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STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

SNOHOMISH RIVER BRIDGE REPORT

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and
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SNOHOMISH RIVER BRIDGE REPORT

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Your: Snohomish
River Bridge Cont.

INTRODUCTION:

Two pieces of Armco Sheffield Super Strength 100 steel from a girder intended for use on the Snohomish River Bridge were received from the State of Washington on or about May 20, 1963. These pieces were sawed from the edge of the top and bottom flanges of the girder at a place that was suspected of containing defective steel which was about three feet from the end of the section. The pieces were 13/16" thick by the full 1-7/8" flange thickness in width and approximately 12" long in the direction parallel to the girder. Thus each piece had two 13/16" x 12" as rolled surfaces, a 1-7/8" x 12" flame cut and ground surface, and a 1-7/8" x 12" saw cut and ground surface. As received, these pieces were stamped "TOP" and "C", and "BOT" respectively to identify the pieces according to the flange from which they originated. The top piece had been air arc gouged to a depth of 3/8" along the center of the flame cut surface for about 1/2 the length of the piece.

EXAMINATION PROCEDURES:

Specimens for testing and examination were sawed and machined from these pieces as illustrated in Figure 1. The bend test was made using a guided bend jig which provided 13% elongation at the outside radius of the bend on a 3/8" thick piece. The break test was performed by clamping the specimen in a vise and using a hammer blow to fracture it. Vise and hammer marks visible on the gouged specimen in Figures 2 and 3 were made after the top flange piece had been cut into separate specimens and examined. The metallographic specimens were prepared by wet grinding, dry sanding through 0 to 4/0 papers, polishing with a mixture of alumina and stannous oxide, etching 10 to 15 seconds in 2% Nital, and drying in Ethanol. The polishing, etching and drying sequence was repeated once. Microphotographs of the unetched surface on the top flange specimen were made at 50X after the initial polishing operation. These are shown in Figures 9 through 14. The etched specimens were examined at various diameters under white and polarized light to ascertain the nature of the inclusion material present. Microphotographs of areas of interest on the metallographic specimens were made at a magnification of 500X. These are shown in Figures 15 through 20.

TEST RESULTS:

Top Flange Sample.

A. The guided bend test (13% elongation) failed at less than 1% elongation. It separated almost completely

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at 13% elongation at a plane of layered inclusion material parallel to and half way between the plate surfaces (see Figures 4 and 5).

B. The flexure test against central layer of inclusion material failed in the manner of a lamination. See Figures 6, 7, and 8.)

C. The metallographic specimen showed extensive layers of nonmetallic inclusion material largely connected by what appear to be cracks. See Figure 9 through 20. Macro examination and ultrasonic testing indicated that this condition extended throughout the top flange sample to such a degree that 50% to 70% of the section area was judged separated in a laminated fashion.

Bottom Flange Sample

A. The guided bend test 13% elongation had a laminar separation of about 1/2" long and 1/32" deep on the outside radius of the bend at 13% elongation. While technically a failure, this defect is not considered significant in view of its size and orientation with respect to the applied stress (see Figure 28).

B. The flexure test against the central portion of plate withstood all attempts to fracture it by means of hammering.

C. The results of the tensile test removed from the bottom flange sample as shown on Figure 1 are as follows:

Ultimate Strength	114,000 psi
Yield Strength	105,500 psi
Elongation @ 2"	15%
Reduction of Area	43%

The specimen exhibited sufficient length of visible seams on the side and through the fractured ends to cause the bottom flange plate to be rejected as firebox quality steel on the basis of the homogeneity requirements under specification ASTM A20-59. See Figure 23. During the machining of this specimen, it was believed advisable to provide more than normal support for the piece in order to counter any tendency of the machine tool to dig into the line of inclusion material that became visible as the piece was being prepared.

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D. The metallographic specimen showed some layers of nonmetallic inclusion material (see Figures 24 through 27). Ultrasonic testing confirmed the existence of these layers of inclusions by micro and macro examination and indicated that they were distributed in a discontinuous and disconnected fashion so that about 5 to 15% of the section area was judged separated in a laminated fashion.

CONCLUSIONS:

The sample taken from the top flange was judged to be so separated by layers of inclusion material as to be incapable of acting as a single thickness of plate at the design stress levels. Therefore, it was considered to be laminated.

The sample taken from the bottom flange did not appear to contain a sufficient number of layered inclusion to impair its capacity to act as a single thickness of plate. Therefore, it was judged to be unlaminated.

RECOMMENDATIONS:

It is recommended that the steel containing defects of the extent and nature represented by the top flange sample should be removed from the member if continuous into the width of the flange plate and especially if this condition enters into the butt weld area.

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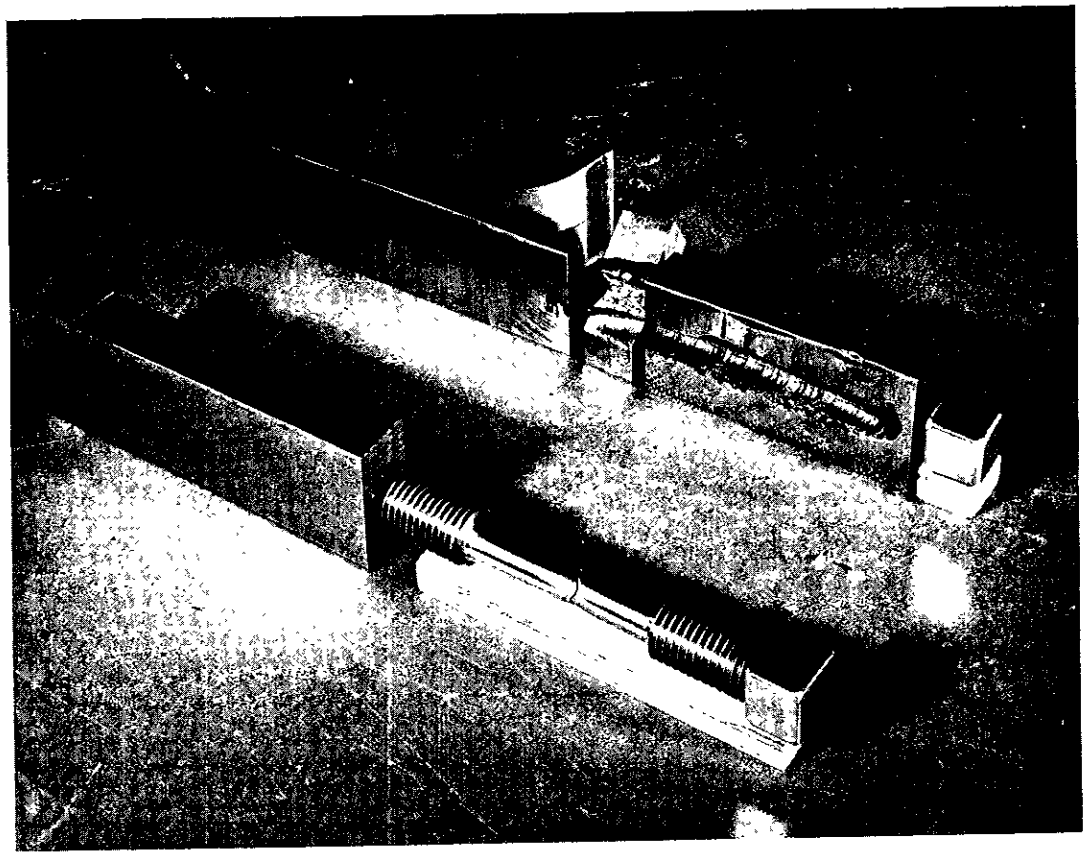

FIGURE 1. Bottom flange sample in foreground - Top flange sample in background - showing how pieces were removed from samples for examination and test.

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FIGURES 2 THROUGH 20

TOP FLANGE STEEL

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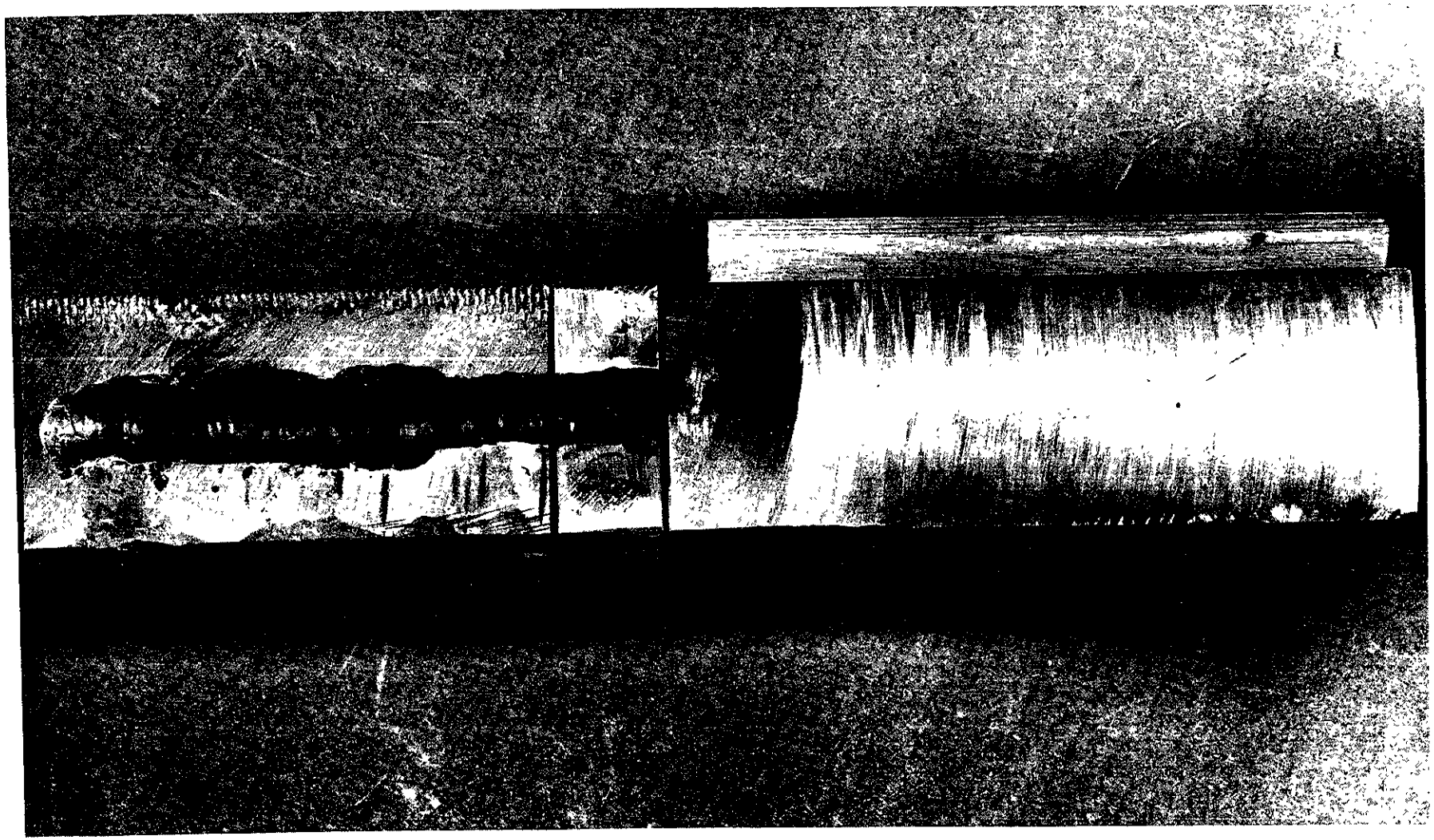

FIGURE 2. Pieces from the top flange sample laid out according to their respective positions in the sample and viewed from the ground flame-cut outside edge of the flange from which the sample was removed. Simple visual inspection of the line of layered inclusion materials visible in the photograph showed it to be virtually continuous throughout the sample. (A fact confirmed by ultrasonic testing.)

