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TITLE INVESTIGATION OF X-RAY INDICATIONS IN GOX LINE WELD

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ABSTRACT

Numerous defect indications were revealed in the 4 1/2" GOX tube by x-ray. Bend tests proved that tubes containing these indications were brittle in the weld areas. Metallurgical tests and vendor plant inspection point to incipient melting of the weld fusion line as the cause of the indications. Proper heat treatment controls eliminated the problem.

KEY WORDS

X-ray Weld indications

Welding

Inconel 718

Incipient Melting

718 Heating

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LIST OF FIGURES

1.0 OBJECT

To determine the nature of x-ray indications in the GOX line longitudinal weld and their effect on the properties of the tubing.

2.0 BACKGROUND

The 4-1/2" welded Inconel 718 tubing used in the GOX duct system of S-IC when x-rayed in the final heat treated condition, revealed numerous indications along the edges of the longitudinal weld, (Figure #1). These welds when x-rayed prior to planishing and solution heat treatment did not show these indications. These tubes have been produced in two production lots; (1) those, solution treated at the tube vendor's plant at 1750° ± 25°F and subsequently at Lindberg in Los Angeles at 1950°F (± 25°), have not shown these indications when x-rayed at the Michoud assembly facility, and (2) those, solution treated at the tube vendor's plant at 1950° F ± 25°F only, showed these indications when x-rayed at Michoud assembly facility. Due to the criticality of the system it was decided to determine the nature and source of these indications and their effect on the reliability tubing.

3.0 CONCLUSIONS

1) X-ray indications were due to incipient melting in the weld fusion lines.

2) Incipient melting was caused by heating tubes in excess of 1950°F ± 25.

3) Incipient melting creates a brittle condition in the weld fusion line.

4.0 RECOMMENDATIONS

1) Heat treatment of welded Inconel # 718 tubes should be conducted in a certified furnace at a temperature not exceeding 1950° ± 25°.

5.0 PROCEDURES AND RESULTS

A section of tubing containing defects was delivered to the M&P Lab accompanied by x-rays of the longitudinal seam welds. "Worst areas" were removed and they in turn were x-rayed to accurately locate the defects. (Figure #1). Sections were cut exposing the cross sections of several defects and these were mounted and given a metallographic examination. This examination revealed an anomaly in the structure of the weld in the area of the weld fusion. (Fig. # 2, 3). These anamolies were located in the first 1/4 to 1/3 of the distance from the inside of the tubing.

5.0 PROCEDURES AND RESULTS (Continued)

To determine the effect of these anomalies on the integrity of the tube, a part was obtained that showed one end free of indication and one end heavy with indications. Six 1/2" wide ring sections were removed from each end. (Each set of six representing defect containing and defect free material respectively). A bend test (across the weld) was performed on these rings. (See Figure #4 for test setup) the ring was set in a jig in a standard test machine and a penetrator with a 1/4" diameter head was placed against the weld center and the ring was compressed. The defect free rings were bent until the inside surfaces of the rings touched. No failure occurred. The rings containing defects were compressed 1/2" maximum when definite failure ocurred,(See Figure #5).

Boeing personnel (Project, M&P, Materiel, Manufacturing Development and Quality Control) then visited the tube vendor to observe tube production. X-rays were taken after welding, planishing, heat treating and sizing. The defects were first reproduced in the ends of the tubes that got excessively overheated during induction heating, (See Figure #6). This pointed to incipient melting as the cause of the defect. To confirm this condition, tubes were processed by the vendor at 1750°F, 1950°F, 2225°F and 2400°F. X-rays of these test tubes showed clear at 1750°F, minor indication at 1950°F (furnace used was improperly controlled and was probaby not 1950°F in defect areas). Continuous defects at 2100°F, continuous and extremely heavy defects at 2225°F and tube melting at 2350°F and 2400°F. In order to confirm improper furnace control at 1950°F four tubes were sent to Los Angeles to be heat treated in a properly certified furnace at 1950°F. X-rays of these welds showed no defects in the four tubes.

6.0 DISCUSSION

The furnace used to heat treat the tubes at the vendor facility is a Tocco induction type with homemade copper coils. The temperature control used was an optical pyrometer. The vendor was' not sure whether the pyrometer was calibrated once every six months, or once per year. The furnace operator measured the temperature on a single spot on the tube through the coils. At 1950°F the pyrometer dot was extremely hard to discern, let alone get an accurate color balance. The tubing, having a slight bow, varied in position relative to the coil. One tube observed was run close to the bottom of the coil and this particular area was in excess of 1950°F. The ends of the tube if not closely followed by another tube, were obviously overheated. The furnace controls were continuously manually adjusted while the Boeing team was observing this operation.

