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ORNL
CENTRAL FILES NUMBER
CF-56-8-166

COPY NO. 1

DATE: August 24, 1956

SUBJECT: EXAMINATION OF TITANIUM PULSE FEEDER DIAPHRAGM FAILURE

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FROM: T.M. Kegley, Jr.

Photostat Price $ 3.30

Microfilm Price $ 2.40

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EXAMINATION OF TITANIUM PULSE FEEDER DIAPHRAGM FAILURE

Metallography Report (Y-12) No. 30

Introduction

A titanium pulse feeder diaphragm failed by cracking after 450 hours service in the HRT mock-up. The diaphragm, which was made of MST Grade III titanium, was vibrated at 78 cpm at 40-50°C temperature. One side of the diaphragm was exposed to demineralized water and the other side was exposed to 10 g U/l UO_2SO_4 solution. The diaphragm had been sealed into the pulse feeder pump by means of bolts and a tin gasket placed on each side of the diaphragm.

Both surfaces of the diaphragm, as removed from the pump, were covered with considerable corrosion products. These products, as analyzed by X-ray diffraction, were shown to be predominately TiO_2.

Procedure

After the diaphragm was photographed the loosely adhered scale was removed from the diaphragm by brushing. The diaphragm was then checked for cracks by the use of liquid penetrants. Portions of the diaphragms were then photographed again. Following this, sections were taken for metallographic examination through the cracks at positions A, B, and C. as indicated in Fig. 1. Further sections for study were taken at F and E as shown in Fig. 1, and at D as shown in Fig. 2.

Results

The appearance of the as-received titanium diaphragm, (see Figs. 1 and 2), might lead to the conclusion that the diaphragm was severely corroded. However, upon removal of the surface scale by brushing, the surface appeared to be relatively unattacked. Surface markings due to fabrication were still clearly visible as seen in Fig. 7. Thickness measurements showed the diaphragm to be about the same thickness as a sheet specimen of the material from which the diaphragm was fabricated. Also the diaphragm surface had about the same appearance as the surface of the sheet from which the diaphragm was made.

Liquid penetrants revealed only three crack which are located at A, B, and C in Fig. 1. The cracks at B and C were both located in the lower fourth of the diaphragm.

Crack A, located at A, occurred near the center of the diaphragm in a position such as to be opposite a hole in the face of the stainless steel housing. This hole may be located at G in Fig. 3. A circular groove was formed about crack A on the water side of the diaphragm as shown in Fig. 4. This groove was an image of the hole in the face of the stainless steel housing. A photomicrograph of the section taken through crack A, (see Fig. 5) shows the crack to be transgranular. No impression appeared to be connected with crack A other than the circular groove.

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The hole at G in the stainless steel housing reportedly had a rough edge which remained from drilling. This rough edge would account for the circular groove found about crack A on the water side of the diaphragm.

Crack B, is located at B in Fig. 1, is shown in Fig. 6. Shallow impressions occur in crack B on the water side, but none occur on the soup side.

Crack C, located at C in Fig. 1, is shown in Figs. 7 and 8. Shallow impressions appear on the water side as shown in Fig. 8. One small dent appeared in crack C on the soup side. A section containing crack C is shown in Fig. 9. Again cracking appears to be transgranular.

No evidence of a tensile type failure such as necking was seen in any of the cracks examined. While the crack shown in Fig. 9 appears to be offset somewhat, this probably occurred during the mounting of the specimen.

The layer shown in Fig. 10 proved to be tin and is shown in cross section in Fig. 11. There appeared to be a corrosion product of unknown composition between the tin layer and the titanium surface. The tin layer shown in Fig. 12 appeared to be fairly adherent as it did not come off during the brushing. However, during mounting for metallographic examination, the tin layer was pulled away from the titanium surface as shown in Fig. 13. The titanium surface beneath the tin layers did not appear to be corroded.

Small areas of the diaphragm surface were colored with a reddish metallic deposit suggestive of copper. X-ray diffraction had previously verified that this was copper. One copper deposit on the diaphragm surface is shown in Fig. 14. Since the uranyl sulfate solution contained copper, the supposition might be that tin displaced the copper from the solution causing the copper to plate on the titanium.

The surface of the titanium was attacked very little, if at all. A typical surface found at F (Fig. 1) $1\frac{1}{2}$ inches from the lower edge of the diaphragm is shown in Fig. 15.

Discussion of Results

X-ray diffraction analysis indicated that the rather abundant corrosion product was predominately TiO_2. This appears to be at variance with the negligible amount of corrosion attack found in the metallographic examination. No explanation for this is evident unless it might be that very slight corrosion of the titanium would result in a voluminous corrosion product.

The titanium diaphragm was in operation for more than two million cycles. The two cracks in the lower fourth of the diaphragm were associated with surface impressions which act to lower the fatigue strength of the metal. Spretnak, et al.[1], have shown that at room temperature the endurance

1. Spretnak, Fontana, and Brooks, Trans. ASM, V. 43, (1951) P. 556

limit of titanium decreases from 73,500 psi for an unnotched specimen to 27,500 psi for a notched specimen. Impressions such as those found on this diaphragm would probably lower the fatigue strength of titanium even more than in the preceding example. While there are a number of misunderstood variables, it seems likely that the titanium diaphragms failure was due primarily to fatigue; or corrosion and fatigue acting together.

T.M. Kegley, Jr.