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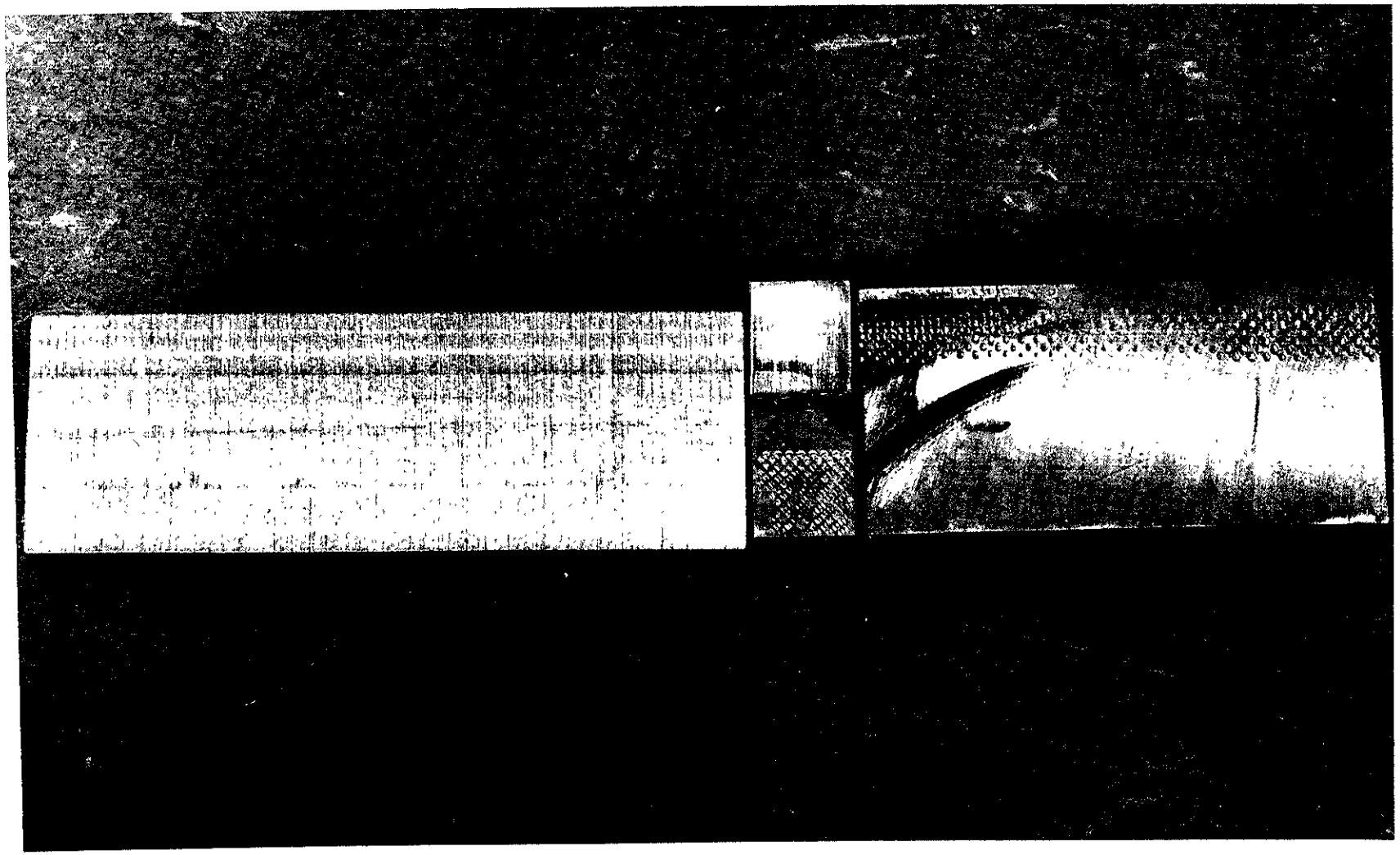

FIGURE 3. Pieces from the top flange sample laid out according to their respective positions in the sample and viewed from the side closest to the web and opposite the flame-cut edge of the flange. Notice that the layers of non-metallic inclusions are visible without magnification or etching on both the band-sawed and the ground surfaces.

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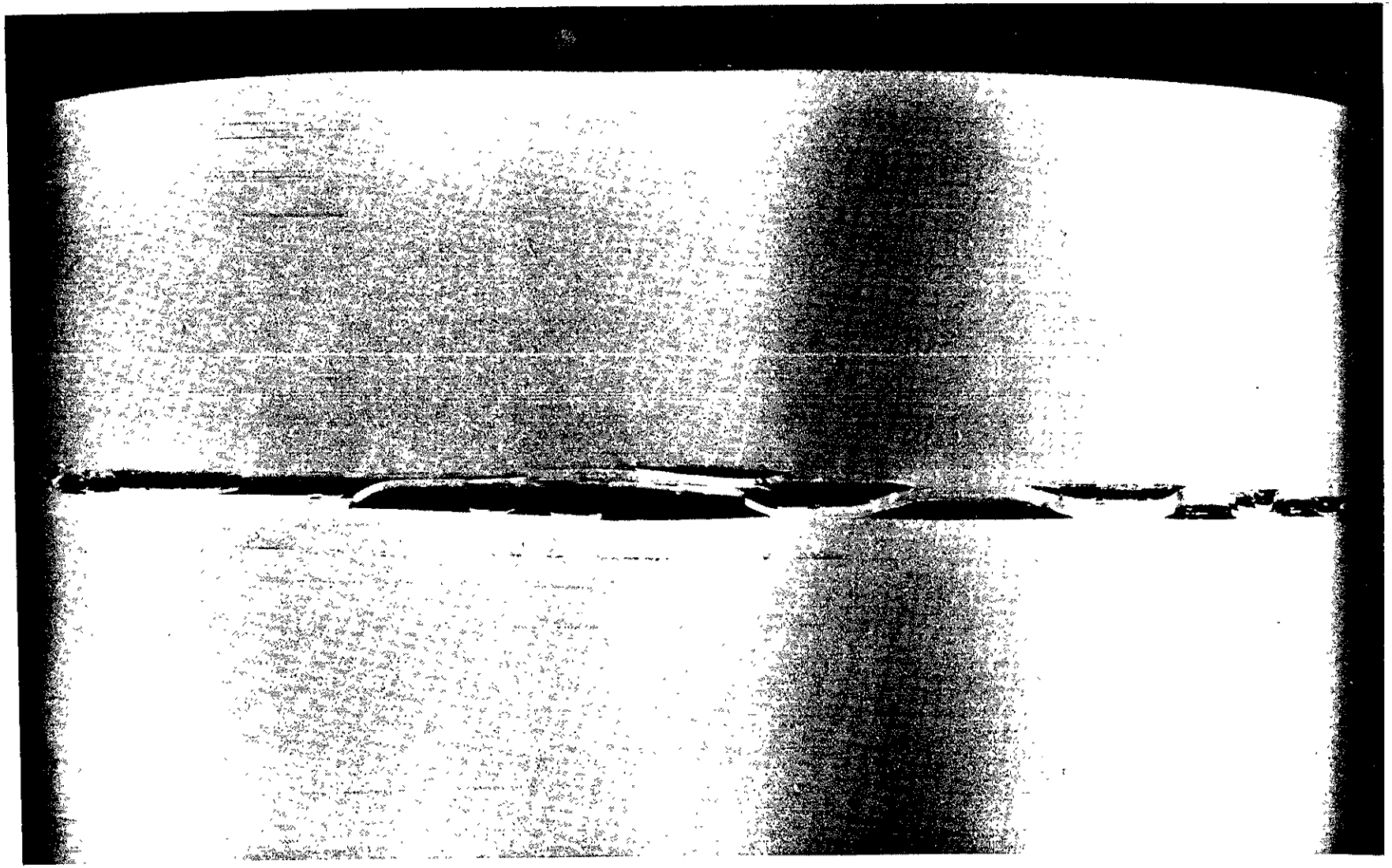

FIGURE 4. 3X Face of Guided Bend Test of Top Flange at 13% elongation. This surface, developed from a band sawed face, has been shaped, ground, and polished on 4/0 paper.

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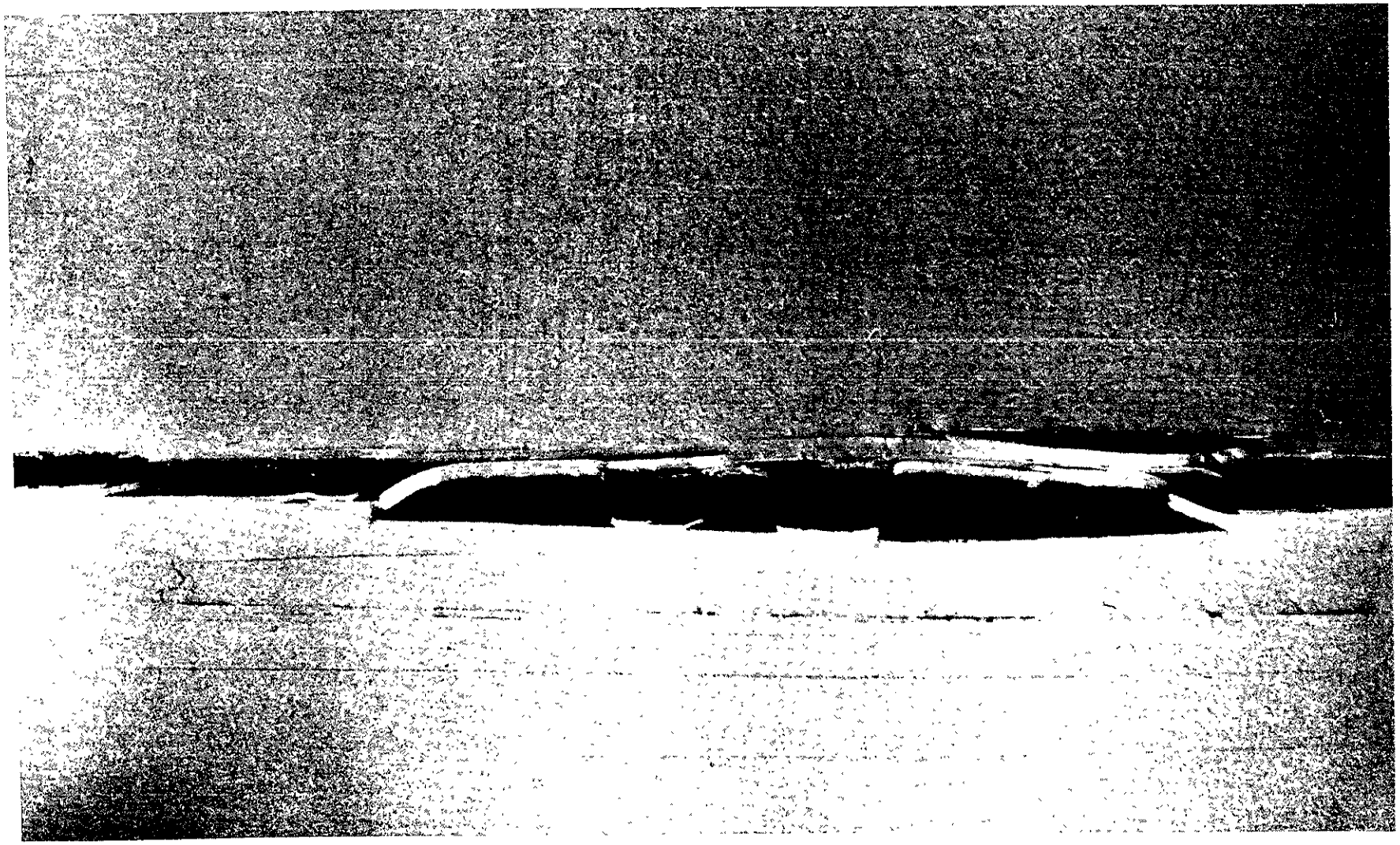

FIGURE 5. 6X Face of Guided Bend Test Top Flange at 13% elongation. Openings began to appear along the line of lamination as soon as bending became noticeable to the eye.

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FIGURE 6. 10X fracture surface of hammer flexure test against the layered inclusions showing the laminated character of the break. Notice that the region affected by the scarf appears to extend only about 1/8" under the surface.

