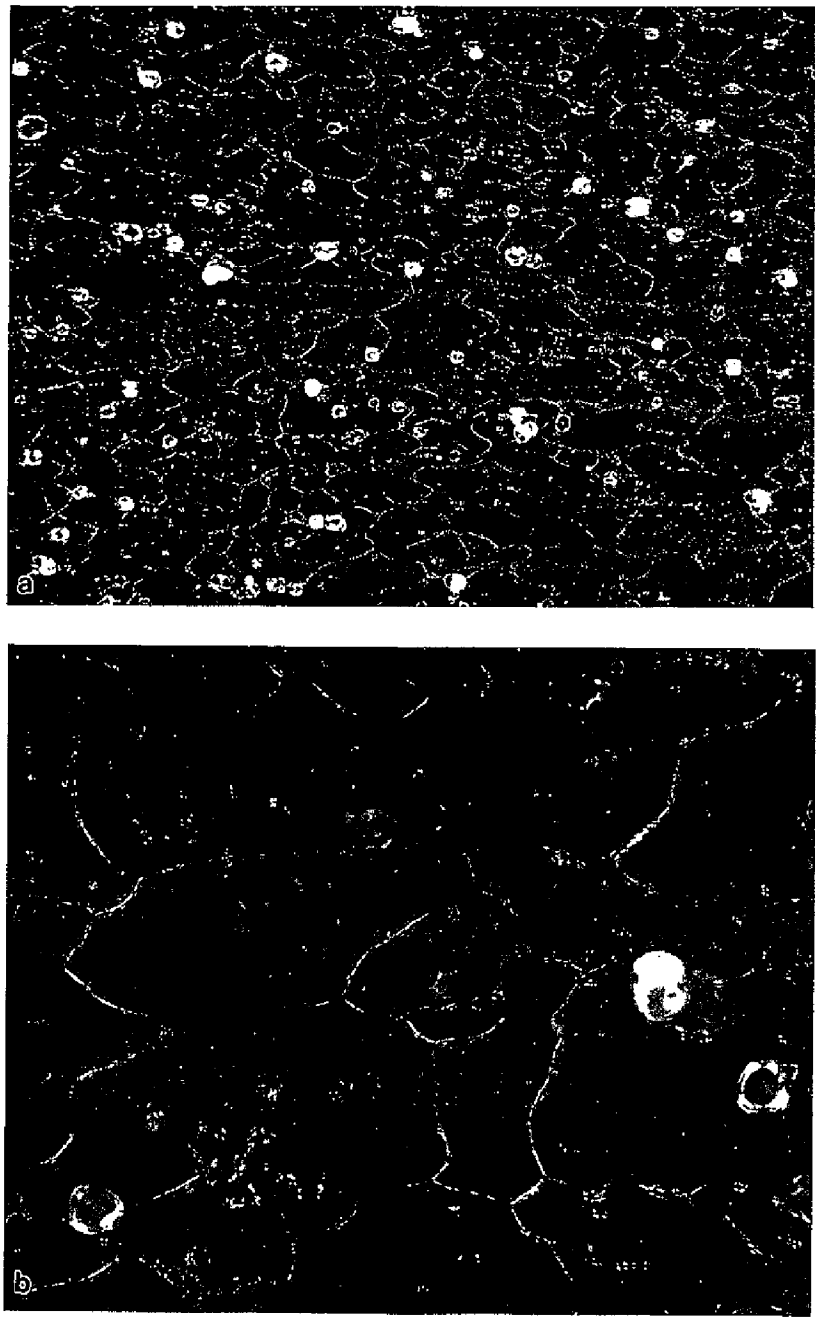


Figure 6. Microstructure of the sidewall region. 10% NaOH, polarized light.
(a) 250X. Photo ID: DC17916-PAL-1-8/22/97.
(b) 1000X. Photo ID: DC17916-PAL-2-8/22/97.