TMK:eo

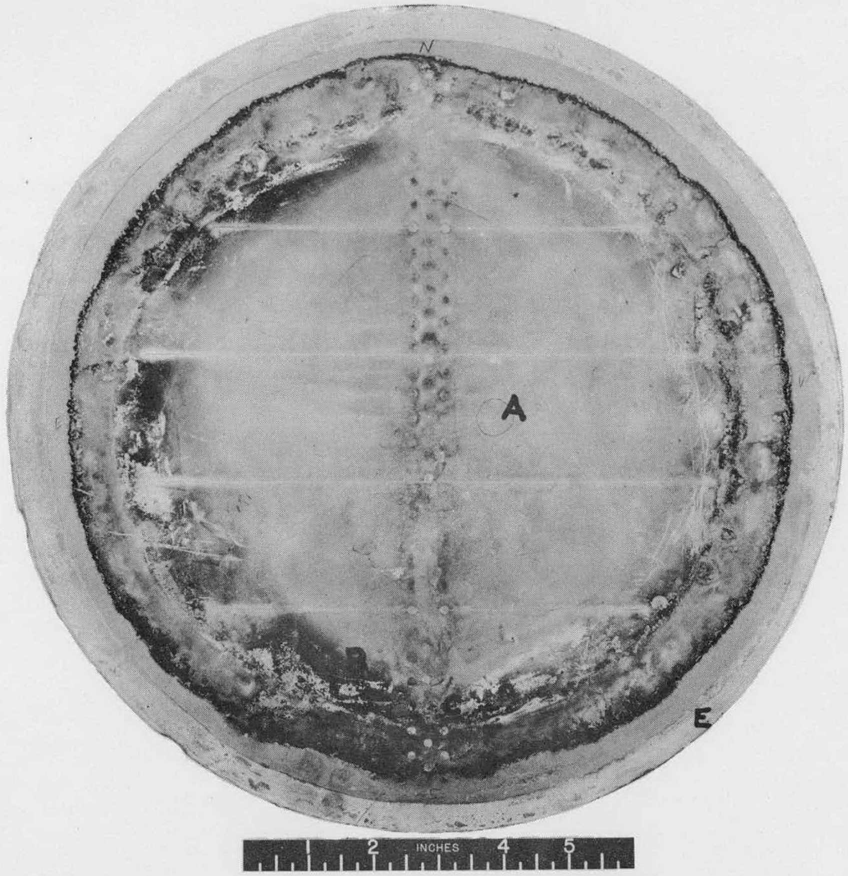

Figure 1 T10150
Soup Side of Titanium Diaphragm

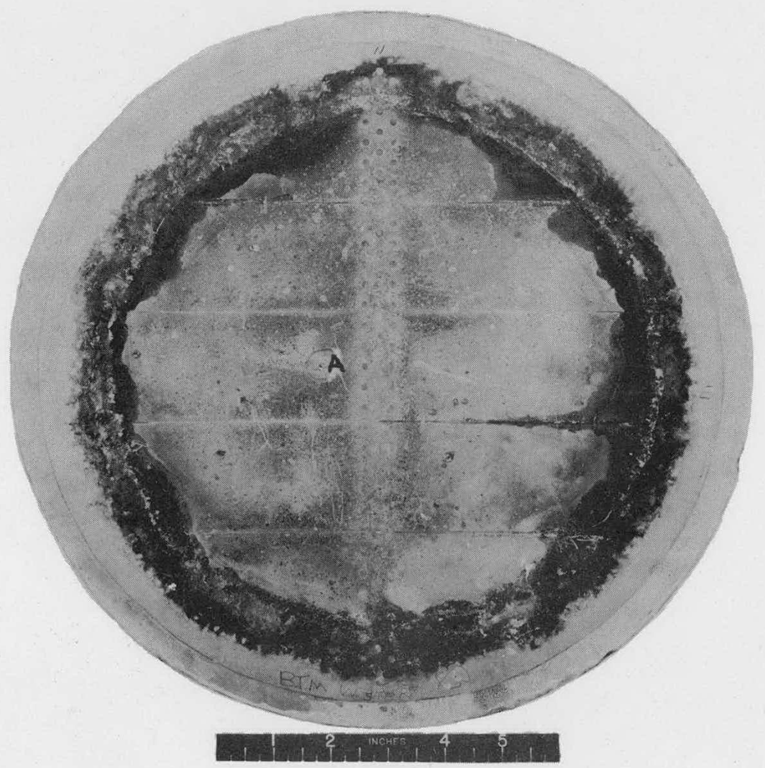

Figure 2 T10149
Water Side of Titanium Diaphragm

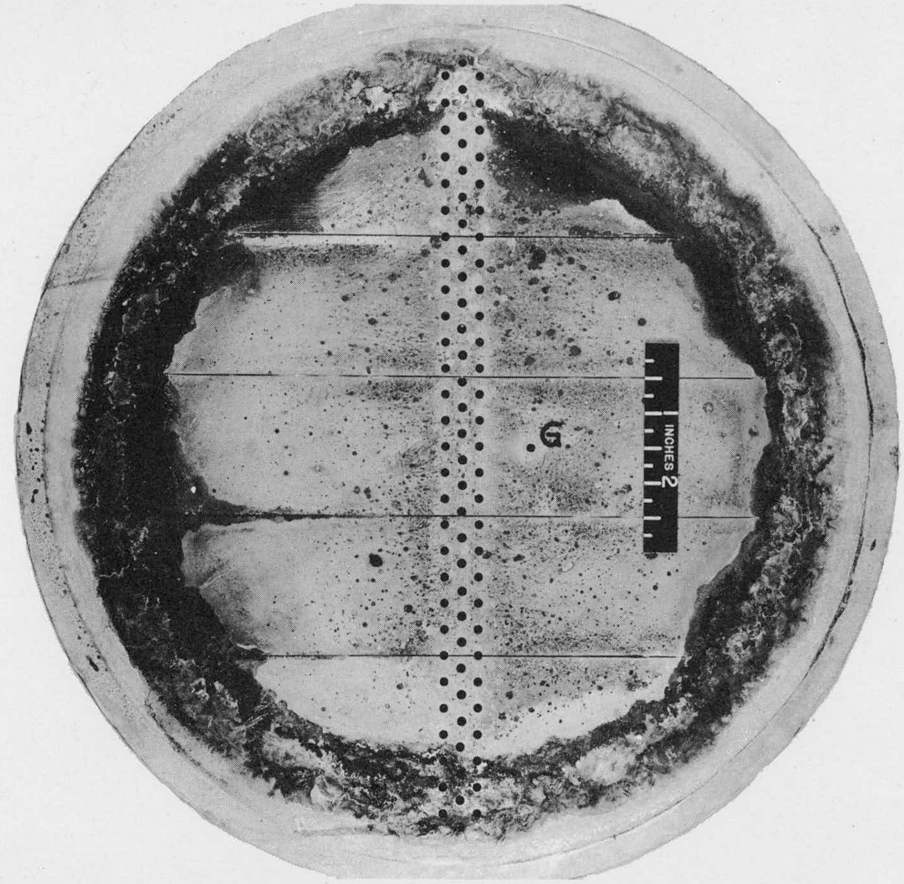