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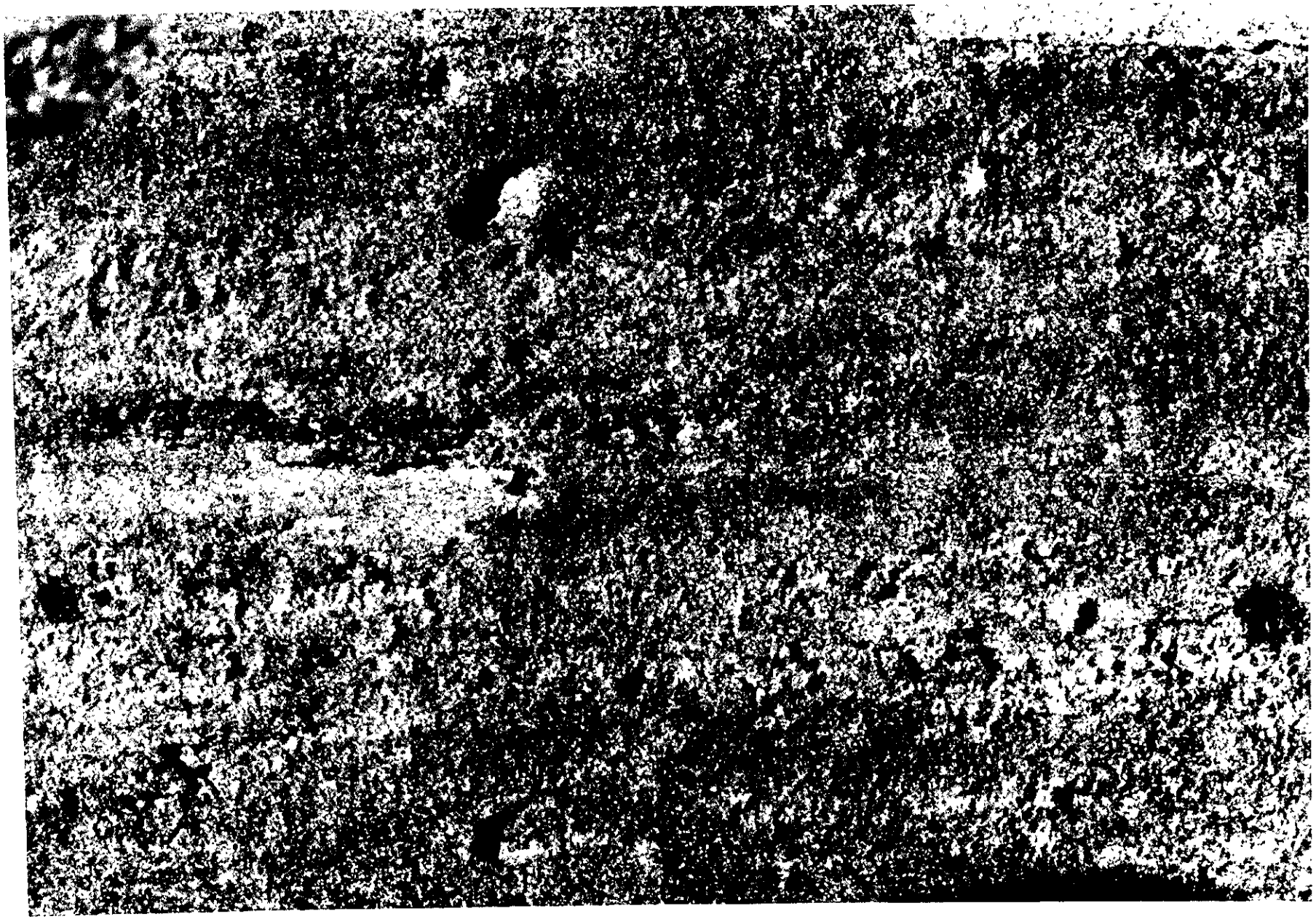

FIGURE 7. Approx. 50X fracture face of hammer flexure test against layered inclusions. Figure shows discoloration visible on fracture face indicating that a separation was present at this point in the sample as it was received -- discolored either by the presence of inclusion material in a layer or by staining from foreign agents which gained access to the face by virtue of its separation.

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FIGURE 8. Approx. 50X fracture face of hammer flexure test against layered inclusions showing laminar character of layered central structure in plate.

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FIGURE 9. 50X polished unetched face of metallographic specimen taken from the top flange sample showing clearly the lines of layered material next to the flame cut edge of the flange from which the sample was taken. These layers of material extended to form a lamination that separated the top flange sample over 50% to 70% of its area.

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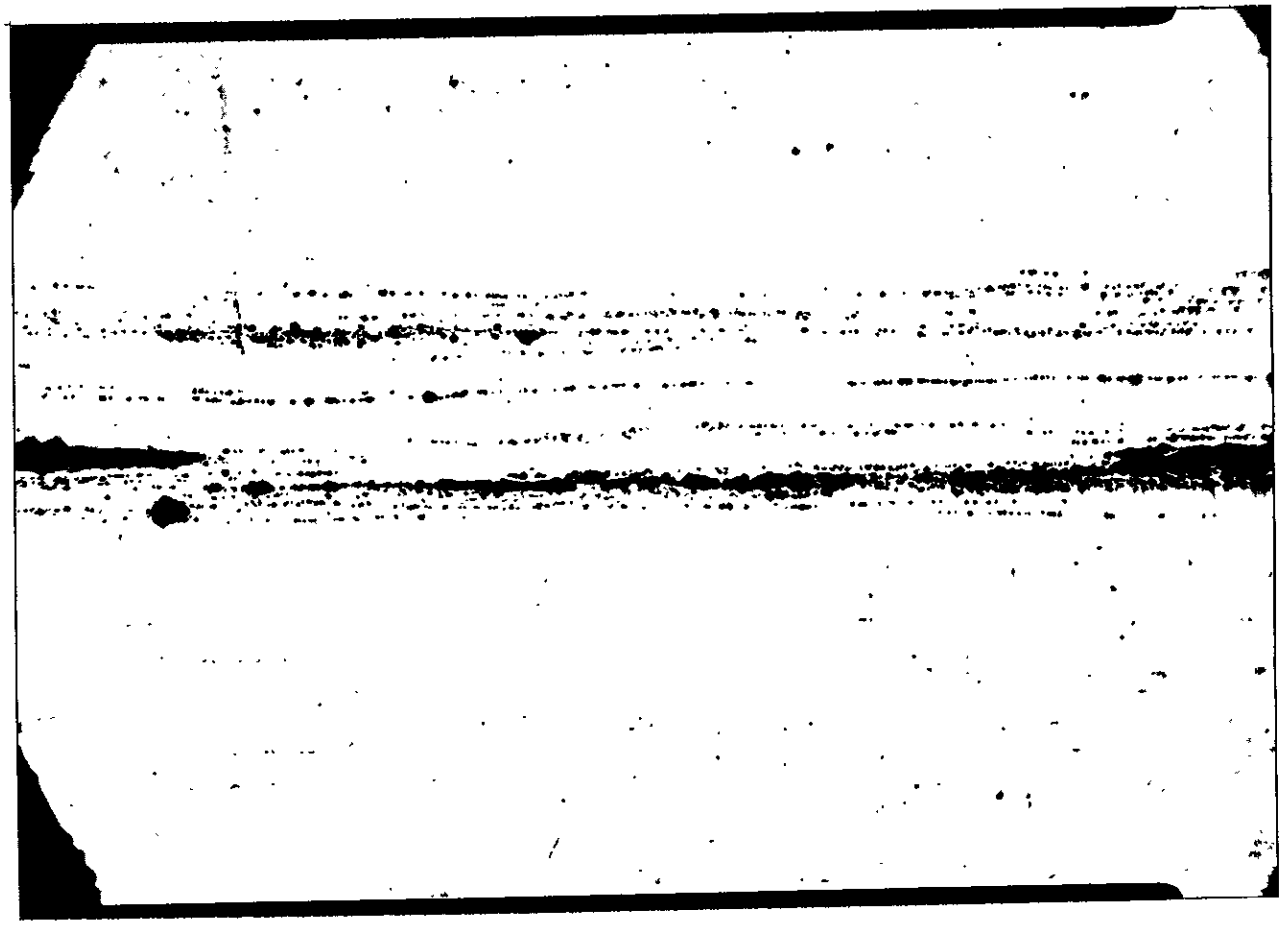

FIGURE 10. 50X polished unetched face of metallographic specimen taken from the top flange sample showing clearly the lines of layered material next to the flame cut edge of the flange from which the sample was taken. These layers of material extended to form a lamination that separated the top flange sample over 50% to 70% of its area.

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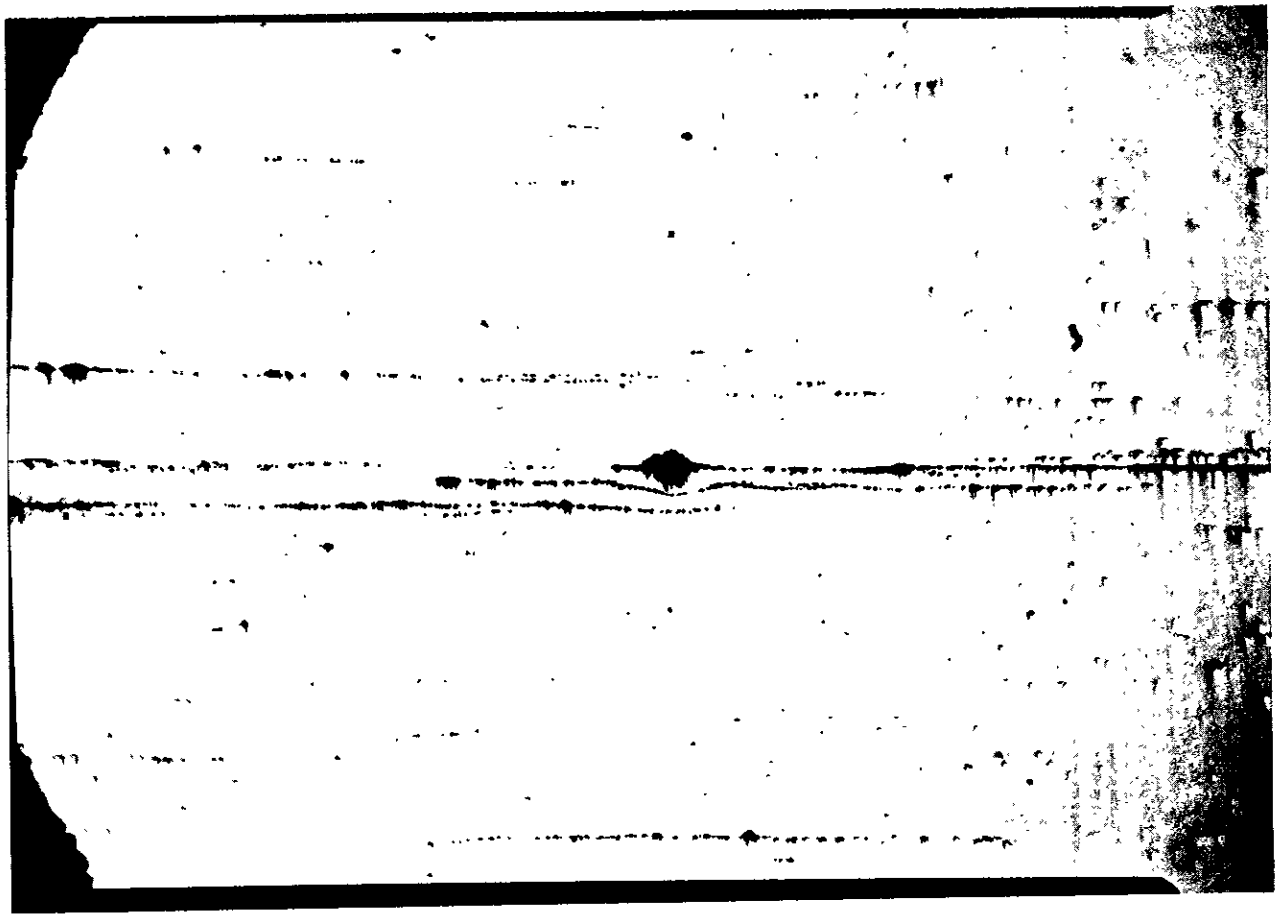

FIGURE 11. 50X polished unetched face of metallographic specimen taken from the top flange sample showing clearly the lines of layered material next to the flame cut edge of the flange from which the sample was taken. These layers of material extended to form a lamination that separated the top flange sample over 50% to 70% of its area.

