

Steel Tubular Products: Metallographic Techniques and Microstructures

Donald S. Dabkowski, Product Manager, Tubular Metallurgy, United States Steel Corporation; Frederick W. Kern, Metallurgical Engineer, Tubular Metallurgy, United States Steel Corporation

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Atlas of Microstructures for Steel Tubular Products



Fig. 1 API 5L, Grade X52, as-rolled seamless steel pipe. Microstructure consists of small colonies of pearlite in a ferrite matrix. Picral. 500×

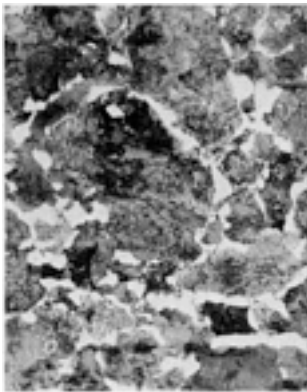


Fig. 2 API 5A, Grade K55, as-rolled seamless steel pipe produced by press-piercing. Pearlite colonies with ferrite partially outlining the prior-austenite grain boundaries. Picral. 500×

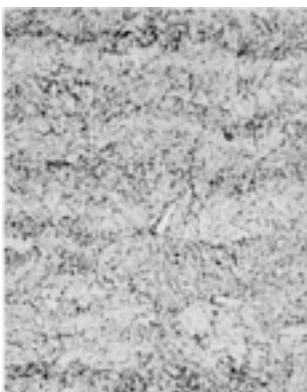


Fig. 3 API 5AX, Grade N-80, seamless steel pipe, austenitized at 845 °C (1550 °F), water quenched, and tempered at 620 °C (1150 °F). Microstructure is tempered martensite. Picral. 500×

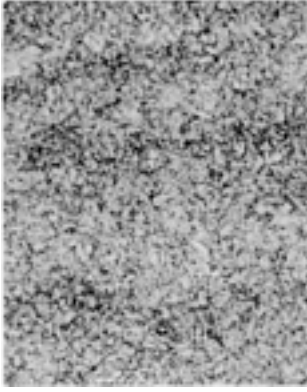


Fig. 4 API 5AX, Grade P-110, seamless steel pipe, austenitized at 845 °C (1550 °F), water quenched, and tempered at 595 °C (1100 °F). Microstructure is tempered martensite. Picral. 500×



Fig. 5 API 5AC, Grade C-90, seamless steel pipe, (24 HRC maximum), austenitized at 870 °C (1600 °F), water quenched, and tempered at 705 °C (1300 °F). Tempered martensite. Picral. 500×

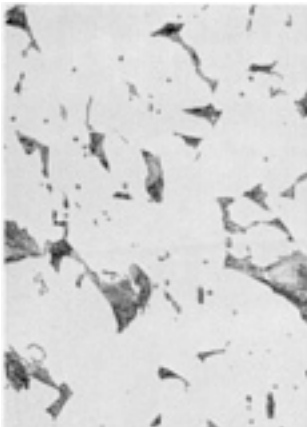


Fig. 6 API 5L, Grade A, continuous welded pipe, as-rolled. Microstructure consists of large pearlite colonies in a ferrite matrix. Picral. 500×



Fig. 7 API 5L, Grade X60, electric resistance welded pipe, as-rolled. Small angular carbides in a ferrite matrix. Picral and nital. 500×

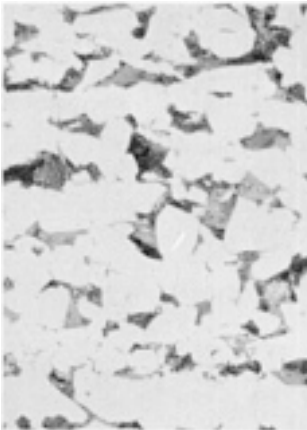


Fig. 8 API 5L, Grade X52, double submerged arc welded pipe showing pearlite colonies in a ferrite matrix. Picral. 500×

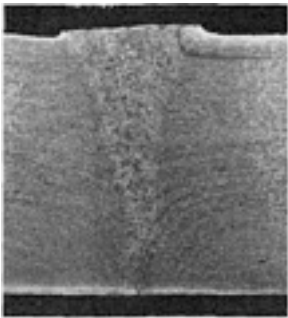


Fig. 9 Section through a resistance weld in API 5L-X46 steel pipe, 18-in. OD by 0.375-in. wall. Weld is sound. $(\text{NH}_4)_2\text{S}_2\text{O}_8$.