Figure 3 T10168
Face of Stainless Steel Housing Adjacent to Water Side of Titanium diaphragm.

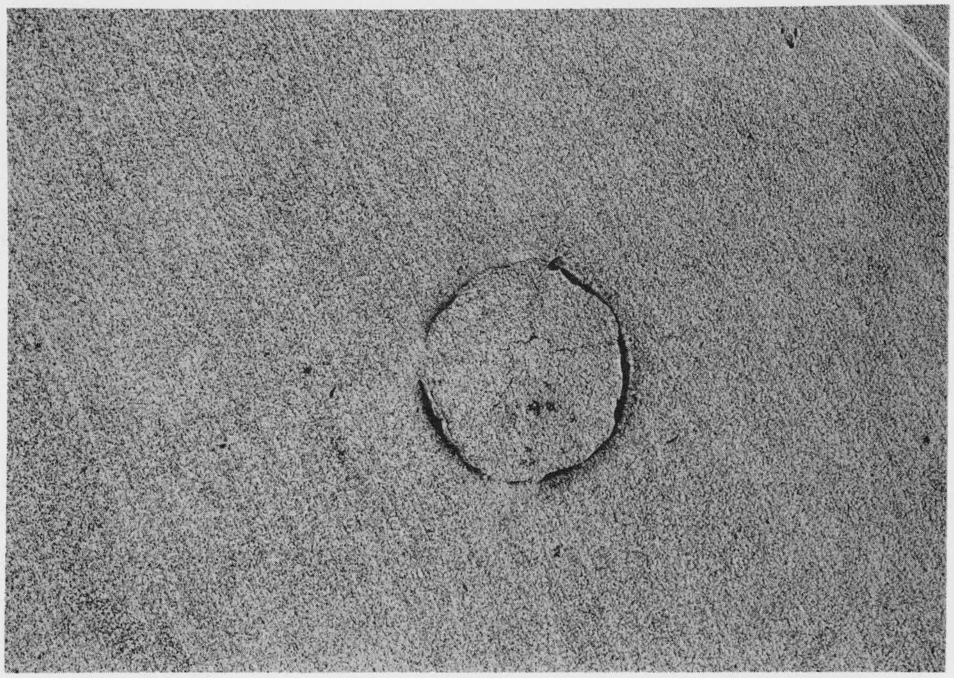

Figure 4. T10154 10X
Crack A, see Fig. 2 for location. Water Side of Diaphragm After Scale Removal