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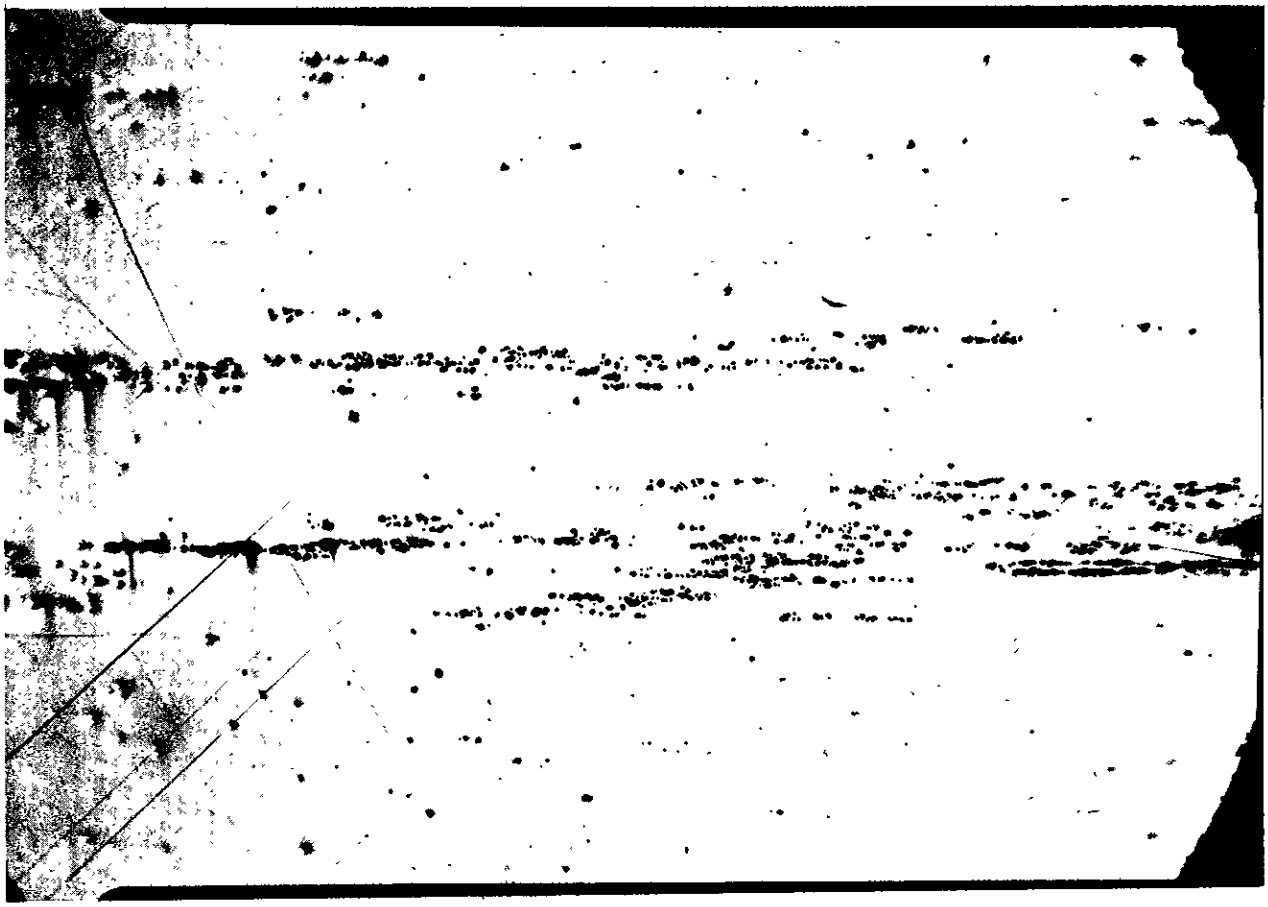

FIGURE 12. 50X polished and unetched surface of metallographic specimen taken from the top flange sample. This shows a section of steel in the beam at a point 5/8" away from and transverse to the flame cut edge of the flange from which the sample was removed.

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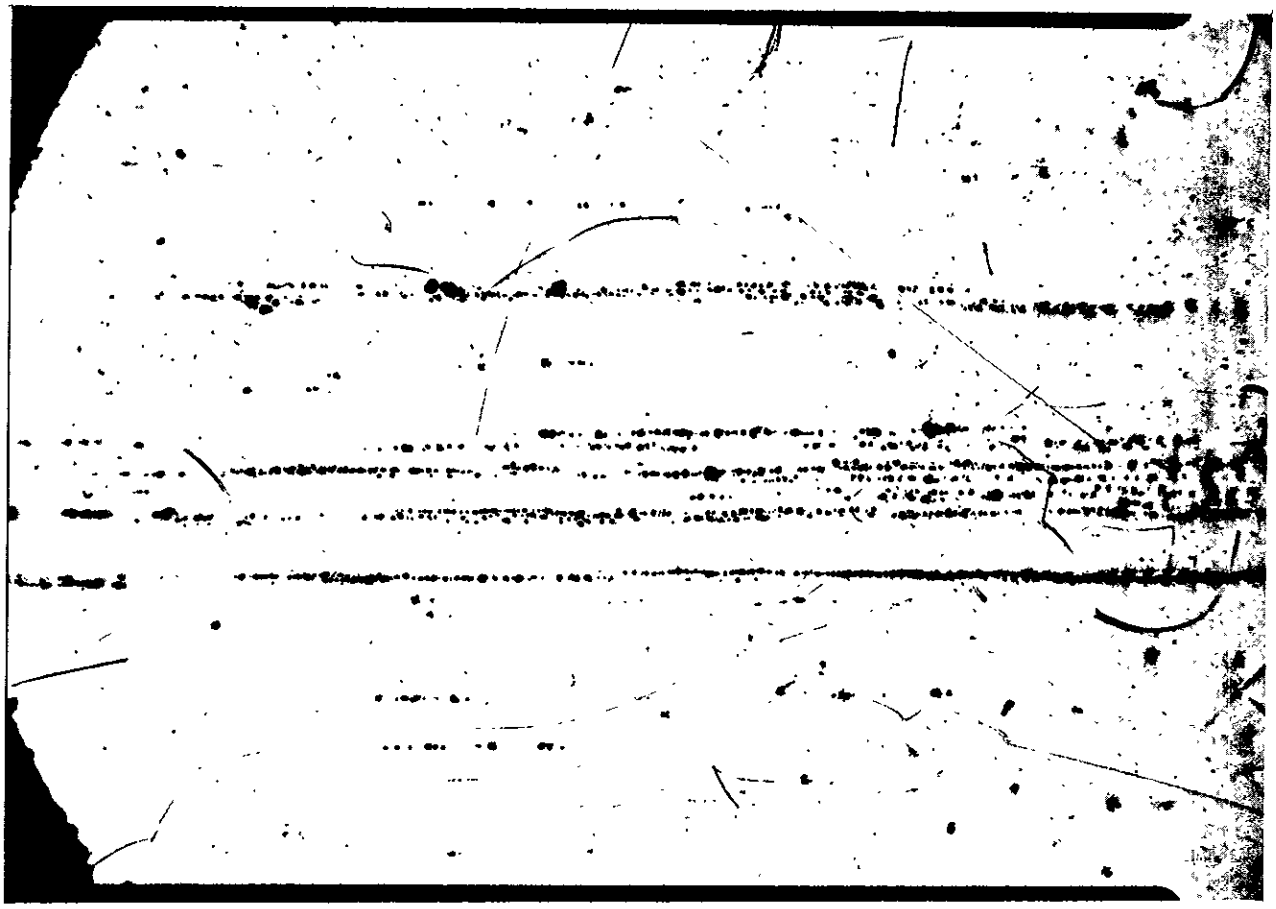

FIGURE 13. 50 X polished and unetched surface of metallographic specimen taken from the top flange sample showing the layered inclusion material in a surface 13/16" away from and parallel to the flame cut edge of the flange from which the sample was removed. Layers of inclusion material of this nature appeared to be typical of those found through the specimen and presumably throughout the top flange sample as it was received.

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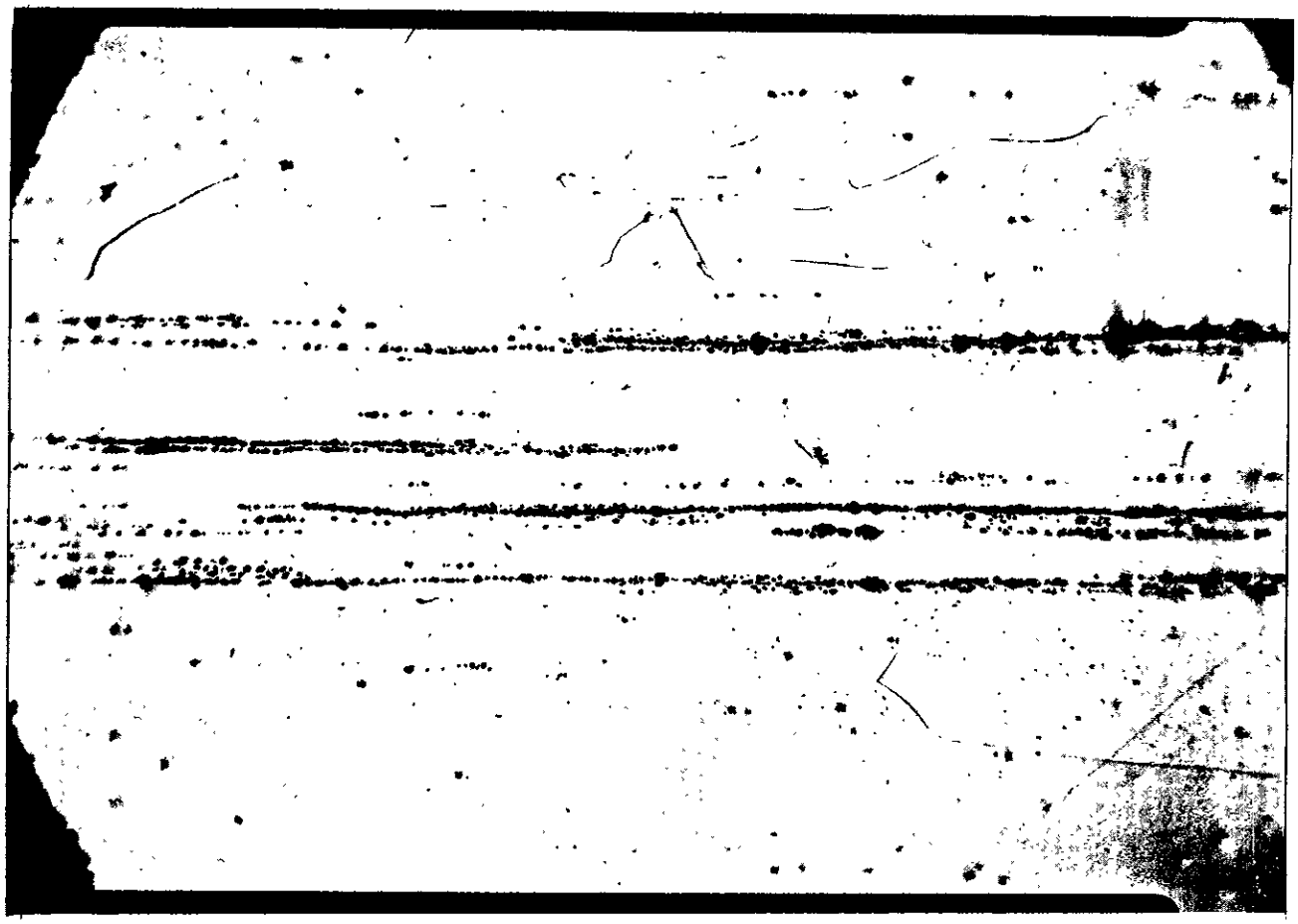

FIGURE 14. 50X polished and unetched surface of metallographic specimen taken from the top flange sample showing the layered inclusion material in a surface 13/16" away from and parallel to the flame cut edge of the flange from which the sample was removed. Layers of inclusion material of this nature appeared to be typical of those found through the specimen and presumably throughout the top flange sample as it was received.

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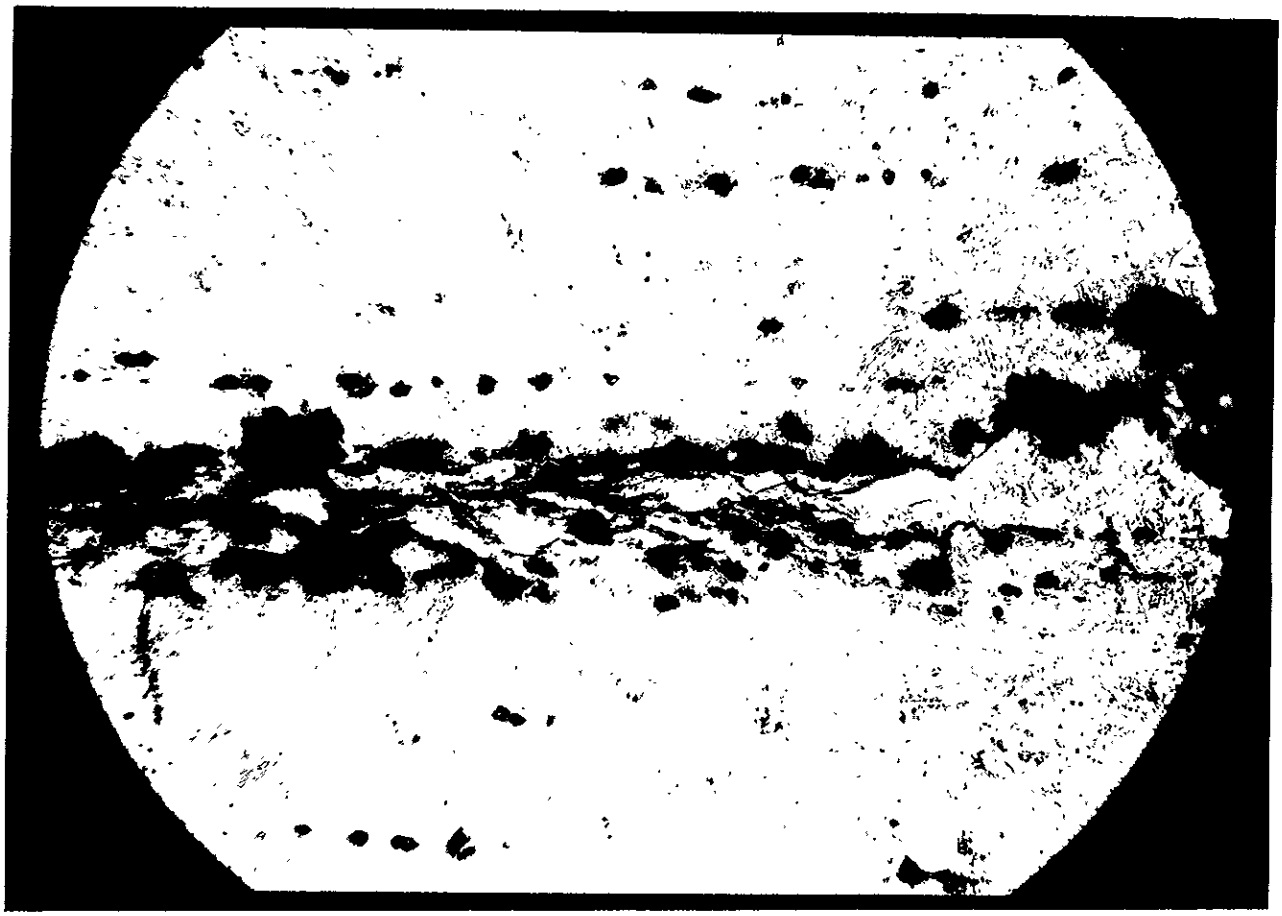

FIGURE 15. 500X Nital etch showing lines of inclusions next to flame cut surface connected by cracks to form a continuous separation in metallographic specimen from top flange.