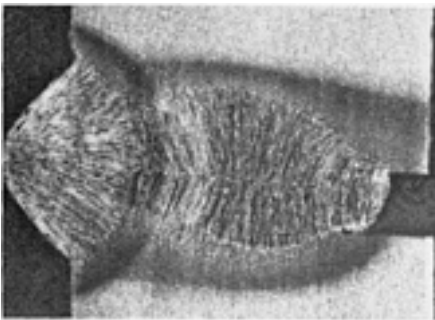


Fig. 10 Section through a two-pass butt weld (automatic gas metal arc process, CO_2 shielding) in API 5L-X60 steel pipe, 30-in. OD by 0.25-in. wall. A defective weld (note incomplete fusion, right).

4% nital. 10×

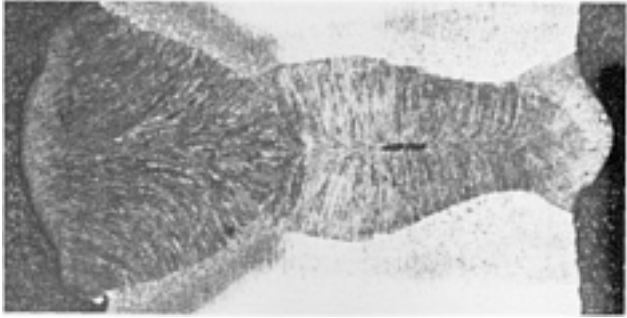


Fig. 11 Section through a two-pass butt weld made in the same size of API 5L-X60 steel pipe as in [Fig. 10](#) and by the same process (automatic gas metal arc, CO₂ shielding). Fusion is complete. A defective weld (note shrinkage crack in the weld bead, which occurred during solidification). 4% nital. 15×

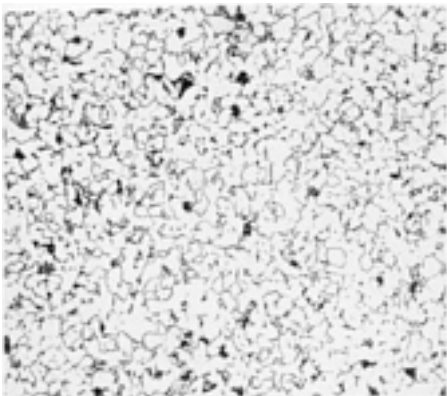


Fig. 12 ASTM A106, Grade A, seamless steel pipe, 0.84-in. OD, 0.147-in. wall, normalized by austenitizing at 870 °C (1600 °F), air cooling. Longitudinal midwall section. Ferrite (light areas) and pearlite (dark). Nital. 250×



Fig. 13 ASTM A106, Grade A, seamless steel pipe, 1.315-in. OD by 0.179-in. wall, as hot drawn. Specimen was longitudinal at midwall thickness. Structure is ferrite (light gray) in a matrix of pearlite (gray and black). Nital. 275×

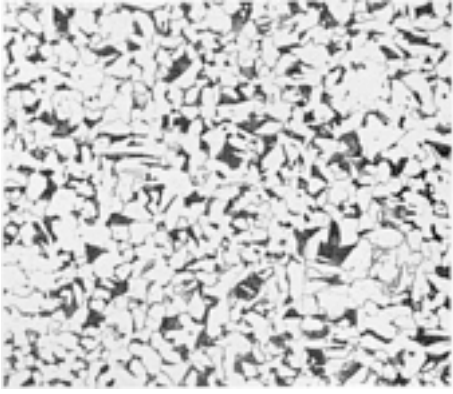


Fig. 14 ASTM A106 Grade B, seamless steel pipe, 3-in. OD by 0.43-in. wall, as-fabricated. Specimen was taken in longitudinal direction. Structure consists of ferrite (light areas) and pearlite (dark areas). Nital. 100×



Fig. 15 ASTM A106, Grade B, seamless steel pipe, 12-in. OD by 1.3-in. wall, as-fabricated. Specimen was taken in longitudinal direction. Light areas are ferrite; dark areas are pearlite. Nital. 100×