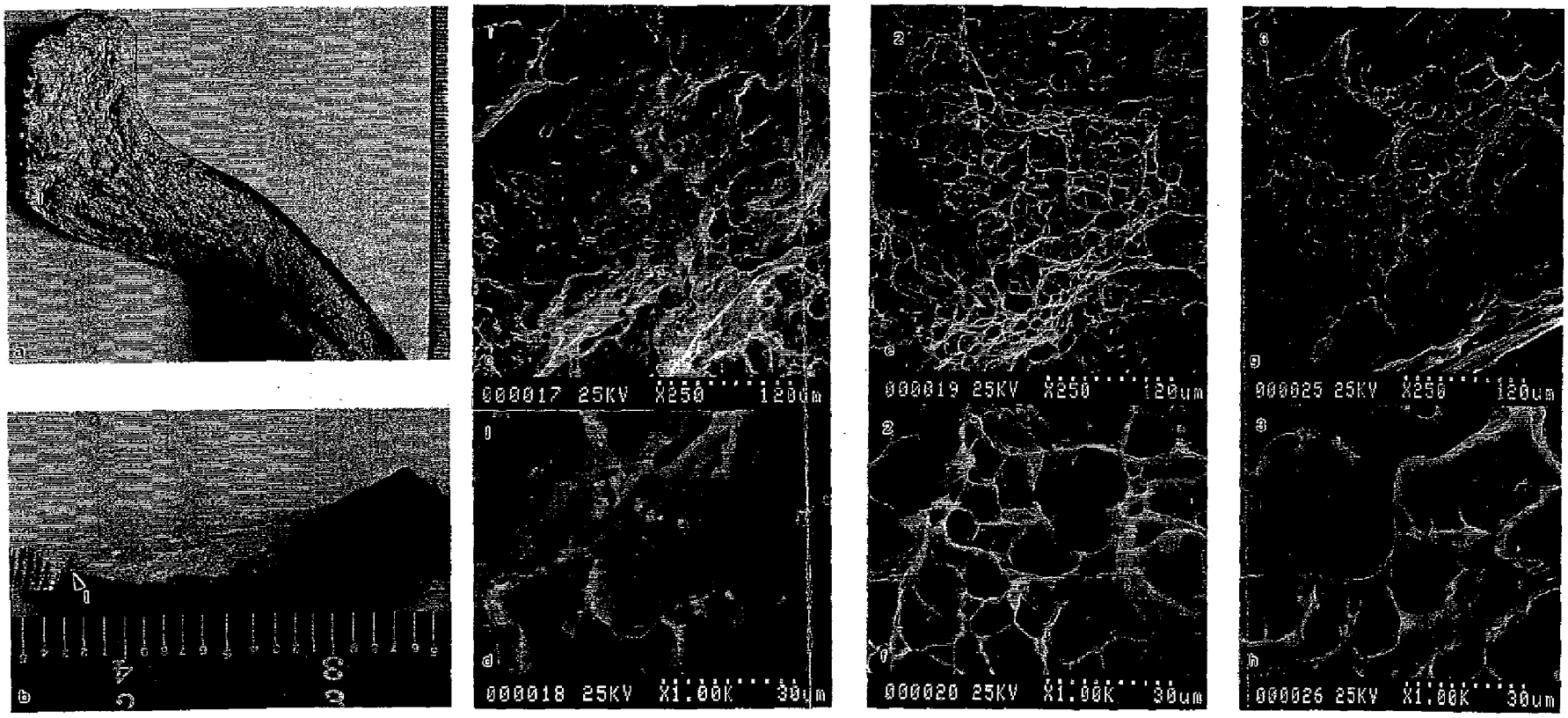


Figure 7. **Fractography of fracture surface "A" (Section 1A-3) from the neck region (see Figure 3).**

(a) Optical fractograph depicting neck region.
Photo ID: DC17916-PAL-21A-12/10/96.

(b) Side view of fracture surface shown in (a). *Note the non-planar character of the fracture surface in this region.*
Photo ID: DC17916-TRS-1-8/22/97.

(c) SEM fractograph of region 1 from (a). 250X.
Photo ID: DC17916-PAL-17-12/10/96.

(d) SEM fractograph of region 1 from (a). 1000X.
Photo ID: DC17916-PAL-18-12/10/96.

(e) SEM fractograph of region 2 from (a). 250X.
Photo ID: DC17916-PAL-19-12/10/96.

(f) SEM fractograph of region 2 from (a). 1000X.
Photo ID: DC17916-PAL-20-12/10/96.

(g) SEM fractograph of region 3 from (a). 250X.
Photo ID: DC17916-PAL-25-12/10/96.