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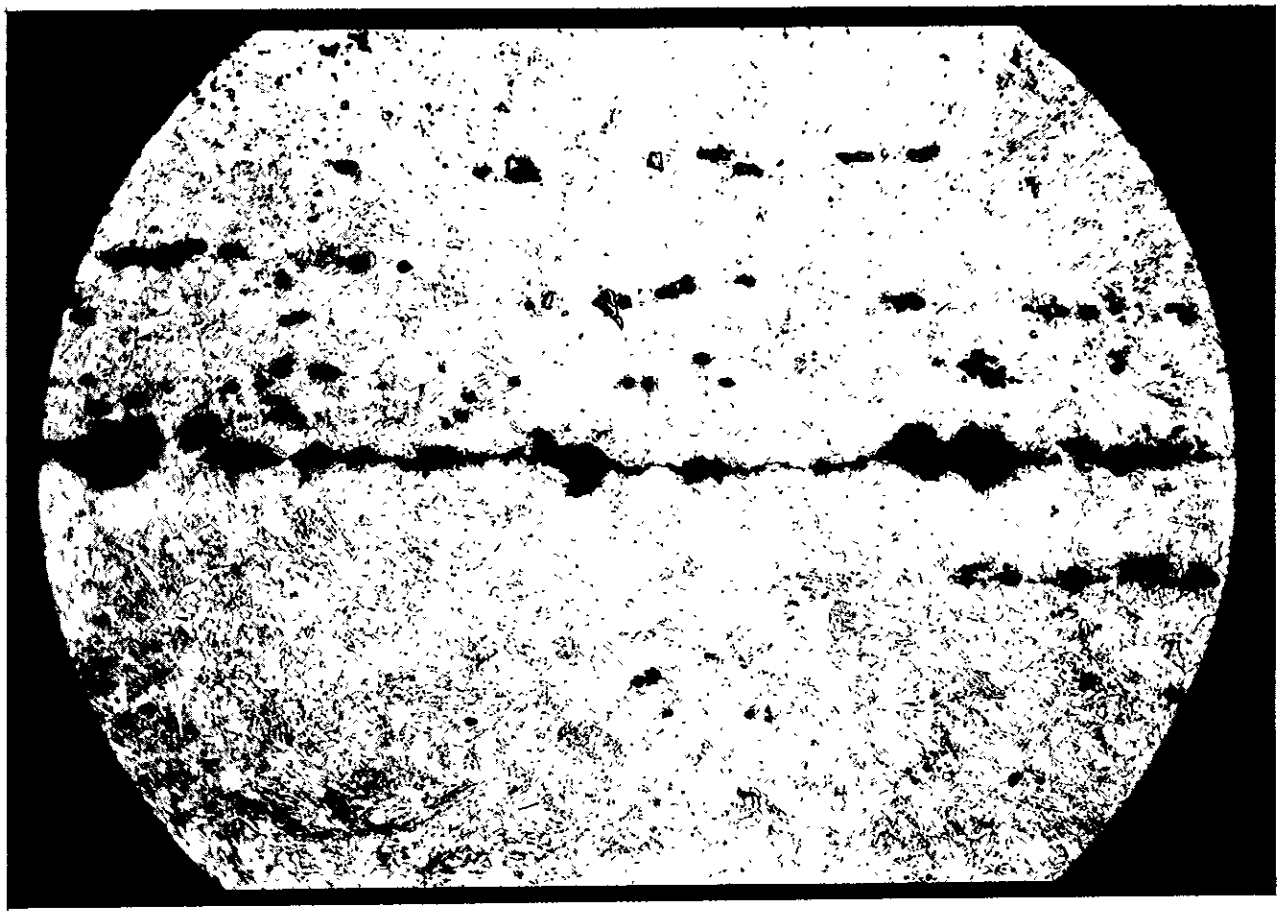

FIGURE 16. 500X Nital etch showing lines of inclusions next to flame cut surface connected by cracks to form a continuous separation in metallographic specimen from top flange.

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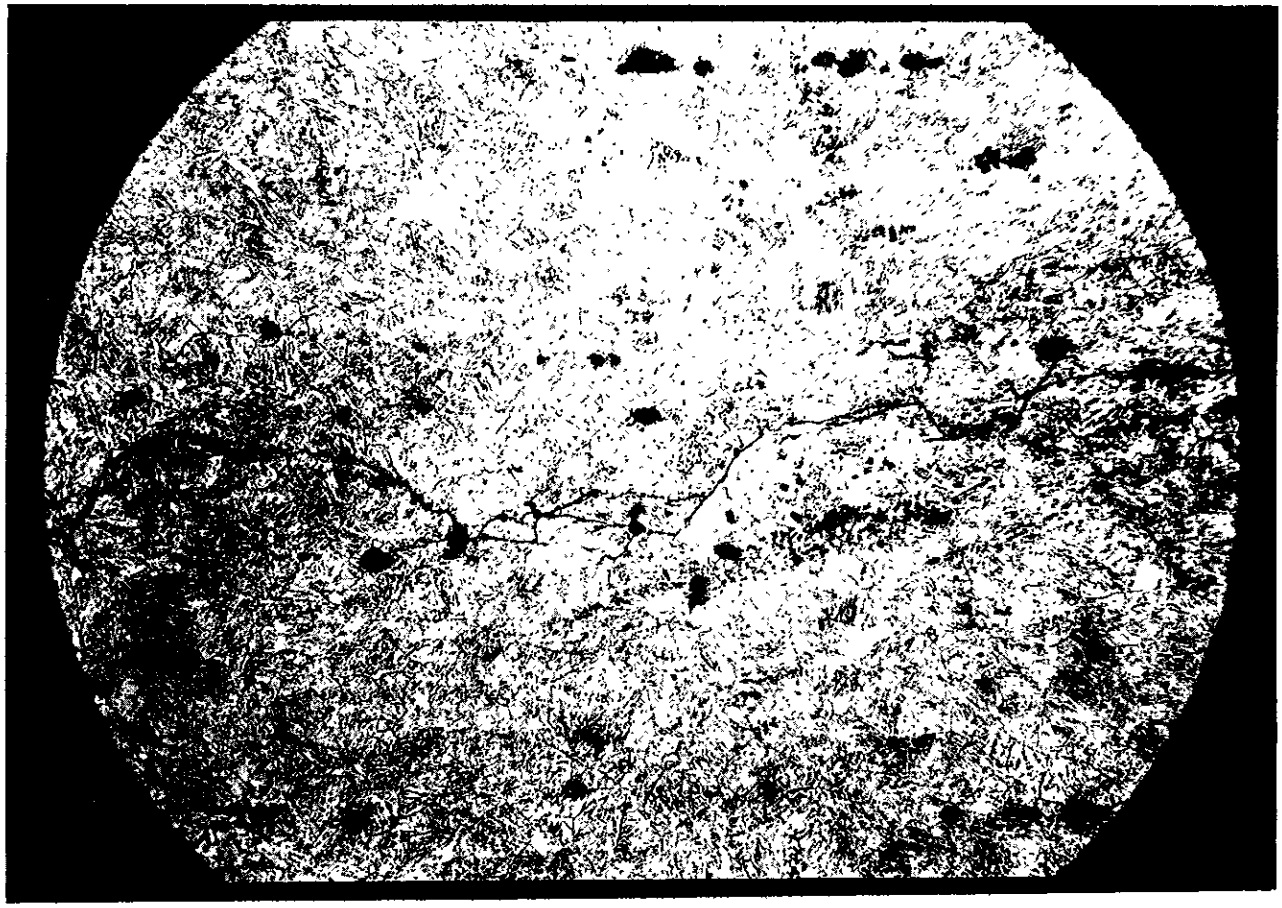

FIGURE 17. 500X Nital etch showing satellite cracks running parallel to and out from the principal layer of nonmetallic inclusion material at the flame cut surface in metallographic specimen from top flange.

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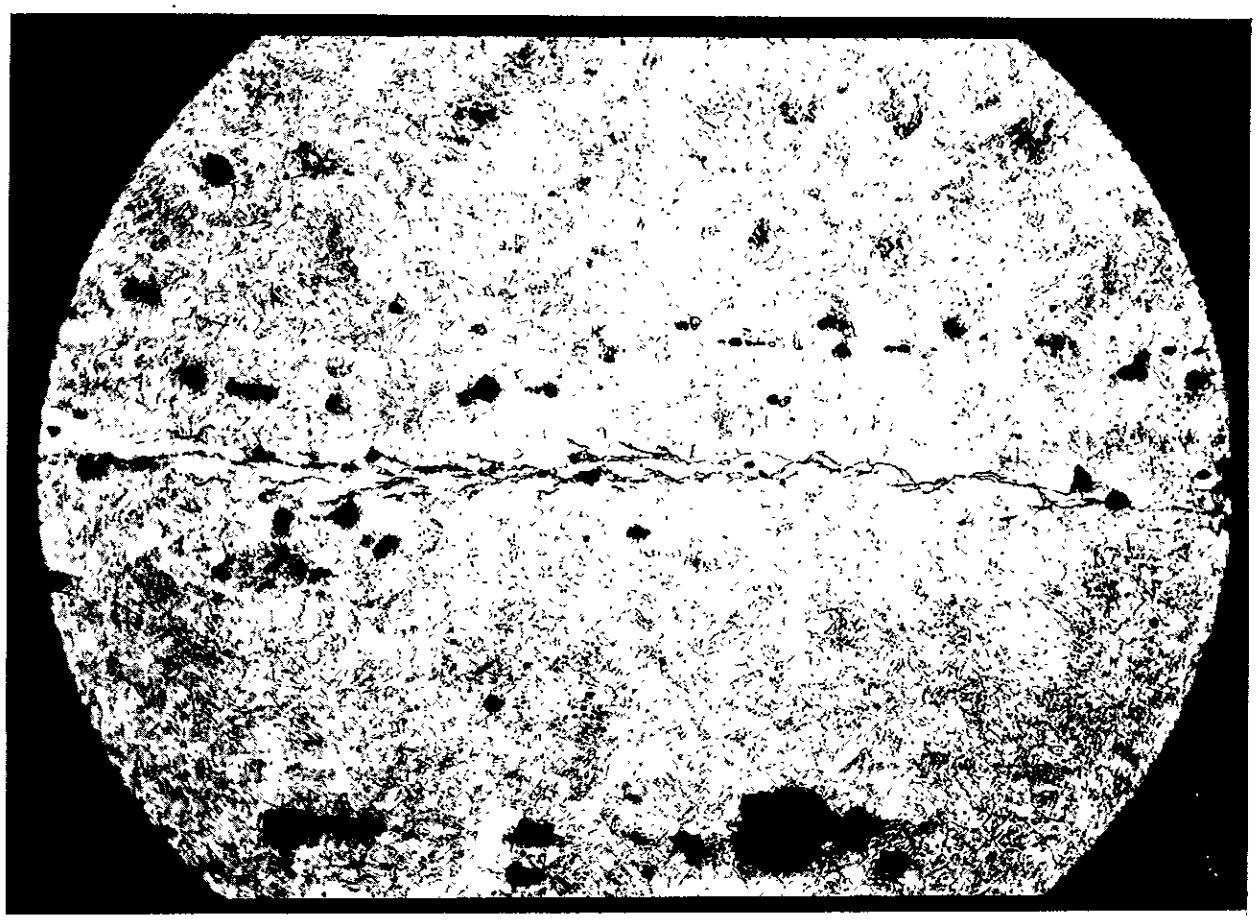

FIGURE 18. 500X Nital etch showing satellite cracks running parallel to and out from the principal layer of nonmetallic inclusion material at the flame cut surface in metallographic specimen from top flange.