Fig. 16 ASTM A106, Grade B, steel pipe, 28-in. OD by 1.22-in. wall, as-extruded. Specimen taken near surface. Ferrite at grain boundaries and as plates in grains. Nital. 100×

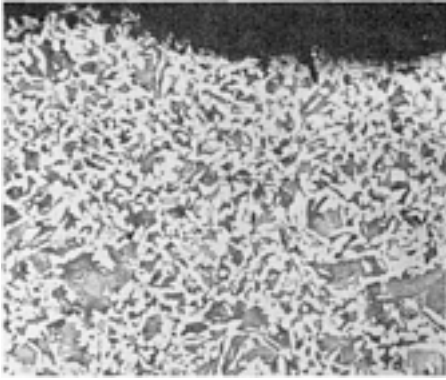


Fig. 17 Same grade and size of pipe as for [Fig. 16](#), but normalized by austenitizing at 870 °C (1600 °F) and air cooling. Specimen was taken near surface. Note absence of decarburization. Nital. 100×

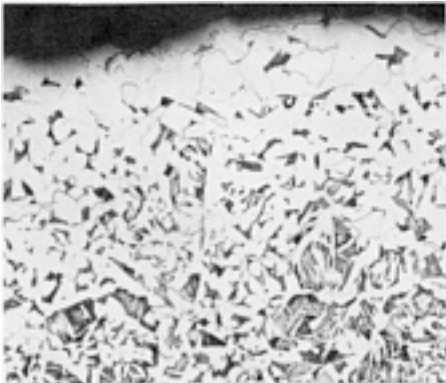


Fig. 18 Same grade and size of pipe as for [Fig. 16](#), but normalized by austenitizing at 1095 °C (2000 °F) for 1 h and air cooling. Surface shows decarburization (light gray areas near top). The light areas near bottom of micrograph are ferrite; the matrix is pearlite. Nital. 100×

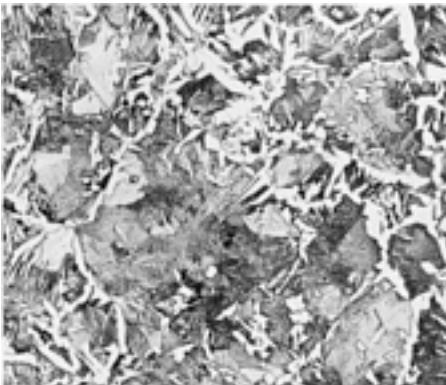


Fig. 19 Same grade and size of pipe as for [Fig. 16](#), and same heat treatment as for [Fig. 18](#), but specimen was taken from center of pipe wall. Structure consists of ferrite (light) at prior austenite grain boundaries and as plates within grains in a matrix of pearlite. Nital. 100×



Fig. 20 Same grade and size of pipe as for [Fig. 16](#), but normalized by austenitizing at 1315 °C (2400 °F) for 1 h and air cooling. The light areas in the structure are ferrite along boundaries of very coarse prior austenite grains and as plates within grains; the matrix is pearlite. Nital. 100×

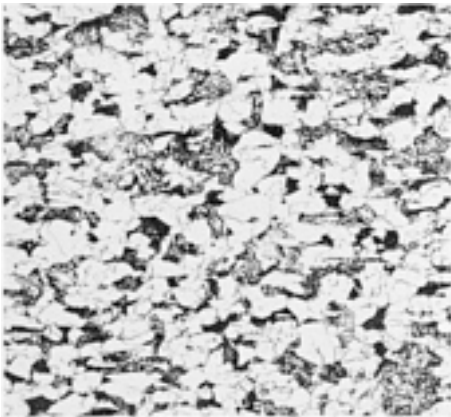


Fig. 21 ASTM A335, Grade P2, seamless steel pipe, cold drawn and stress relieved at 690 °C (1275 °F). Specimen was taken in longitudinal direction. Light areas are blocky ferrite; dark areas, containing ferrite plates. Nital. 100×