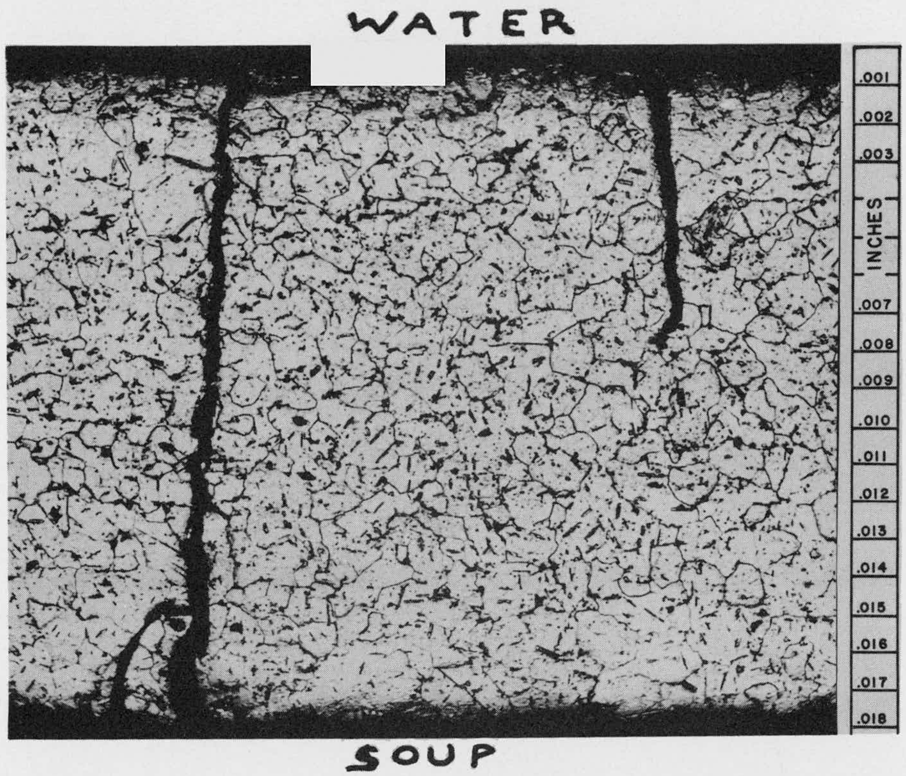

Figure 5 T10358 200X
Section Containing Crack A, See Figure 4

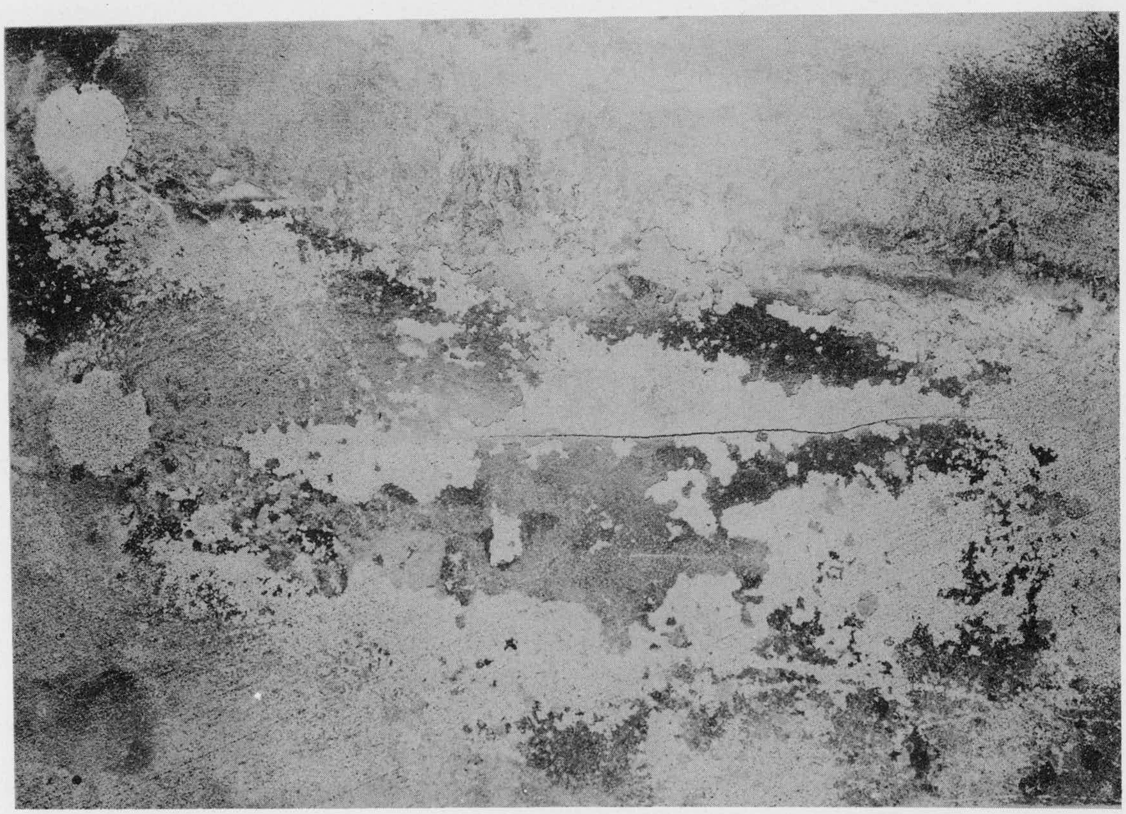

Figure 6 T10160 5X
Crack B, See Figure 1 for Location. Soup Side of Diaphragm before Scale Removed.

