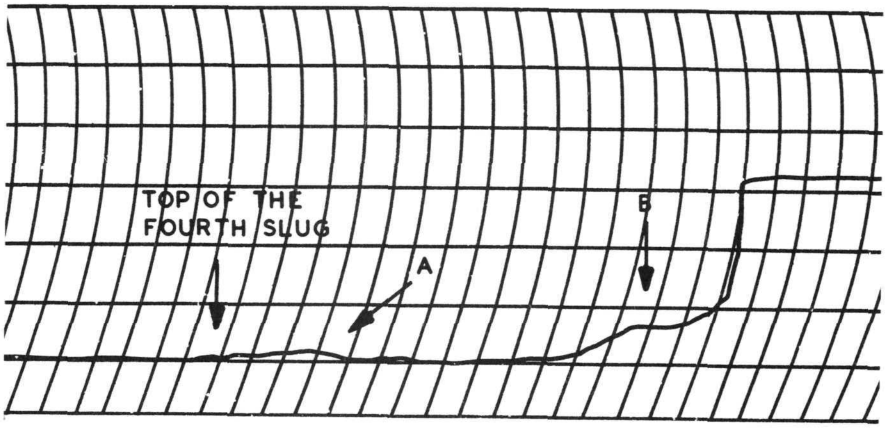
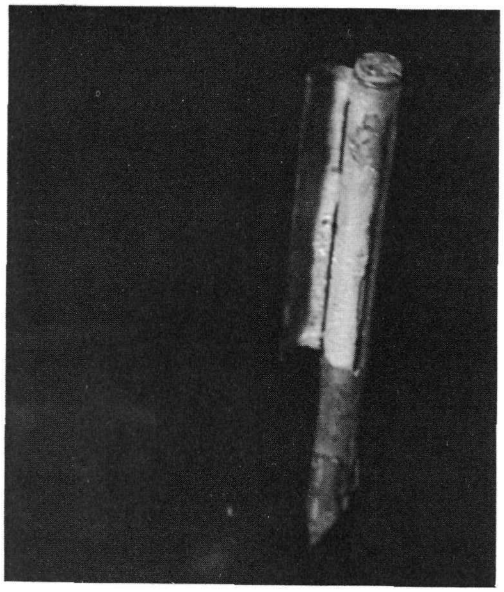


Figure 21b

Part of the trace obtained in testing Rod No. 709 before stripping.



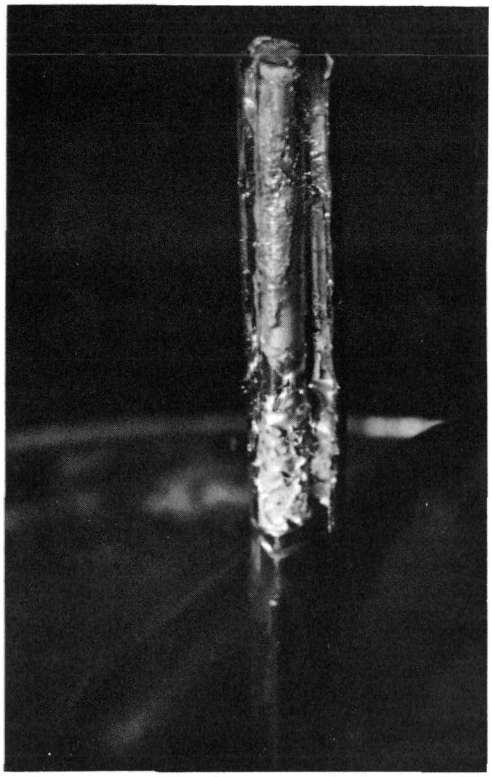
32844

Figure 22

Appearance of the bottom portion of the fourth slug along with partly opened jacket. The slug is upside down. Note the presence of voids at the end near the top of the picture.

3. Blanket Element No. 715

This element was stripped upside down after freezing so that the area of interest appears at the top of Figure 23a. The trace (Figure 23b) of blanket element No. 715 indicated a large void area at the bottom of the lower uranium slug. There was very little NaK at this point, and its appearance indicated it may have contained oxide or other impurities.



32846

Figure 23a. Appearance of Rod No. 715 on stripping the bottom portion. Note the appearance of NaK.