(h) SEM fractograph of region 3 from (a). 1000X.
Photo ID: DC17916-PAL-26-12/10/96.

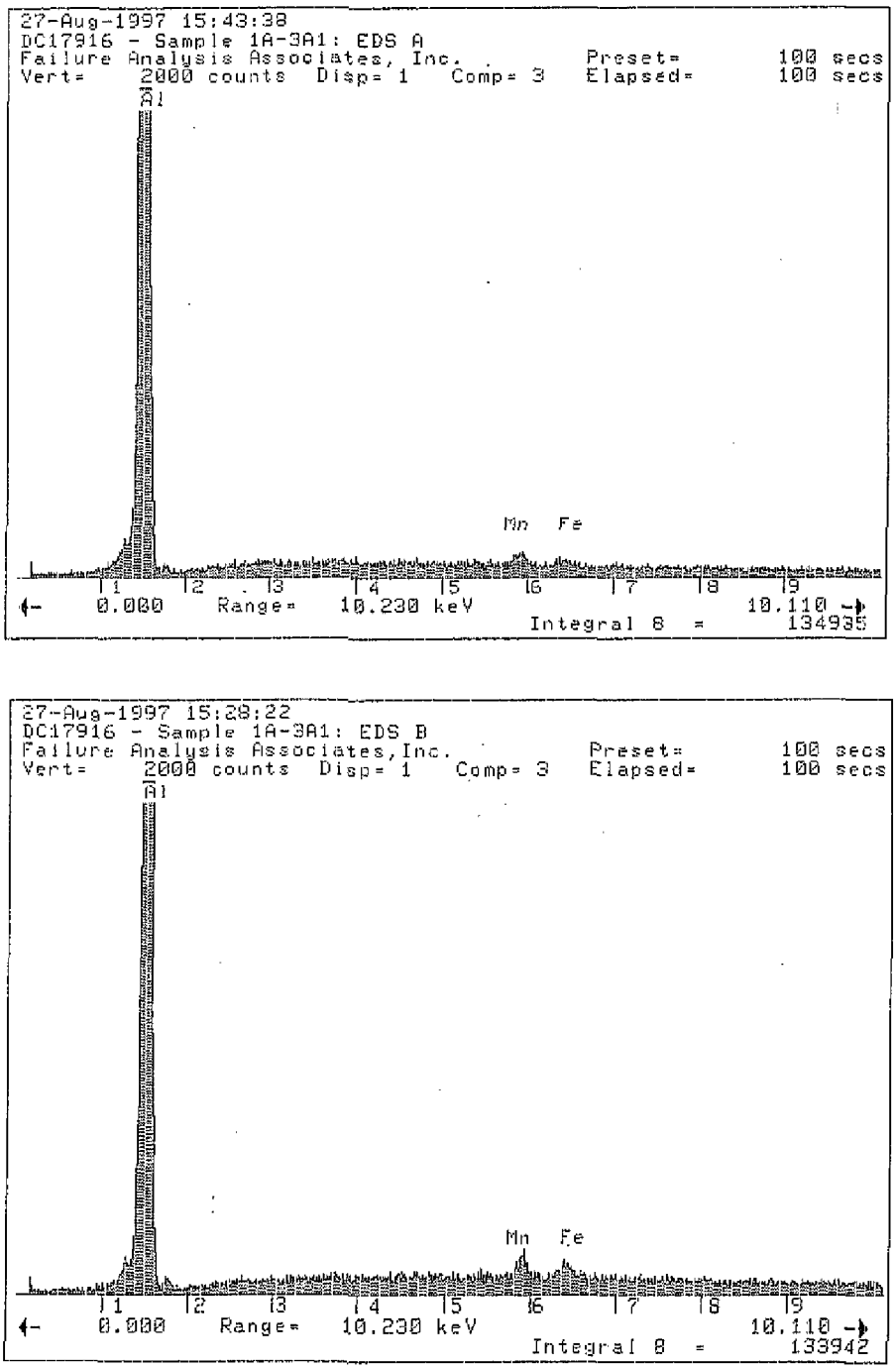


Figure 8. EDS spectra from fracture surface in neck region (see Figure 7).
(a) Region 1.
(b) Region 2.