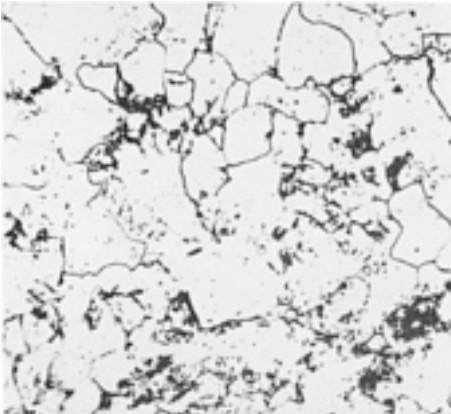


Fig. 22 ASTM A335, Grade P5, seamless steel pipe, 4.75-in. OD by $\frac{1}{8}$ -in. wall. Annealed by austenitizing at 900 °C (1650 °F) for 1 h and furnace cooling. Specimen was taken at midwall thickness. Alloy carbide in a ferrite matrix. Nital. 500×



Fig. 23 ASTM A335, Grade P7, seamless steel pipe, 5.563-in. OD by 0.375-in. wall, fully annealed. Specimen was taken in longitudinal direction. Structure is fine ferrite grains (white) with a dispersion of alloy particles. Vilella's reagent. 100×

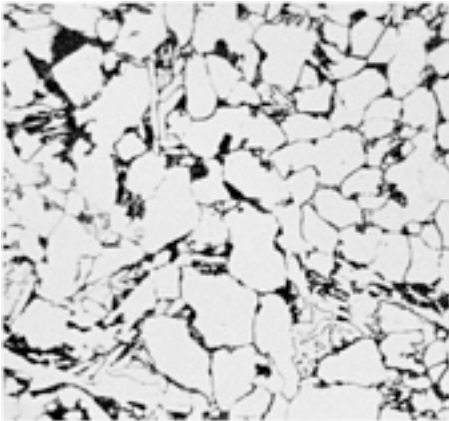


Fig. 24 ASTM A335, Grade P11, seamless steel pipe, 5.563-in. OD by 0.375-in. wall, fully annealed. Specimen was taken in longitudinal direction. Light areas are ferrite; dark areas are pearlite containing some Widmanstätten plates of ferrite. Nital. 500×

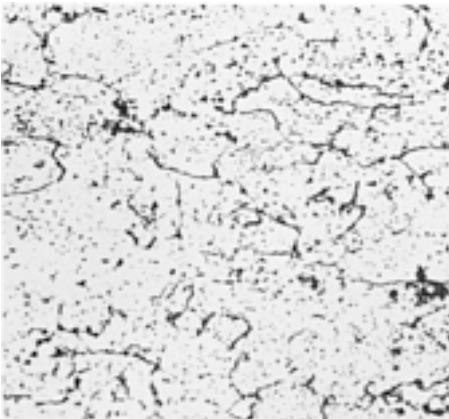


Fig. 25 ASTM A335, Grade P22, seamless steel pipe, 1.312-in. OD by 0.25-in. wall, hot drawn and annealed by austenitizing at 900 °C (1650 °F) for 1 h and furnace cooling. Structure consists of a fine dispersion of alloy carbide particles in a matrix of ferrite. Nital. 550×



Fig. 26 ASTM A381, Class Y52, gas metal arc welded steel pipe, 36-in. OD by 0.406-in. wall, fully annealed. Light areas in the structure are ferrite; dark areas are pearlite; some nonmetallic stringers are present in the ferrite (toward the top of the micrograph). 2% Nital. 100×

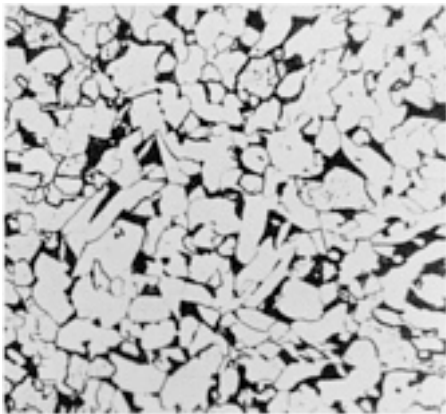


Fig. 27 ASTM A161 seamless steel tube, 5-in. OD by $\frac{7}{16}$ -in. wall, as hot drawn. Specimen from midthickness of wall in longitudinal section. Structure is ferrite and pearlite (dark). Nital. 110×