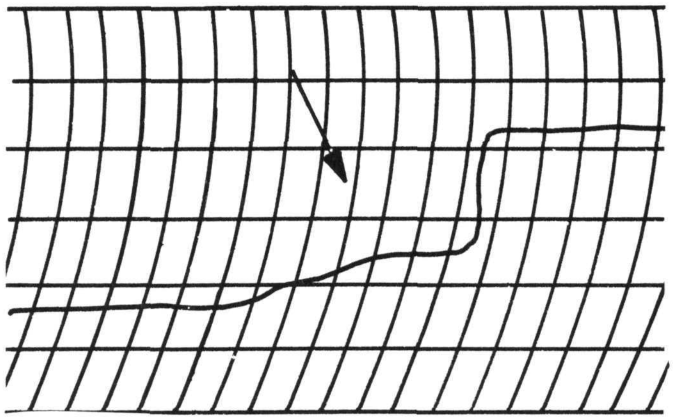
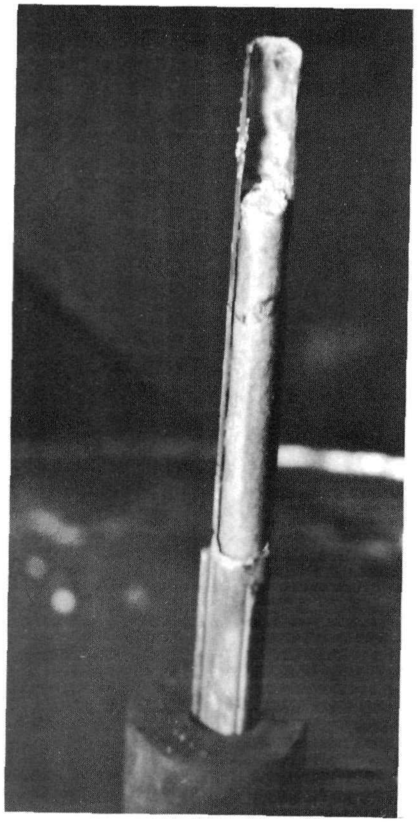


Figure 23b. Bottom portion of the trace obtained on testing Rod No. 715 before stripping. Note the deviation of the trace line.

Figure 24a was typical of the slug ends in the heat treated elements. A dense layer of NaK remained on the end after removing the adjacent slug. The trace in Figure 24b shows a slight indication where one slug ends and another begins. This may be compared with Figure 18b, which was the trace of the element that had not been heat treated.

4. Blanket Element No. 854

The three voids in a vertical line on the jacket in Figure 25a were approximately $\frac{1}{16}$ in. in diameter and represent the limit of sensitivity of the eddy current test, as was shown by the trace in Figure 25b.



32849

Figure 24a

Appearance of Rod No. 715 after stripping one side of the jacket on the second slug from the bottom. Note the presence of NaK at the junction.

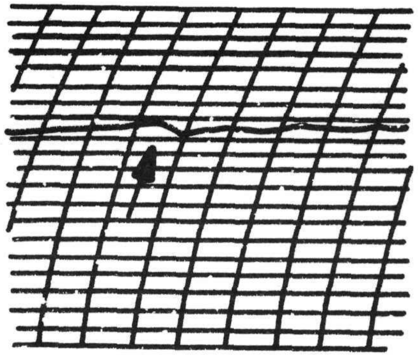
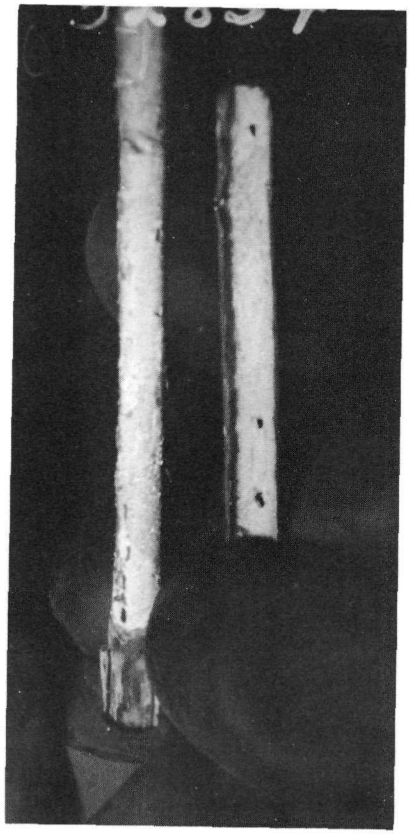


Figure 24b

Indication where one slug ends and another begins.



32854

Figure 25a

The appearance of the top slug portion soon after stripping. Note voids on the frozen NaK of the jacket.

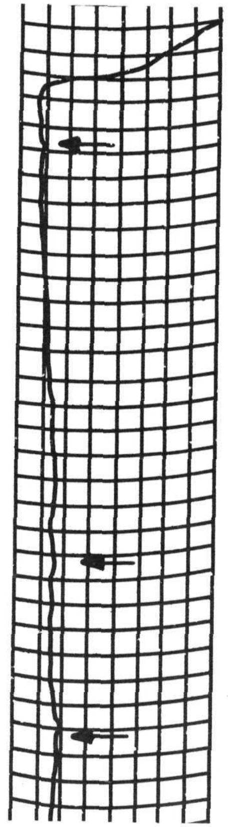


Figure 25b

Part of the trace obtained on testing Rod No. 854 before stripping. The voids indicated by the trace represent the limit of sensitivity of the instrument.

E. Summary

The destructive evaluation of the blanket elements verified that the NaK in heat-treated elements wet the surfaces of the uranium slugs and jacket tubing. The NaK did not peel off readily as it did in the elements that had not been heat treated. The NaK remained frozen longer on the slugs from heat-treated elements because the slug acted as a cool sink due to the excellent heat transfer at the interface. The indications on the eddy current test traces were in good agreement with the observed defects. However, it was found that small voids lying beneath the rib wire could not be detected.

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