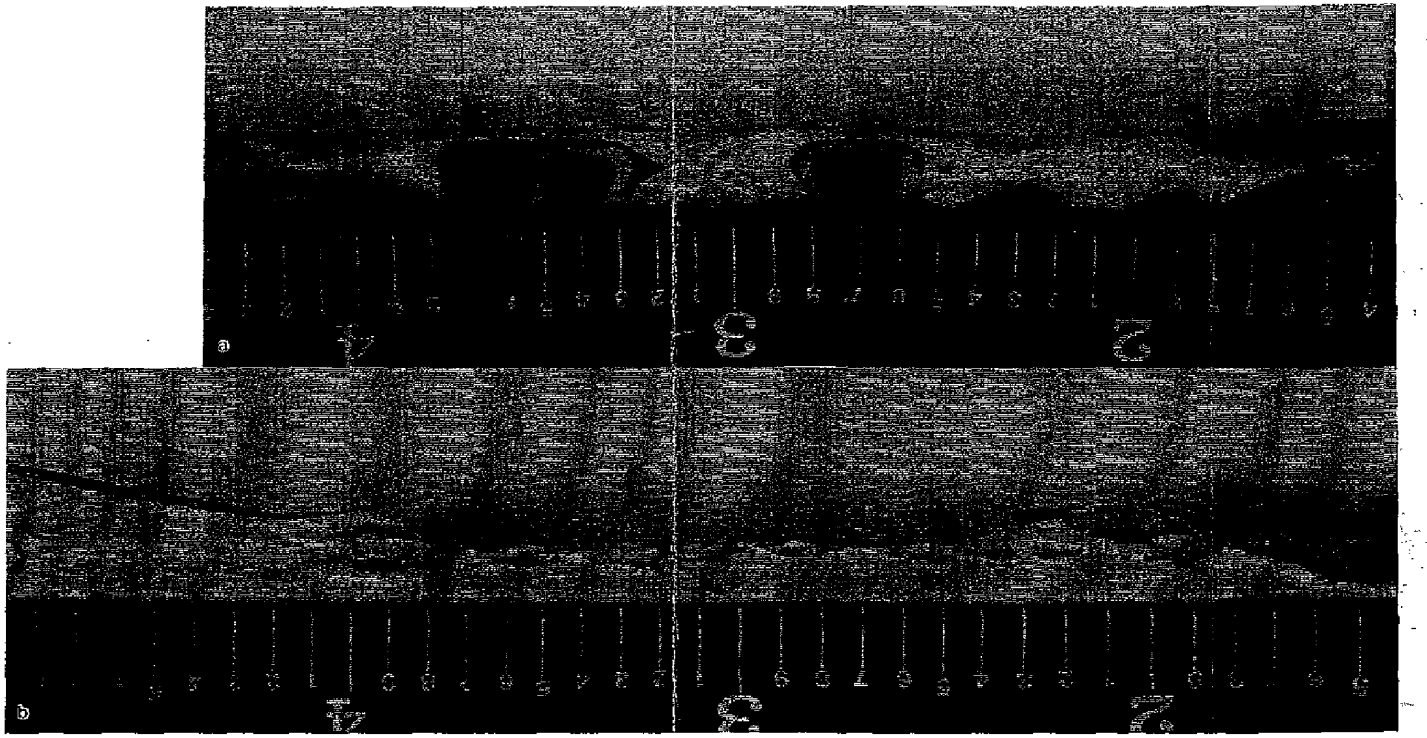