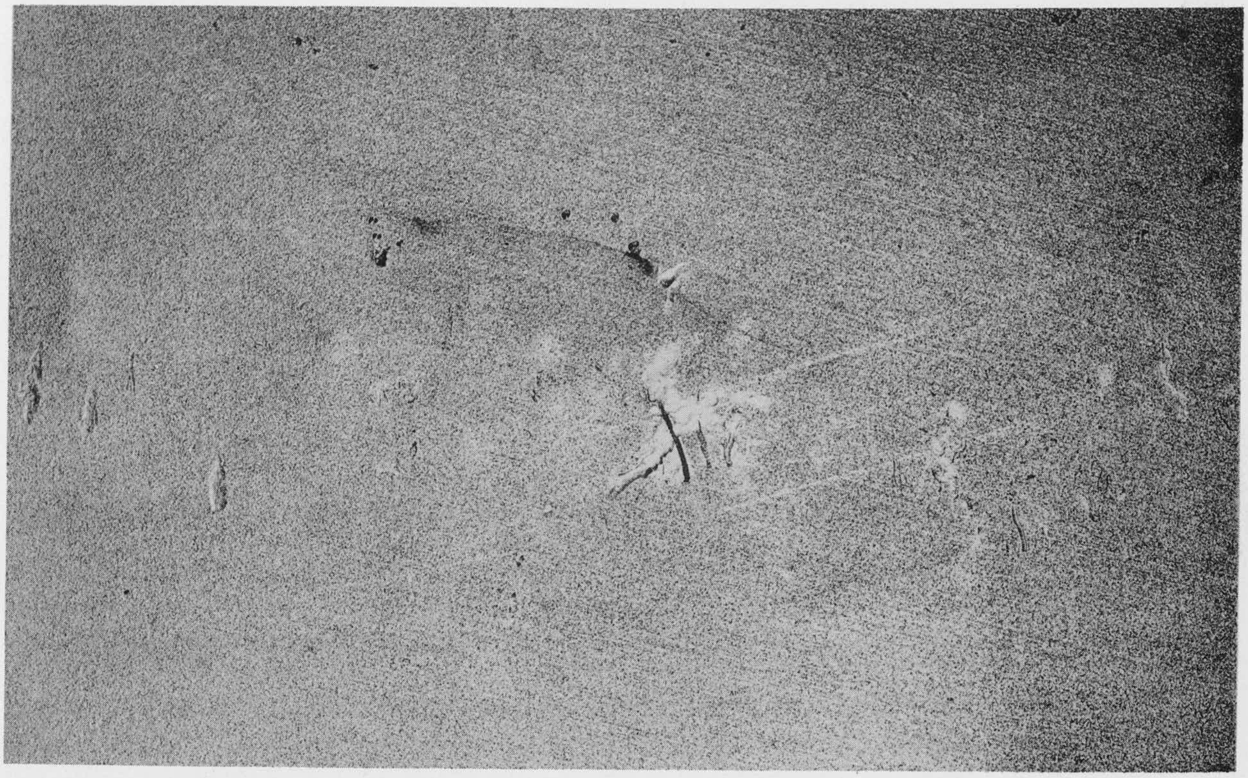

Figure 7 T10162 5X
Crack C, See Fig. 1 for Location. Water Side of Diaphragm After Scale Removed

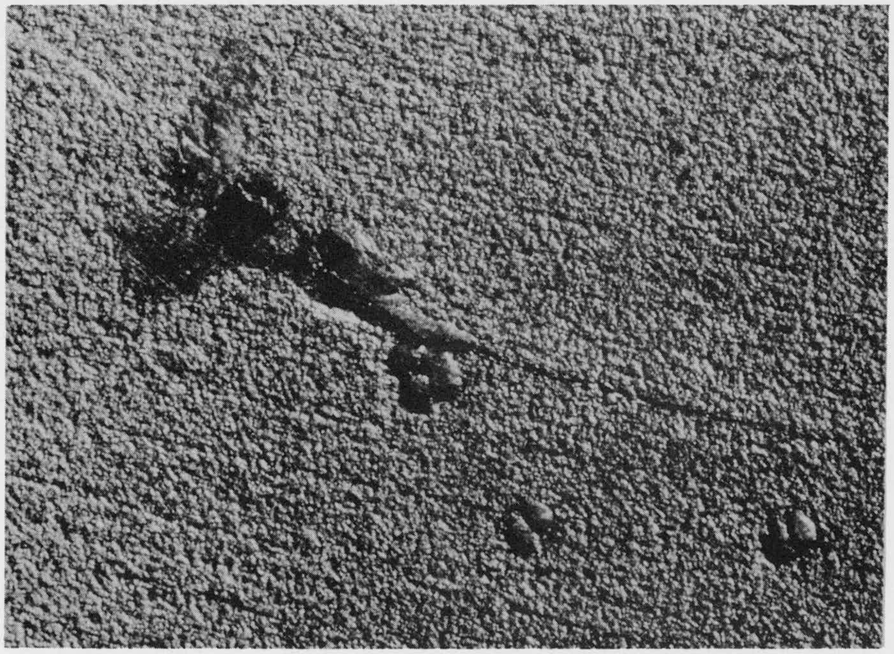

Figure 8 T10163 25X
Indentations in Crack C. Enlargements of Area Shown in Fig. 7.