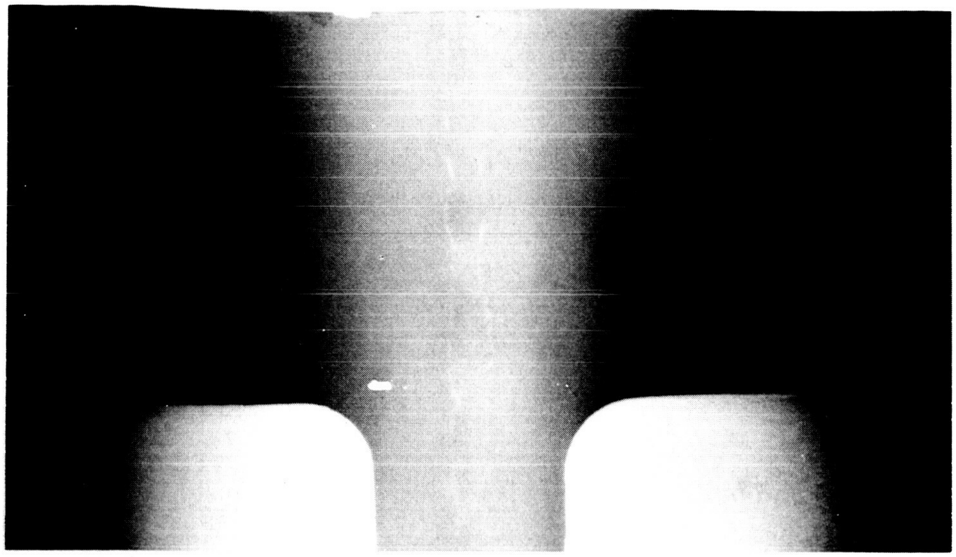


Fig. # 1 X-Ray Positive Print of Showing Defect Indications

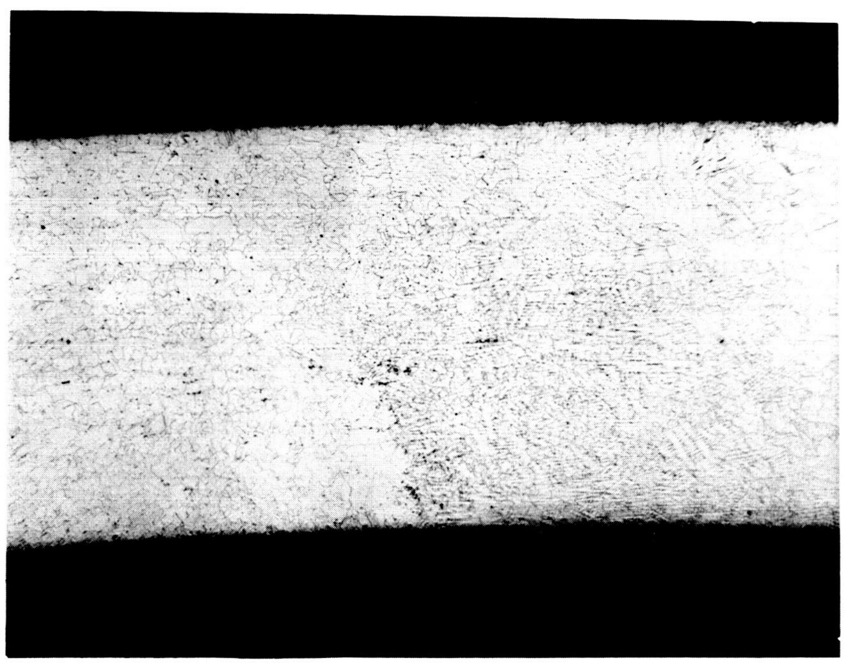
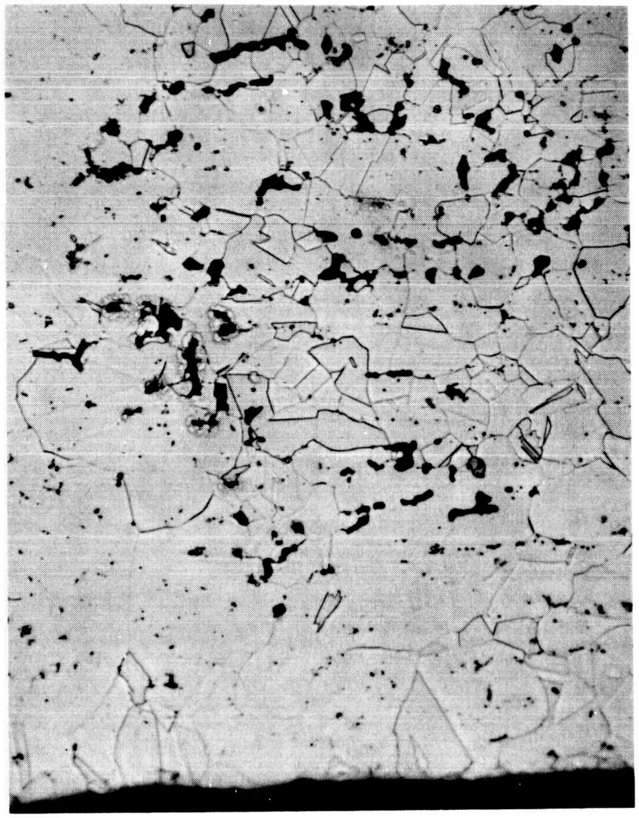