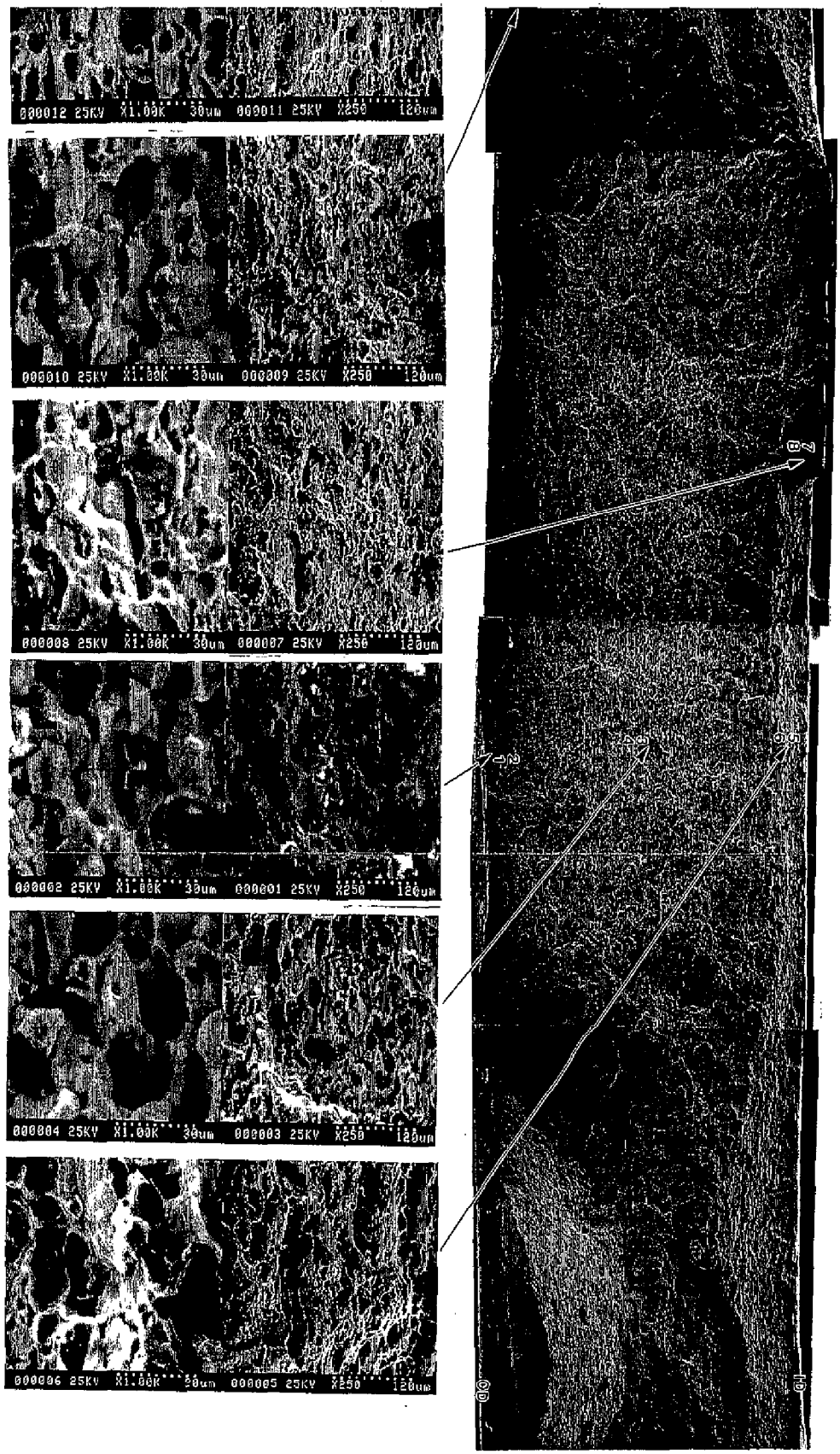