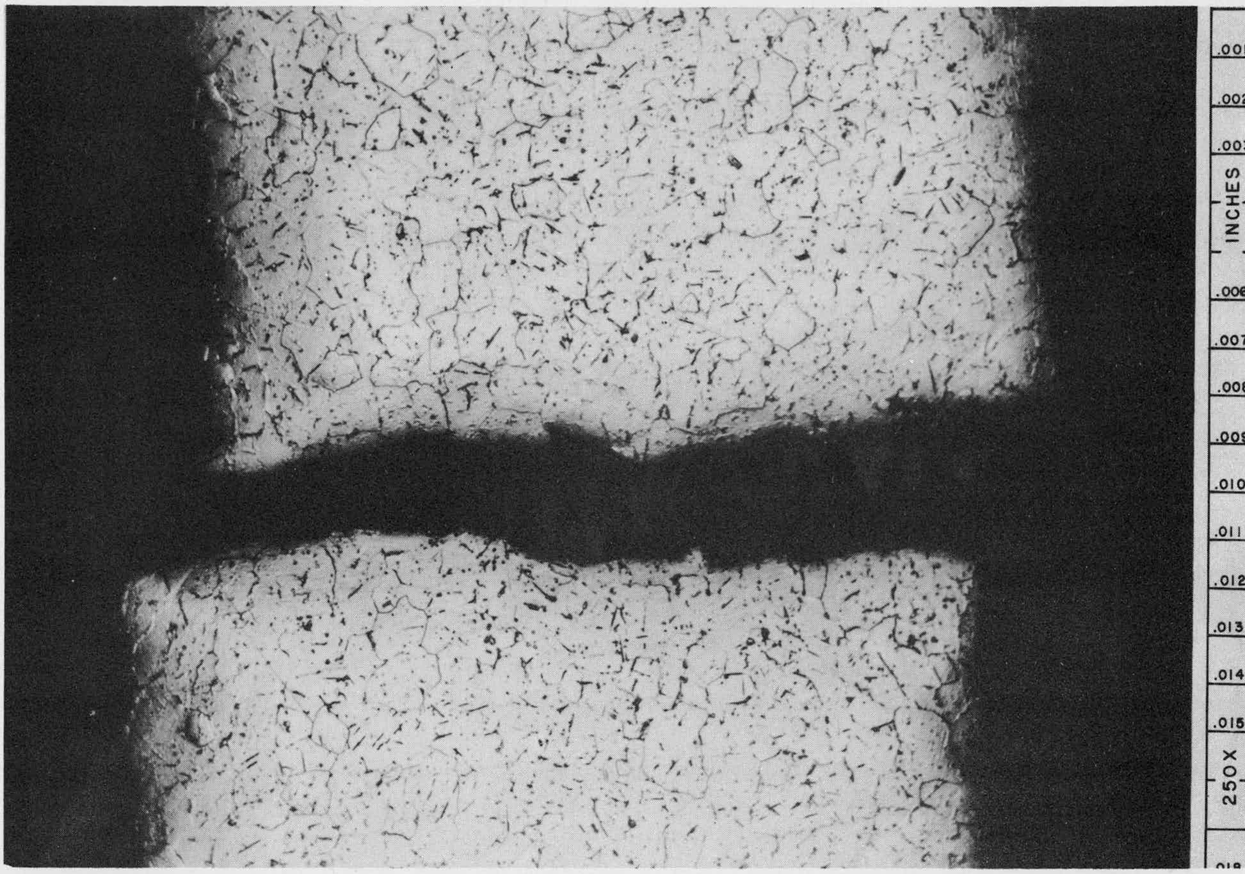

Figure 9. T10362 250X
Section Containing Crack C. Etch: 1HF $1HNO_3$: 2 Glycerine

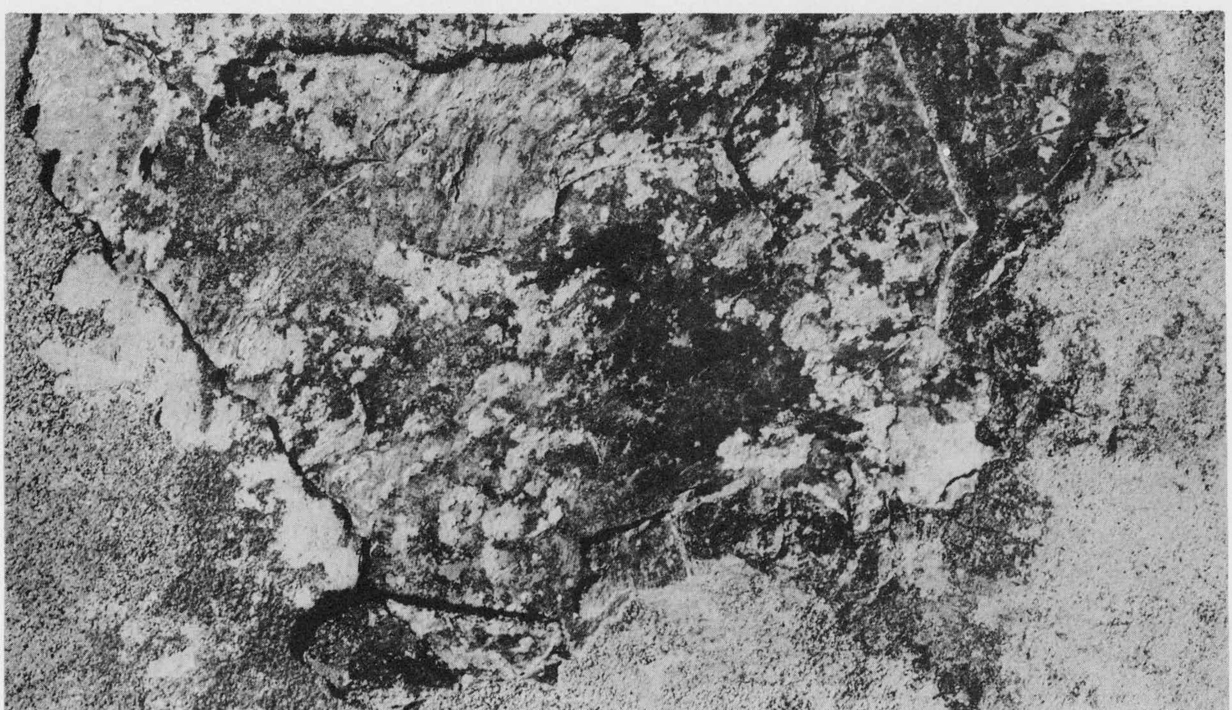

Figure 10 T10165 20X
Tin on Surface of Diaphragm at D, Location Shown in Figure 3