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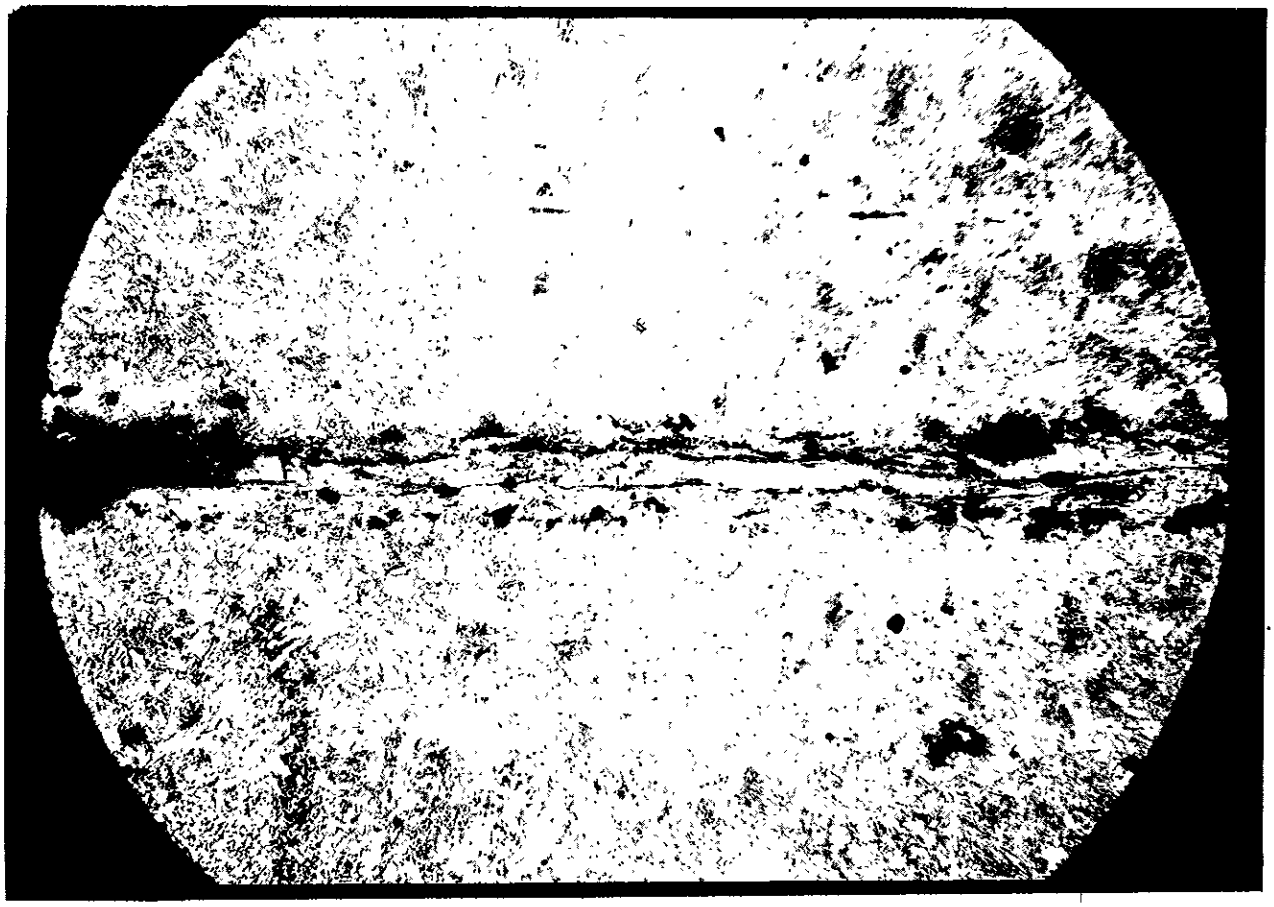

FIGURE 19. 500X Nital etch showing layered metal structure parallel to principal layer of nonmetallic inclusion material of the flame cut surface of the top flange specimen.

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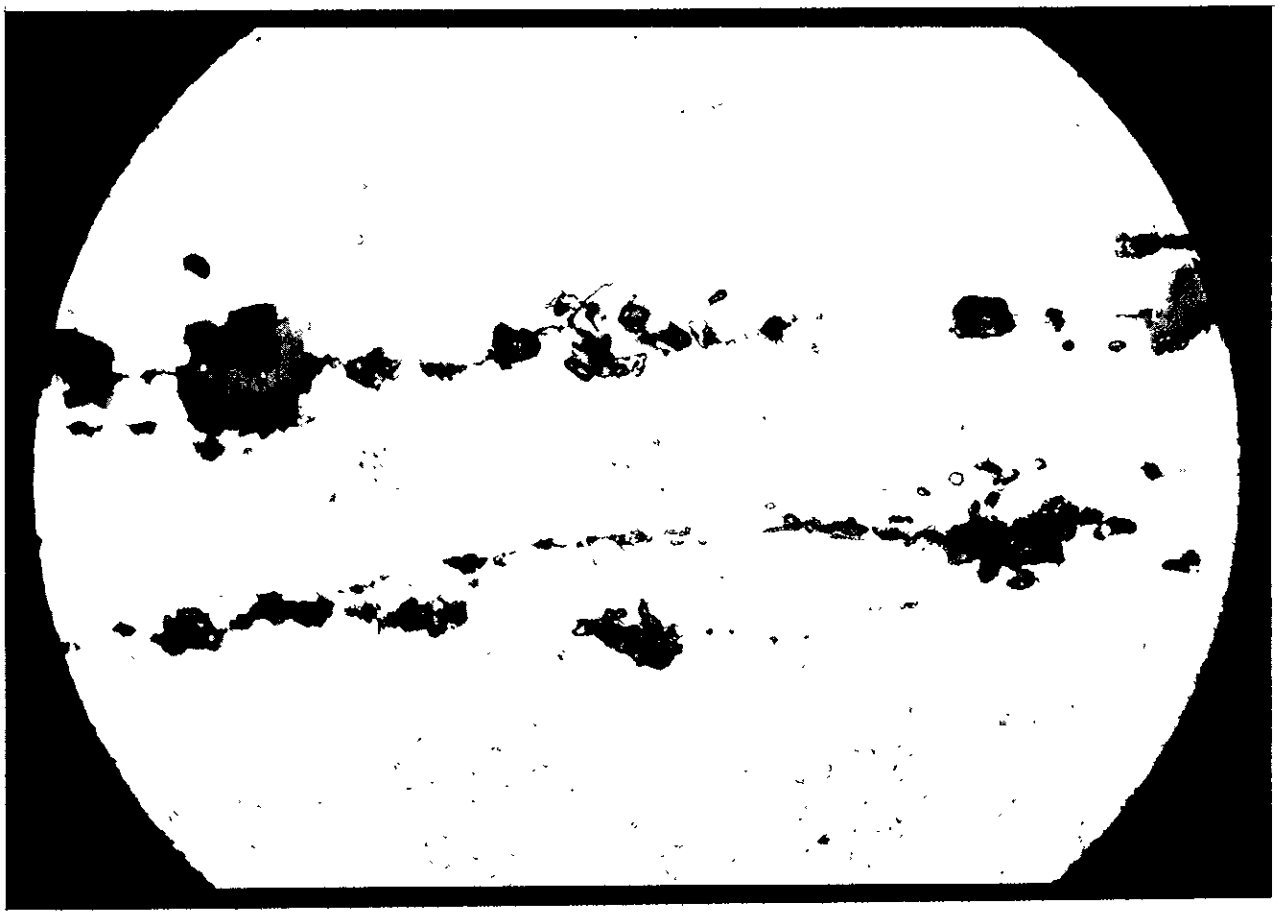

FIGURE 20. 500X Nital etch showing nature of inclusion material. Linear clusters of nonmetallics not plastic at rolling temperature appear to be alumina type, whereas in the material in the larger contiguous inclusions appear to be an iron rich type. Crystals of TiN (?) are scattered extensively in the region of the layers of nonmetallics but these do not appear to contribute significantly to the laminating effect associated with iron and alumina type inclusions.

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FIGURES 21 THROUGH 28

BOTTOM FLANGE STEEL

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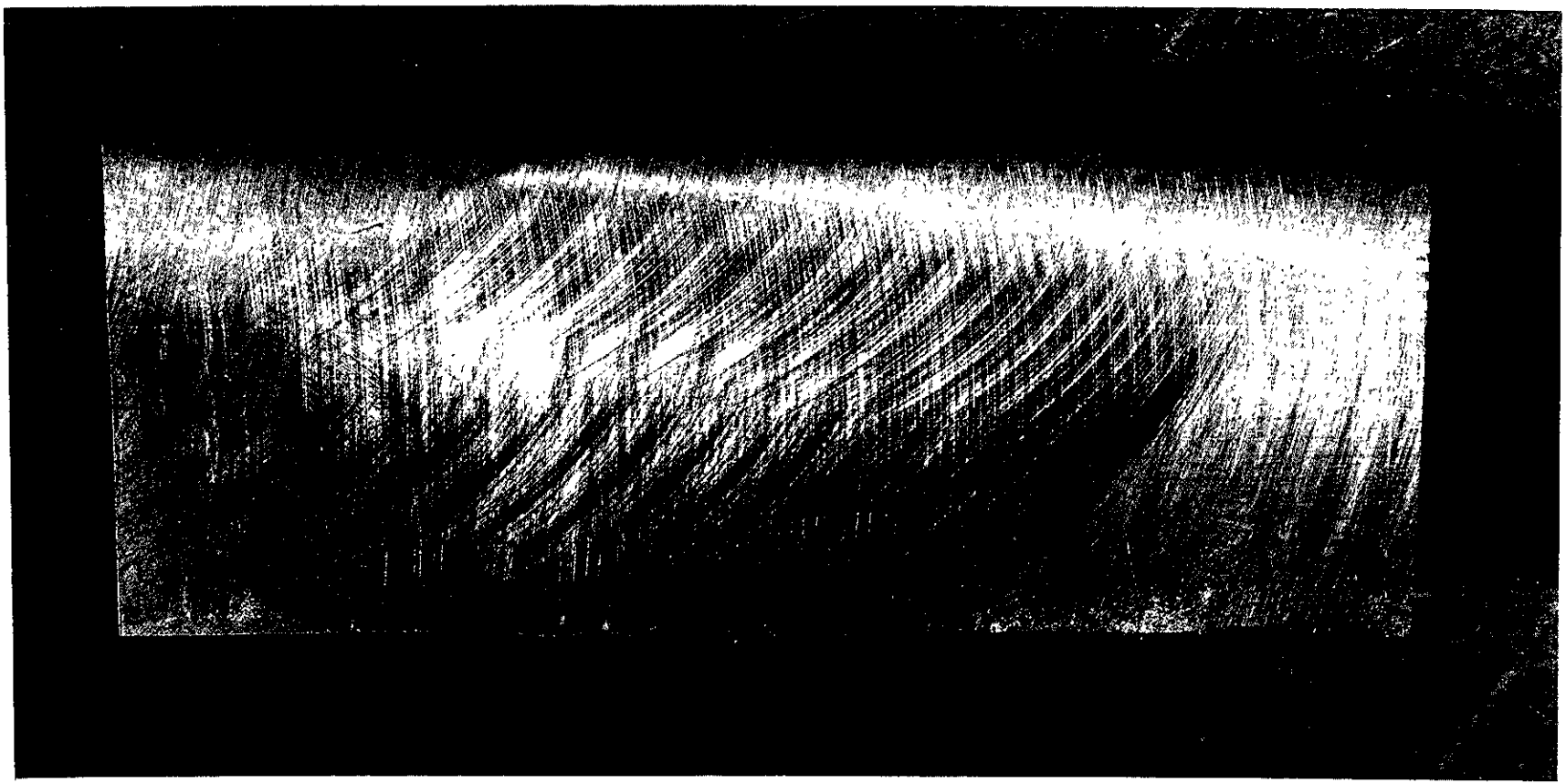

FIGURE 21. Piece from bottom flange sample viewed from the ground flame-cut edge of the flange from which the sample was taken. No layered inclusion material is visible in this surface to the unaided eye without further polishing or etching. Nevertheless, micro and macro examination of the polished surfaces and ultrasonic of the sample showed that some layered inclusion material was present (see Figures 24 through 27).