Figure 9. Fractography of fracture surface in sidewall region shown in Figure 1.

(a) Fracture surface montage. Photo ID: DC17916-TRS-1,2,3-8/15/97.

(b) Montage showing the exterior of the cylinder at the fracture surface location. Photo ID: DC17916-TRS-4,5,6-8/15/97.

shown in Figure 9.



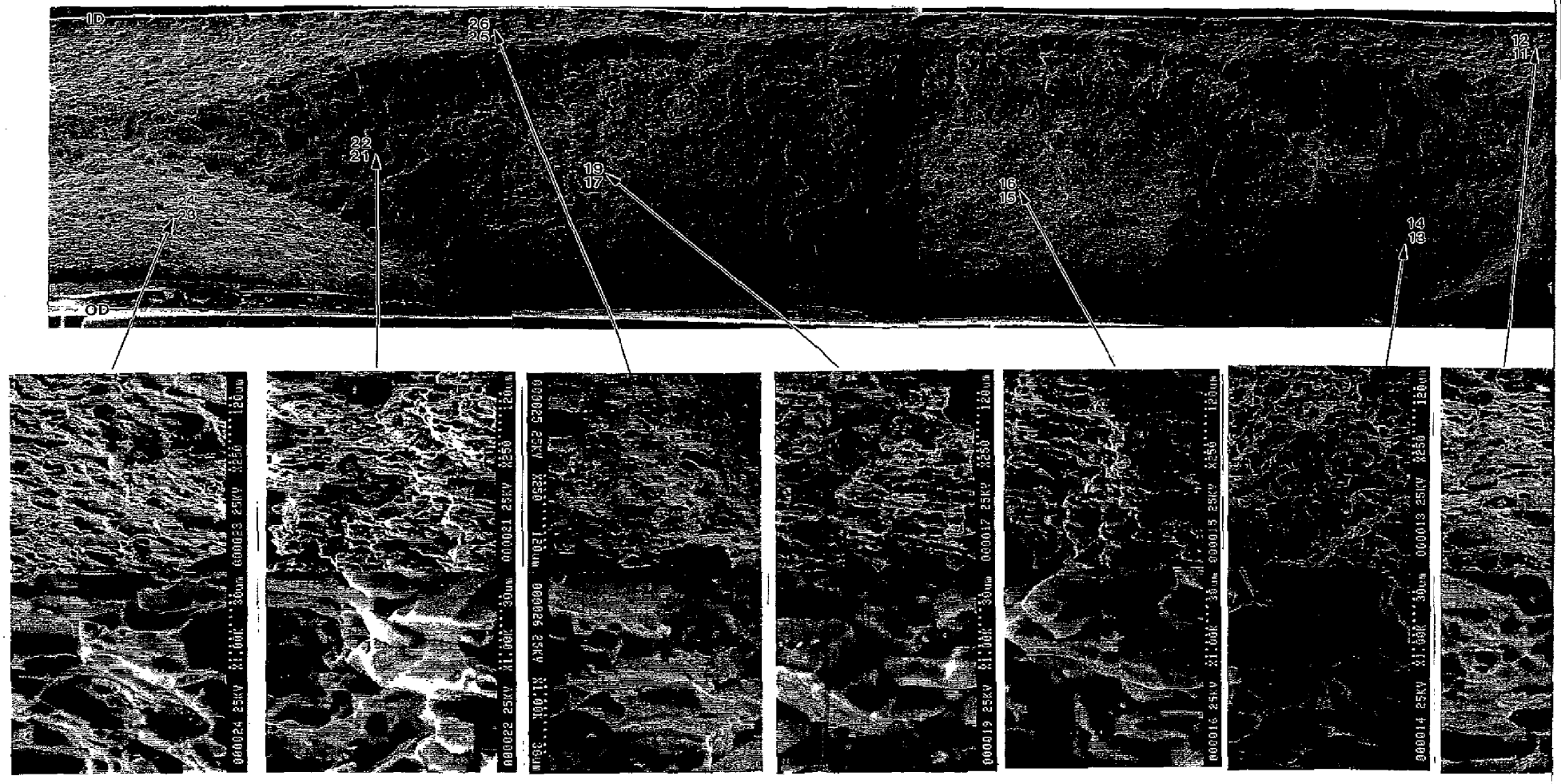
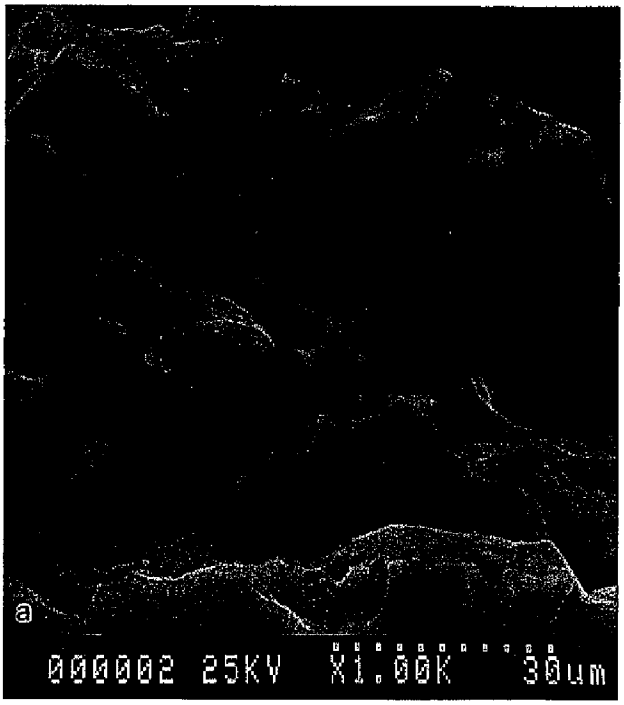