Fig. # 2 Typical Tubing Cross Section in X-Ray Defect Area

100X



200X

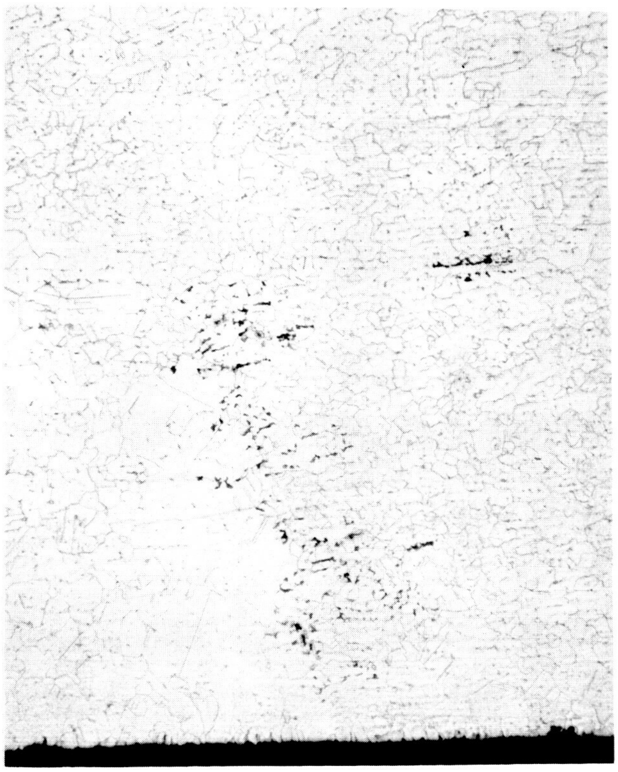


Fig. # 3 Higher Magnification of Figure # 2 Area

50X

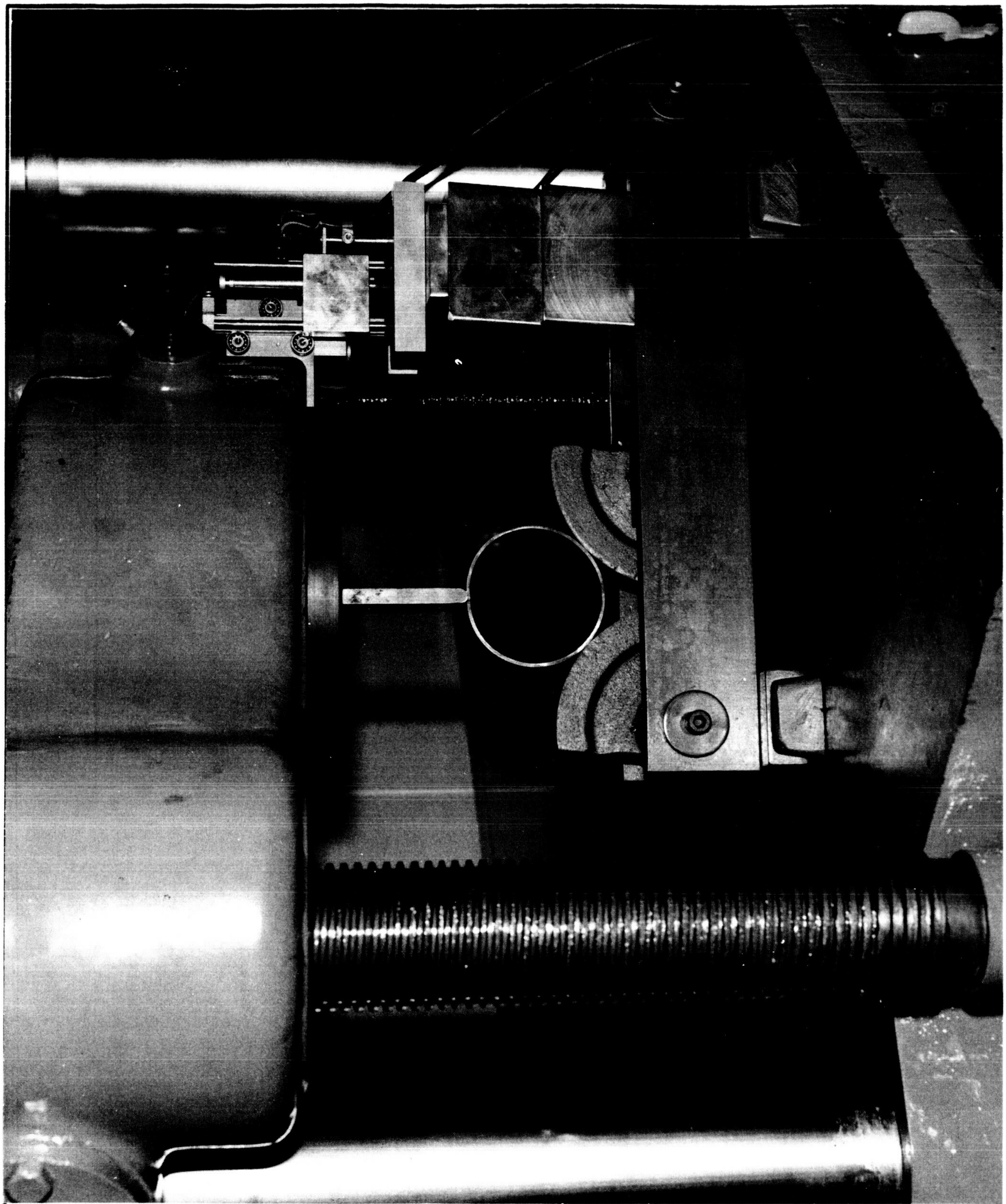


Fig. # 4 Test Set For Bending of Tube Ring Specimens