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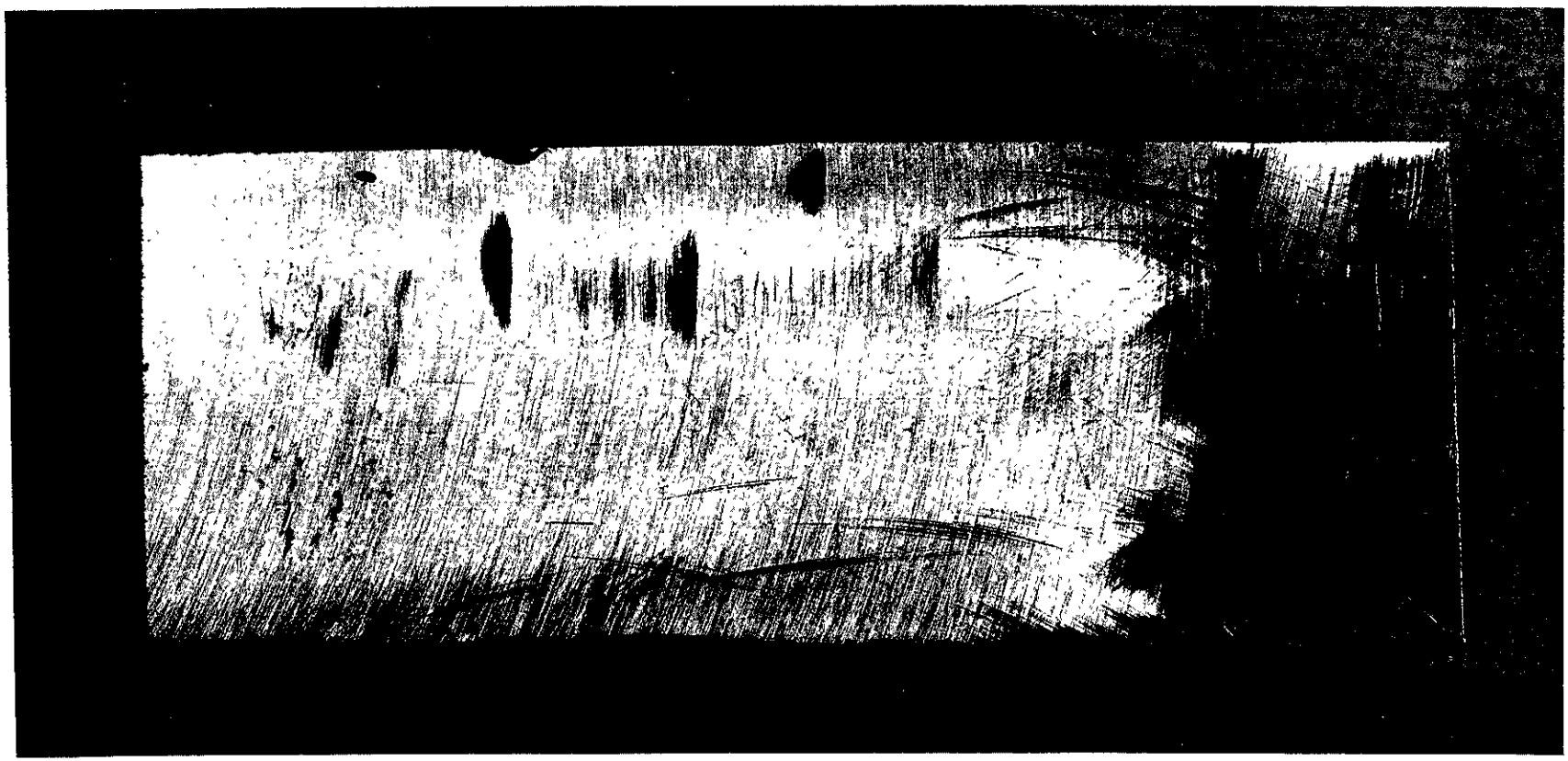

FIGURE 22. Piece from bottom flange sample viewed from the ground surface closest to the web and opposite the flame cut edge of the girder flange. No layered inclusion material is visible in this surface to the unaided eye without further polishing or etching. It was not possible to break a piece of the material from the sample with a hammer flexure test against these layers, and it is believed that no more than about 15% of the section area is separated by this type of layered structure in the bottom flange sample submitted for examination.

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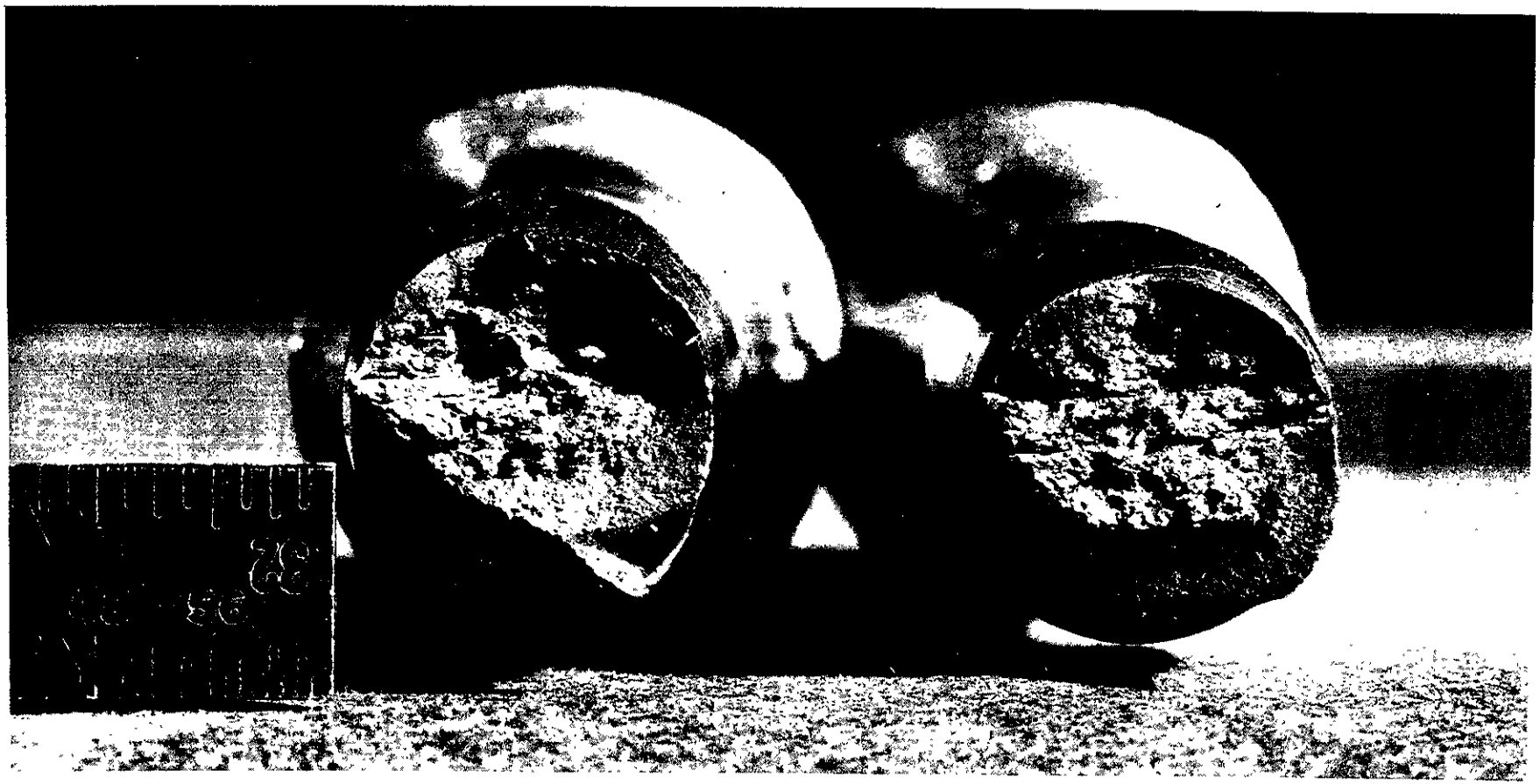

FIGURE 23. Fractured ends of the tensile specimens cut from the central portion on the bottom flange sample. (See Figure 1 for location.) The laminar type of separation visible here would probably be sufficient to cause the plate to fail the homogeneity test required of firebox steel. Machining this piece was complicated by the tendency of the machining tool to catch in these defects during the turning operation. (Ultimate 114,000 psi; yield 105,500 psi; 15% elong. @ 2"; 43% reduction of area.

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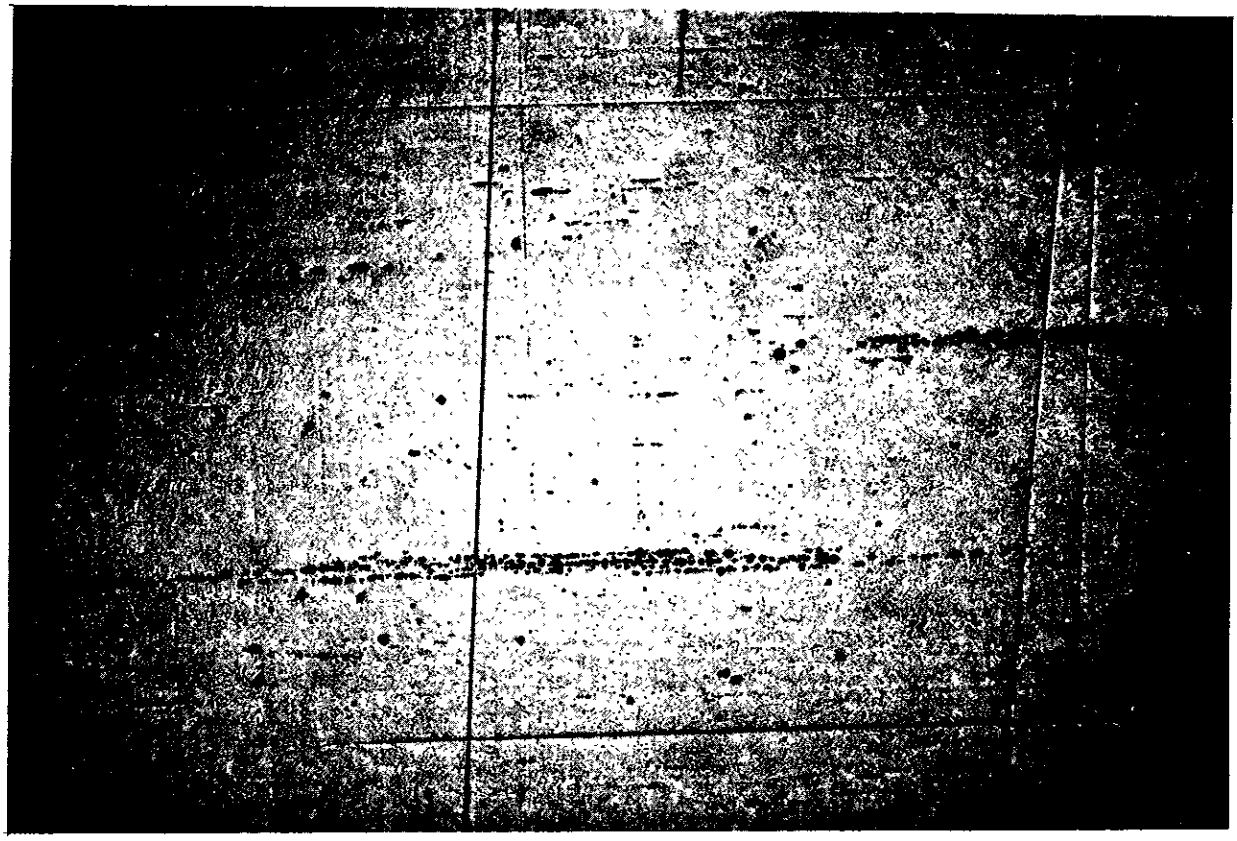

FIGURE 24. 50X polished and etched face of the metallographic specimen from the bottom flange sample viewing a layer of inclusion material in a surface 13/16" away from and parallel to the flame cut edge of the flange from which the sample was removed.