Figure 10. SEM fractography of fracture surface



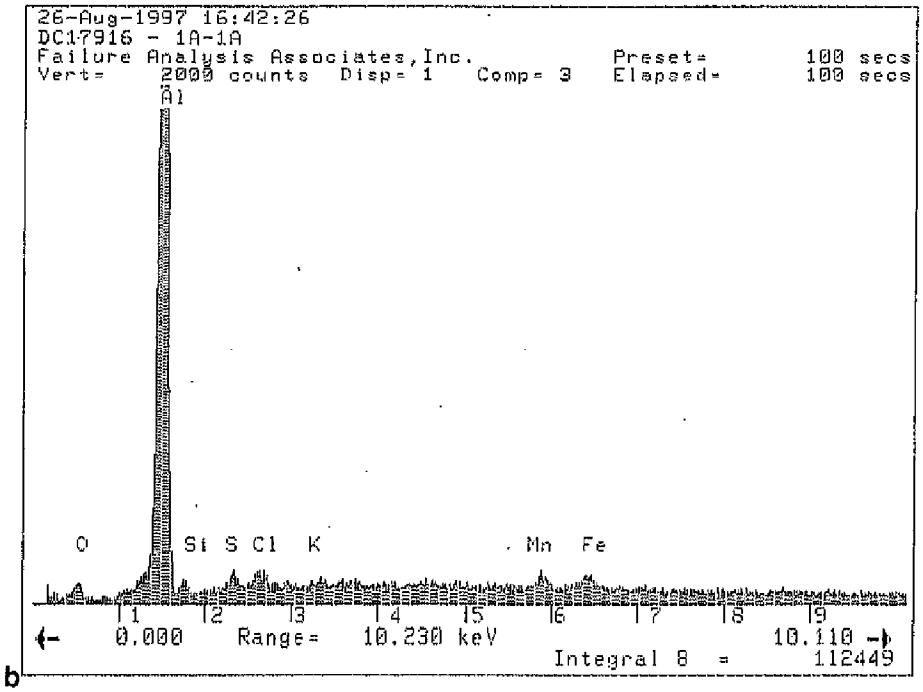
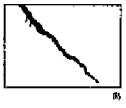


Figure 11. Intergranular region of fracture surface showing oxidation.
(a) SEM fractograph. 1000X. Photo ID: DC17916-PAL-1-8/27/97.
(b) EDS spectrum.