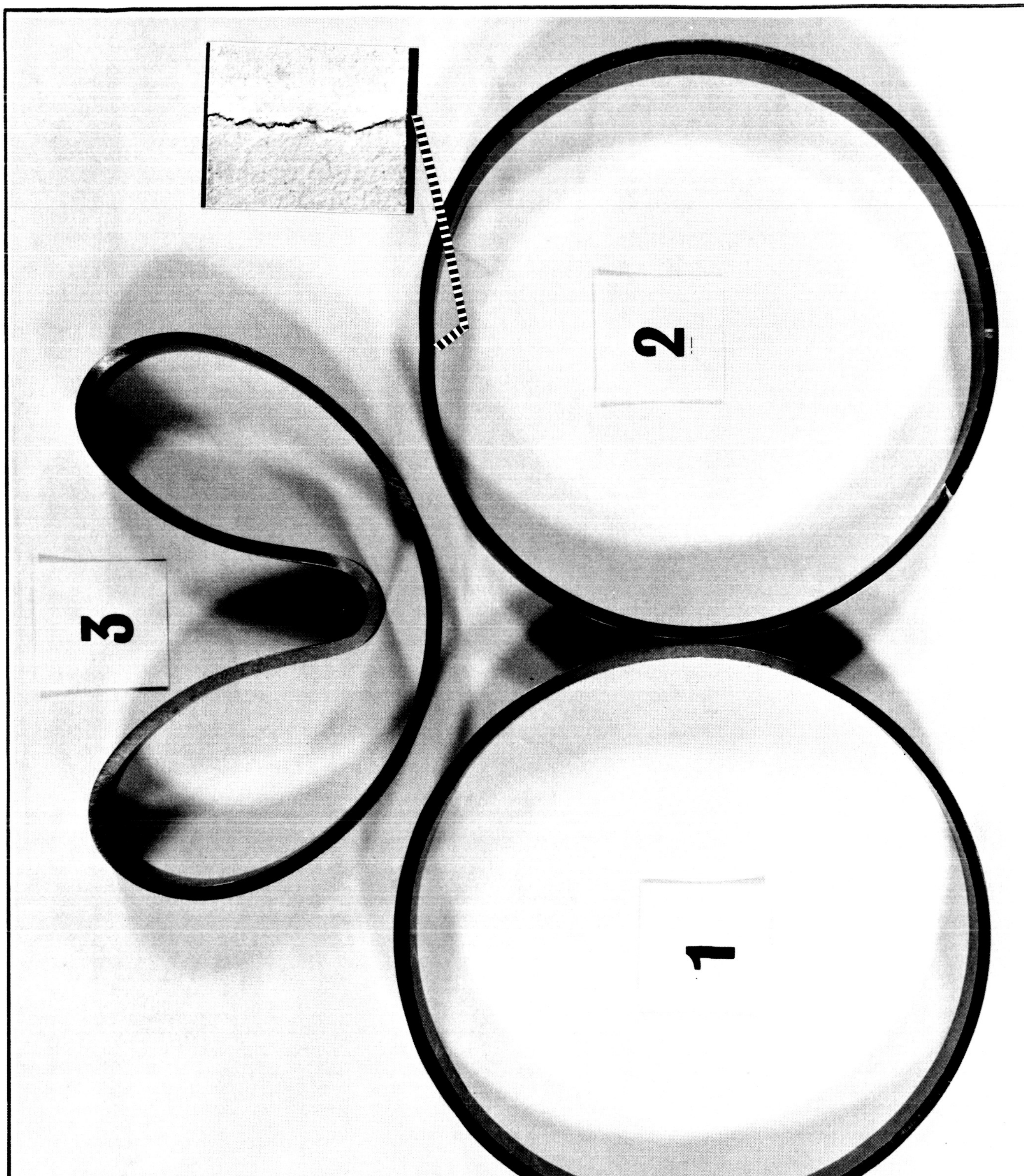


Fig. # 5 #1 Untested Ring
#2 Typical Defect Containing Ring with Crack Detail
#3 Typical Defect Free Ring

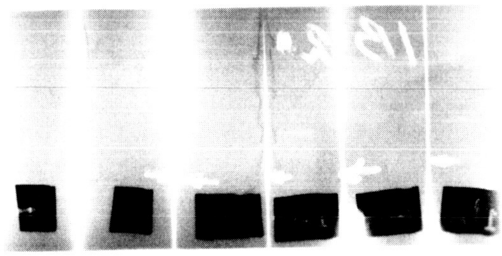