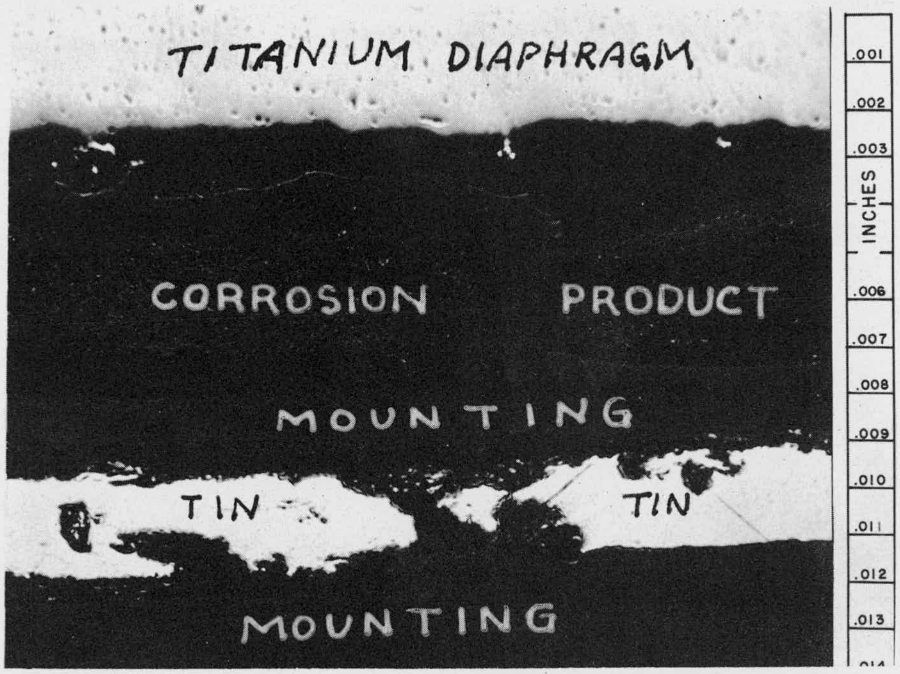

Figure 11 T10367 250X
Section Taken at D Shown in Figures 2 and 10

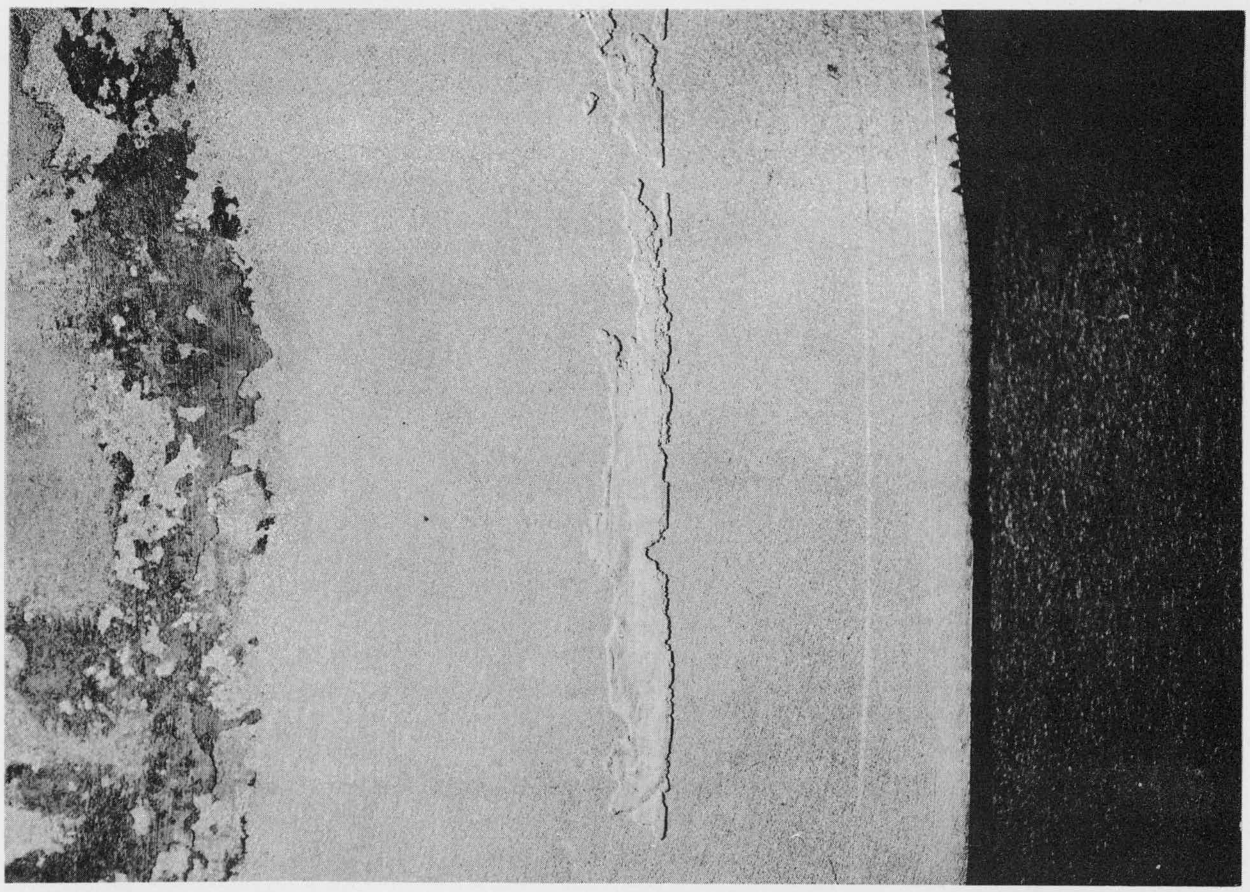

Figure 12 T10151 5X
Tin Layer on Surface at E (see Fig. 1) near Outer Edge of Diaphragm. Soup Side of Diaphragm before Scale Removed.