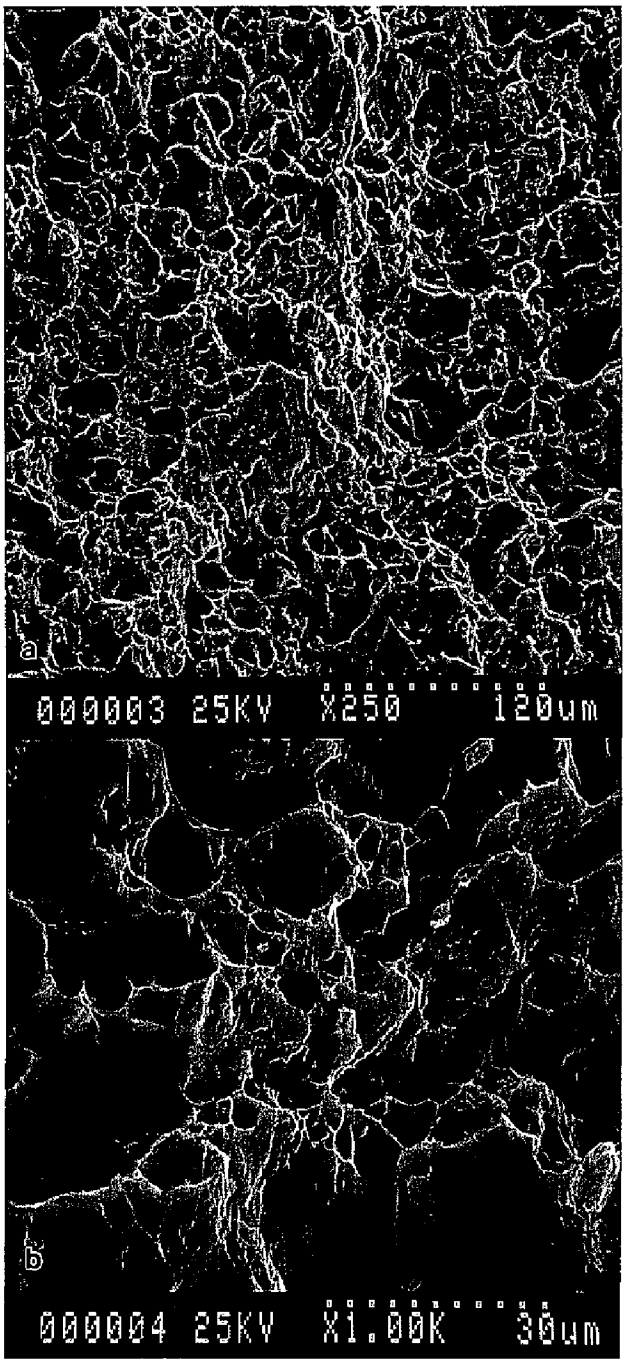


Figure 12. SEM fractographs of a tensile specimen.
(a) 250X. Photo ID: DC17916-PAL-3-12/10/96.
(b) 1000X. Photo ID: DC17916-PAL-4-12/10/96.

Appendix A: Recommended Scope of Work

Recommended Scope of Work for Metallurgical Evaluation of Aluminum Cylinder

1. Photodocumentation. Prior to any destructive examination of this cylinder, it will be photodocumented to illustrate its "as-received condition". After each cutting operation needed to remove samples for testing or evaluation (such as required for chemical samples) the cylinder and sample will be photodocumented to illustrate the sample location. Photodocument the primary fracture surface as well as any secondary cracks that may be present. Any corrosion deposits or other visible surface contaminates should also be photodocumented

2. Corrosion. Testing for corrosion product should be done prior to any extensive cutting or handling of the cylinder remains. Swipe samples or cutting of material containing any such potential corrosion products should be taken. When cutting is performed, care should be used to minimize contamination of the cylinder surfaces. Swipe samples or samples containing potential corrosion products should first be analyzed by scanning electron microscopy and energy dispersive spectroscopy (SEM/EDS).

3. Chemical Analysis. The cylinder aluminum alloy will be analyzed for chemical composition to compare with materials specifications. Material from the neck region, side wall and cylinder bottom will be analyzed to check for alloy homogeneity. The analysis will also determine the concentration of potentially detrimental trace elements, such as lead.

4. Macroetching. A thin slice of material will be removed from the neck of the cylinder that includes a least one-inch of sidewall material. This slice will be macroetched to show the grain macro/microstructure in this area.

5. Fractography. SEM and stereo-microscopic examination should be performed on all fractures. Particular attention should be focused in the regions where the fracture originated. Any indications of fatigue, stress-corrosion cracking, ductile rupture, inter/intra-granular fracture features, etc., should be photodocumented.

6. Dimensional Checking. Prior to extensive cutting, the cylinder wall thickness at various locations and other cylinder features, such as threads, cylinder internal diameter, inlet hole diameter should be measured and compared to the original cylinder drawings. Measurements done should be sufficient to determine the minimum wall thickness as well as to document any extensive plastic tearing that may have resulted in the failure event.

7. Secondary Cracking. A section of the primary fracture surface near the crack origin should be metallographically polished. Any secondary cracking near the failure origin should be evaluated. These sections should be first examined in the unetched condition and photodocumented to look for crack branching. The sample should then be etched, re-examined and photodocumented.

8. Material Hardness. The material hardness shall be evaluated in the neck, wall and cylinder bottom by means of macrohardness testing according to ASTM standards.

9. Physical Testing.

- mechanical test per 49 CFR, 178.46-13
- flattening test per 49 CFR, 178.46-12

10. Report. Report should contain a description of all tests performed and the results obtained. If possible, state the location of the crack origin, mode of fracture, and likely cause of failure.

Appendix B: Detailed Photodocumentation of Cylinder