Fig. # 6 X-ray Positive Print Showing Defects Reproduced in Hot Ends of Tubing During Production

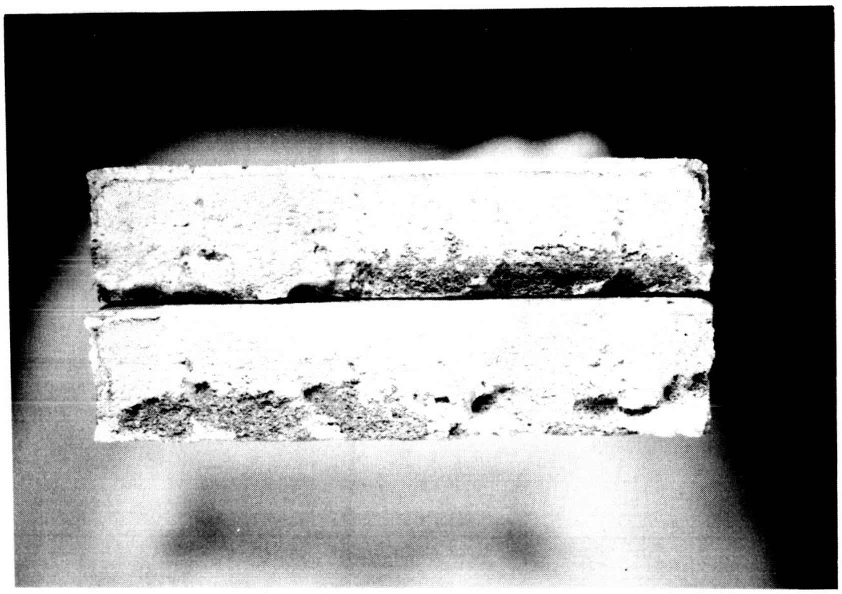


Fig. # 7 Fracture Face of Failed Ring 6X

100X

Fig. # 8 Metallographical Crossection of Failed Ring - Note Crack Propagates Through Defect Area