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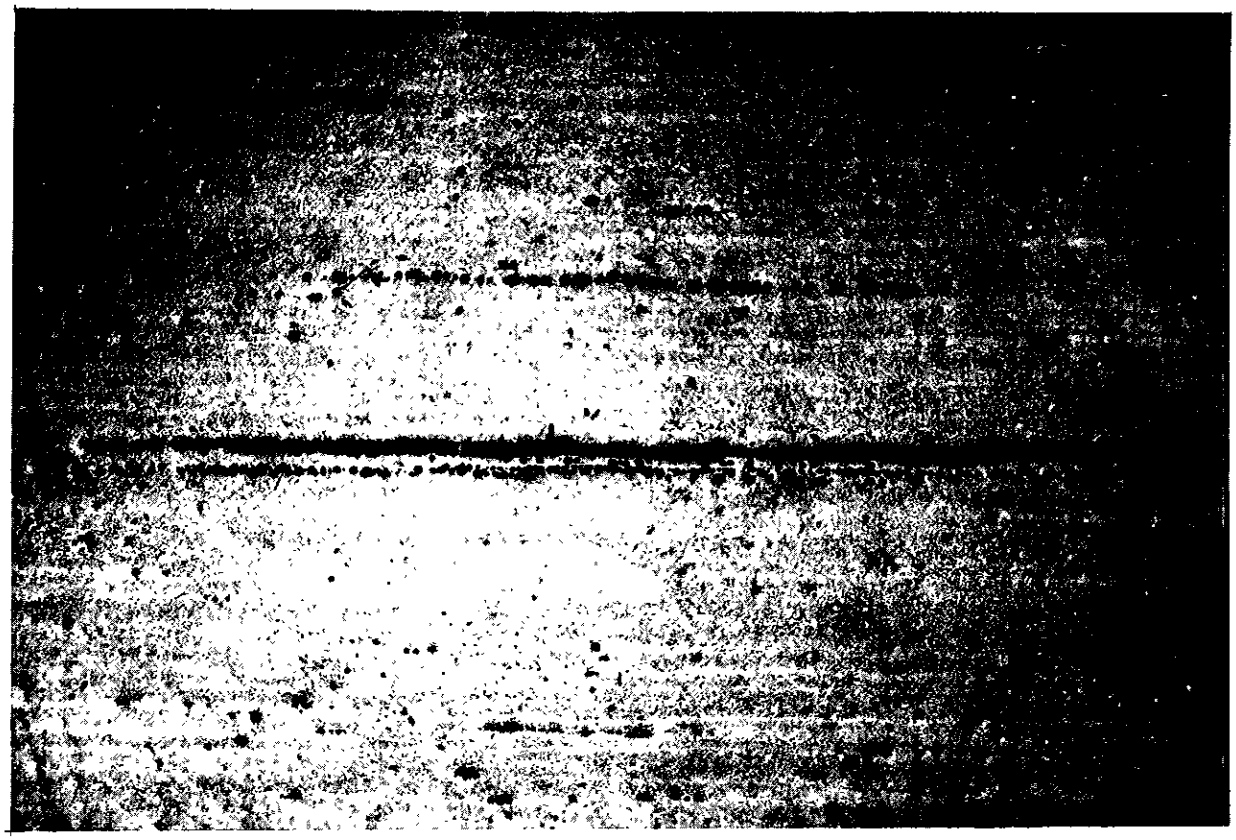

FIGURE 25. 50X polished and etched face of the metallographic specimen from the bottom flange sample viewing a layer of inclusion material in the surface next to the flame cut edge of the flange from which the sample was removed. This inclusion did not extend significantly beyond the margins of the figure, and it was not so typical of this piece as was the smaller line of inclusion material above it.

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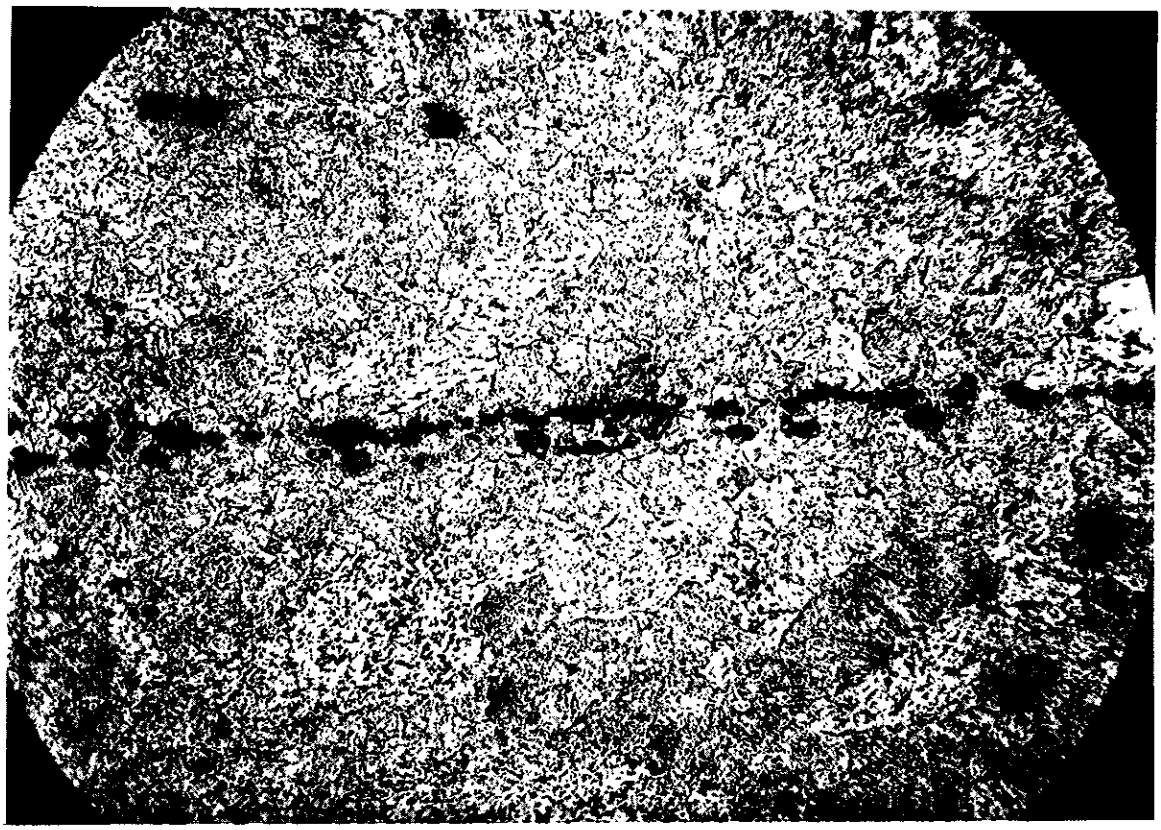

FIGURE 26. 500X polished and etched surface of metallographic specimen taken from the bottom flange sample showing a line of inclusion material in a surface 13/16" away from and parallel to the flame cut edge of the flange from which the sample was removed.

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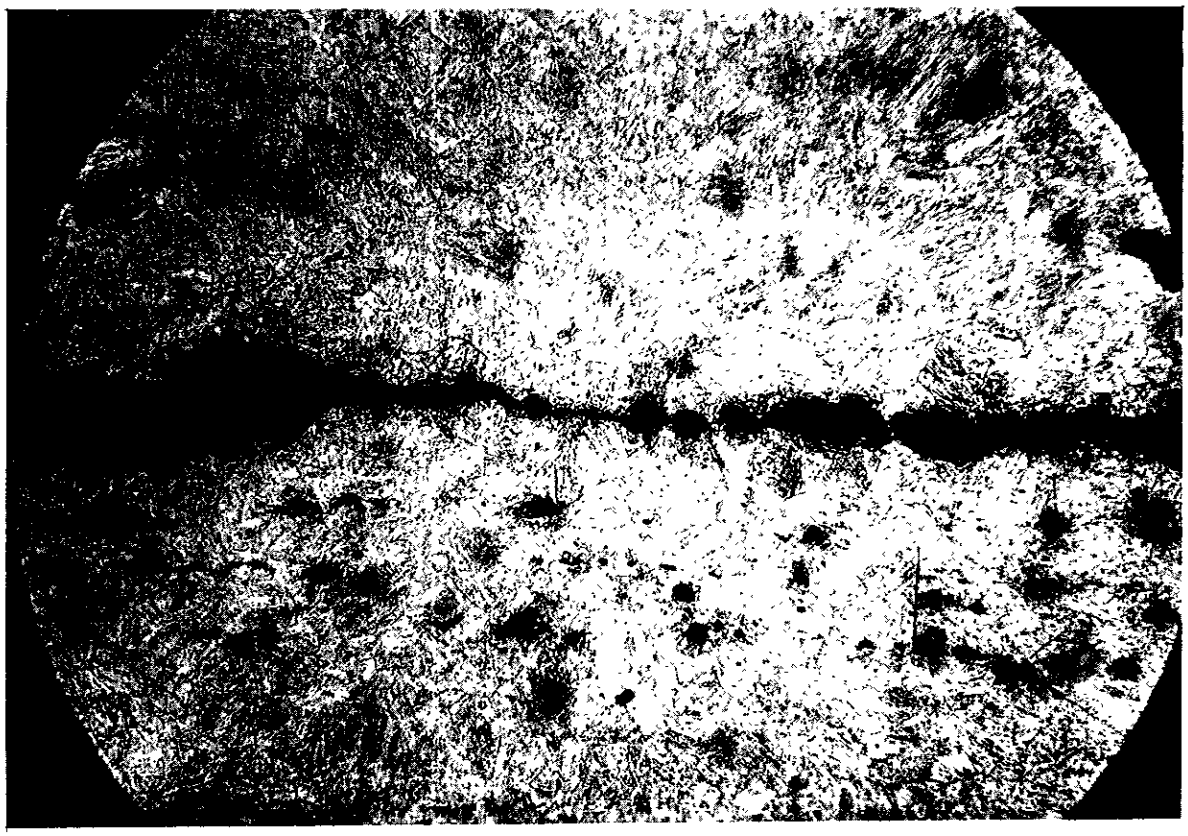

FIGURE 27. 500X polished and etched surface of metallographic specimen taken from the bottom flange sample showing line of inclusion material next to the flame cut and ground outside edge of the flange from which the sample was removed.

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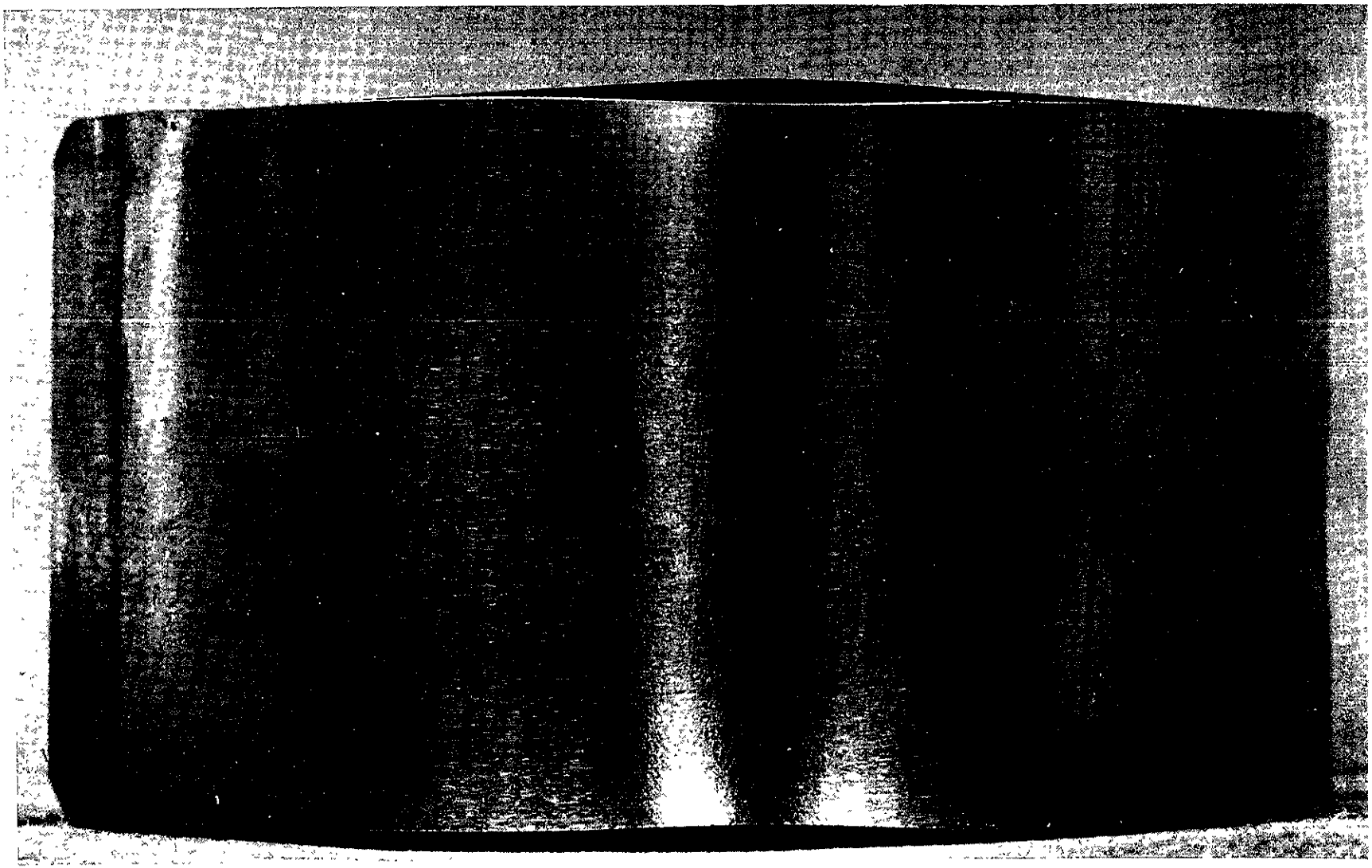

FIGURE 28. 3X Face of Guide Bend Test of Bottom Flange at 13% Elongation.

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