436 010

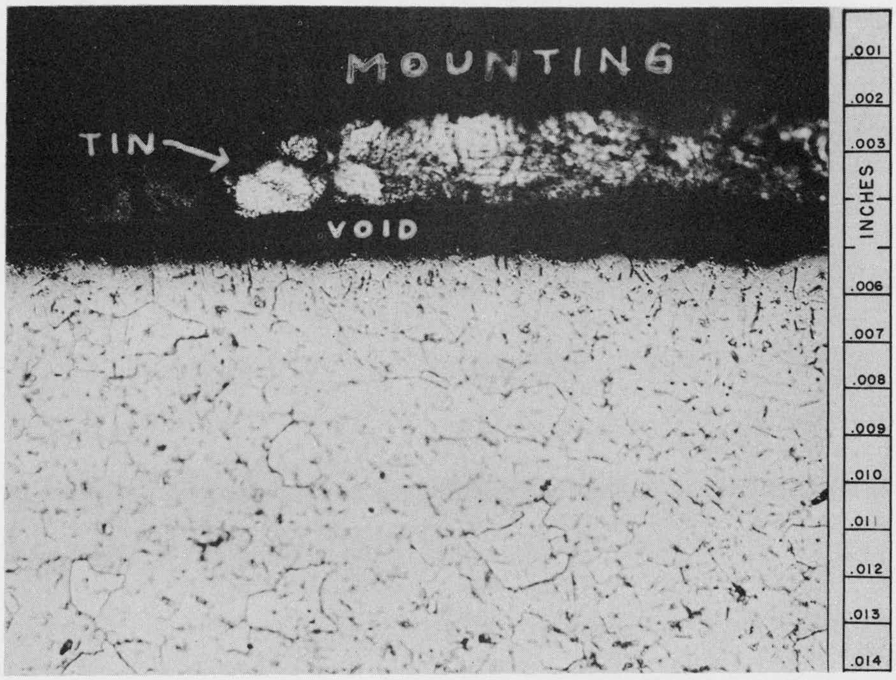

Figure 13 T10414 250X
Tin Layer on Surface at E, see Fig. 1 for location. Etch: 1 HF: $1HNO_3$: 2 Glycerine

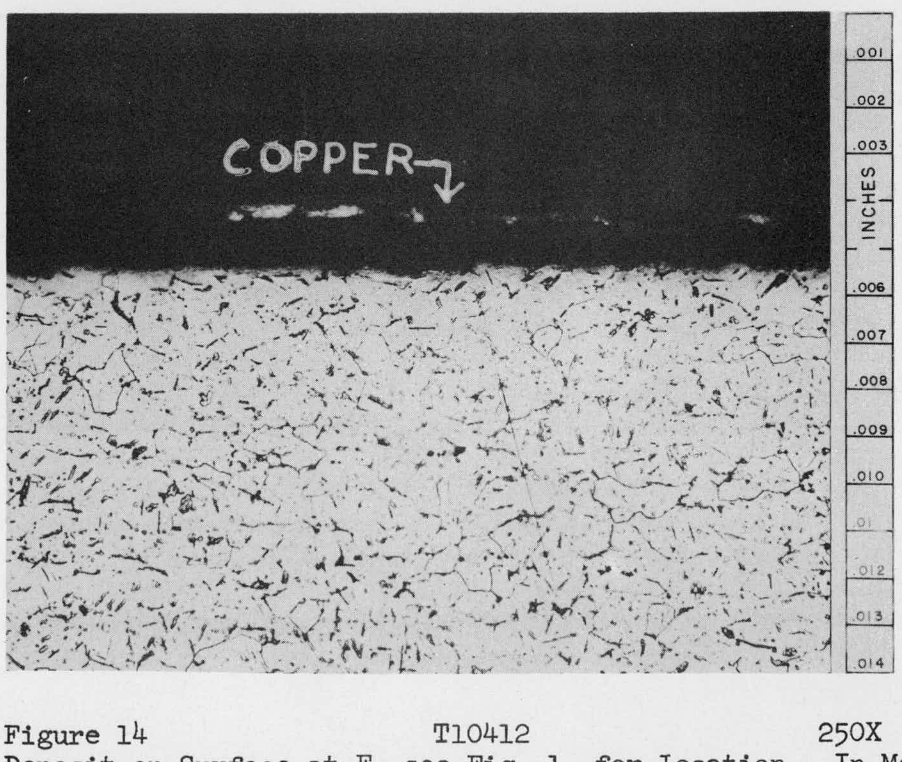

Figure 14 T10412 250X
Copper Deposit on Surface at E, see Fig. 1, for location. In Mounting Process Copper Has Loosened from Surface. Soup Side of Diaphragm. Etch: See Fig. 13.

436 011

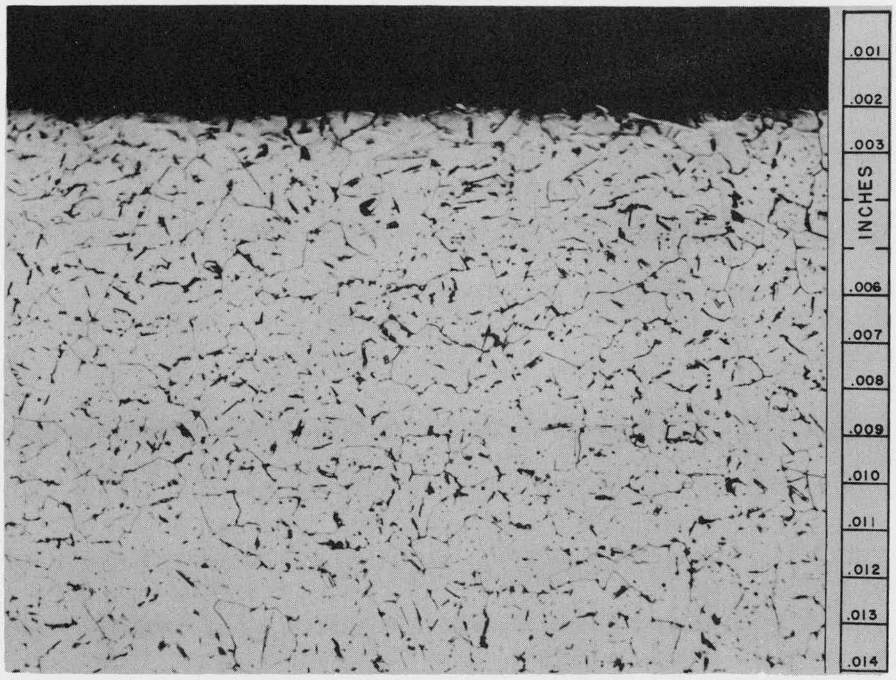

Figure 15 T10410 250X

Surface, water side, $1\frac{1}{2}$ inches from edge. Location is at F in Fig. 1. Surface on soup side was similar in appearance. Etch: See Fig. 13.