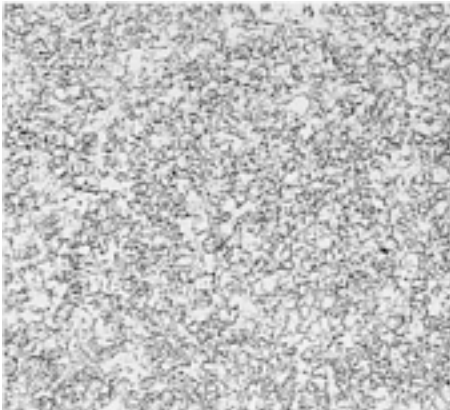


Fig. 28 ASTM A200, Grade T5, seamless alloy steel tube, annealed. Longitudinal section. Structure is a fine dispersion of alloy carbide in a matrix of ferrite (light background). Vilella's reagent. 100×

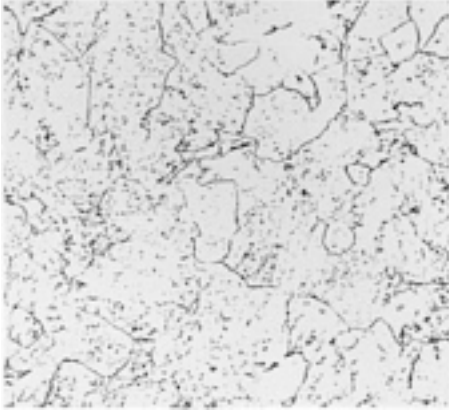


Fig. 29 Same specimen as shown in [Fig. 28](#), but at a higher magnification. Light areas are ferrite; black particles are alloy carbide, located mostly within the ferrite grains. Vilella's reagent. 500×

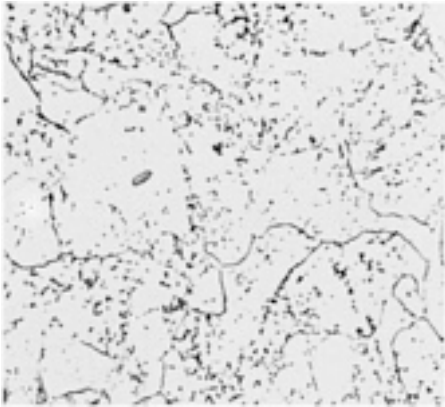


Fig. 30 Same specimen as shown in [Fig. 28](#) and [29](#), but at a still higher magnification. Black constituents are alloy carbide; matrix is ferrite. Vilella's reagent. 1000×

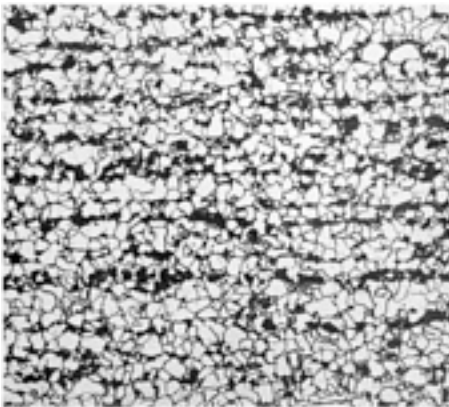


Fig. 31 ASTM A209, Grade T1, seamless alloy steel tube, hot finished and annealed. Ferrite (light) and pearlite; some banding. Nital. 100×

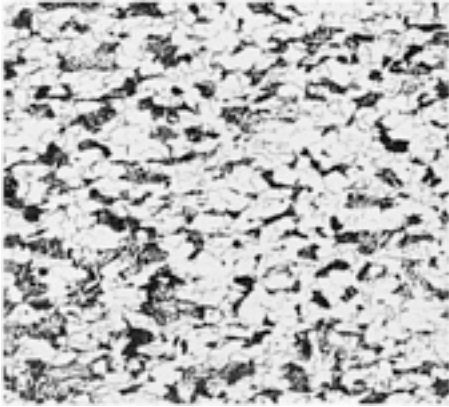


Fig. 32 Same steel as [Fig. 31](#), but cold drawn and stress relieved. Micrograph from longitudinal section. Ferrite and pearlite (see also [Fig. 33](#)). Nital. 100×

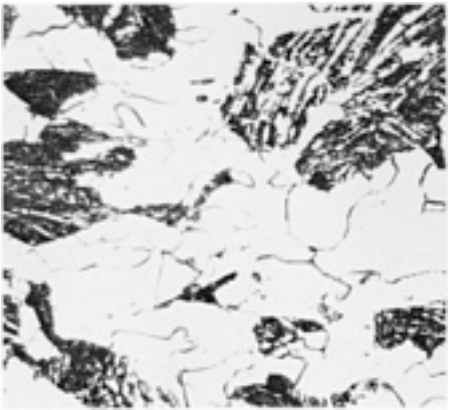


Fig. 33 Same specimen as shown in [Fig. 32](#), but at a higher magnification. The light areas in the structure are ferrite, and the dark areas are pearlite. Nital. 500×

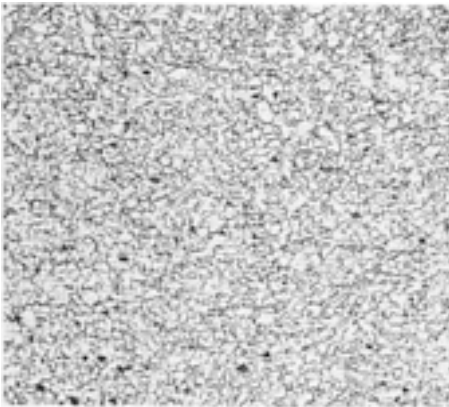


Fig. 34 ASTM A213, Grade T5c, steel tube, hot finished to a 2-in. OD by 0.22-in. wall, held at 730 °C (1350 °F) and air cooled. Dispersed chromium and titanium carbides in ferrite. Vilella's reagent. 100×

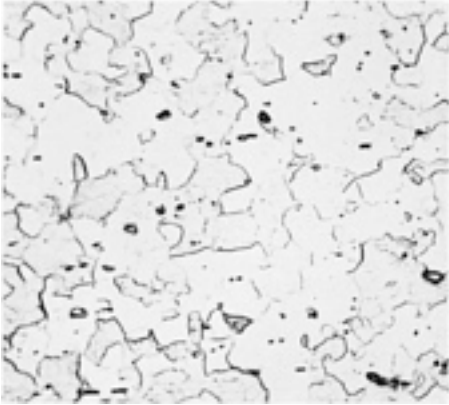


Fig. 35 Same specimen as shown in [Fig. 34](#), but at a higher magnification. The carbide particles are more completely resolved. The small dark areas are titanium carbide. Vilella's reagent. 500×

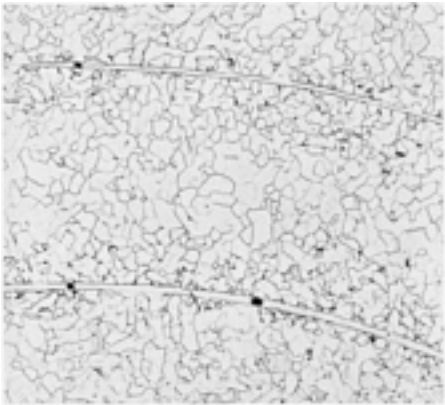


Fig. 36 Copper brazed joints (outlined white bands) in spiral-wound tubing made from ASTM A254, Class I, steel. Specimen is a cross section. Structure is mostly ferrite. 2% Nital. 100×

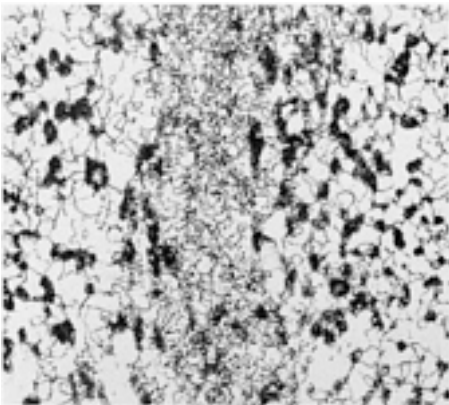


Fig. 37 1015 steel tube, resistance welded without filler metal. Vertical band through the center is the fusion zone; heat-affected zones are on each side. Transverse section. Nital. 100×

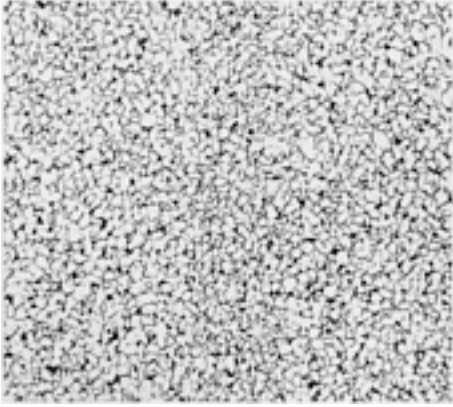


Fig. 38 Same as [Fig. 37](#), except that the tube has been normalized. Light areas are ferrite; dark areas, pearlite. Weld zone is at center. Note general uniformity of structure. Nital. 100×

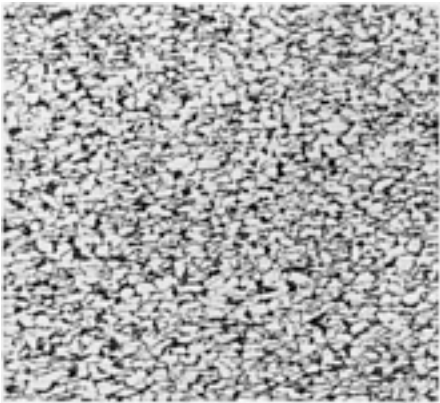


Fig. 39 Same as [Fig. 38](#), except the tube has been cold drawn (note elongated grains). A longitudinal section that was taken near the weld zone. The structure of the weld is the same as the base steel. Nital. 100×

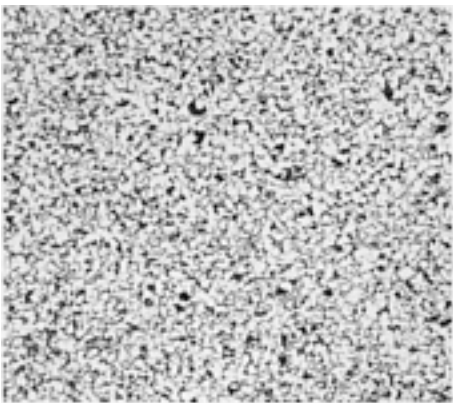


Fig. 40 Same as [Fig. 39](#), but specimen is transverse to the direction of the weld. The tube has been normalized and cold drawn after welding. Structure is ferrite (light constituent) and pearlite (dark constituent). Nital. 100×

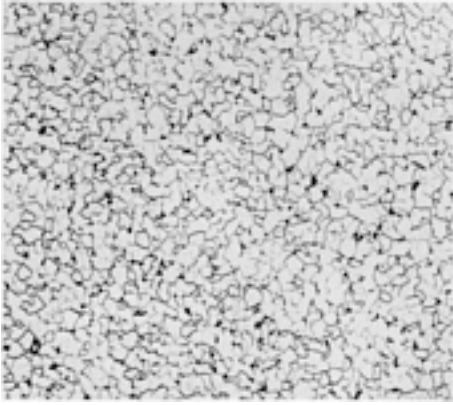


Fig. 41 Same as [Fig. 40](#), except the tube has now been renormalized after cold drawing. Structure is equiaxed ferrite and pearlite. Renormalizing apparently caused some coarsening of the grains (compare with [Fig. 38](#)). Nital. 100×

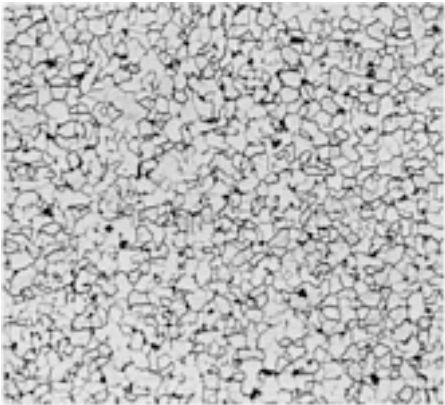


Fig. 42 Same as [Fig. 39](#), except after normalizing, cold drawing, and renormalizing. Specimen is longitudinal. Note equiaxed ferrite grains. Nital. 100×

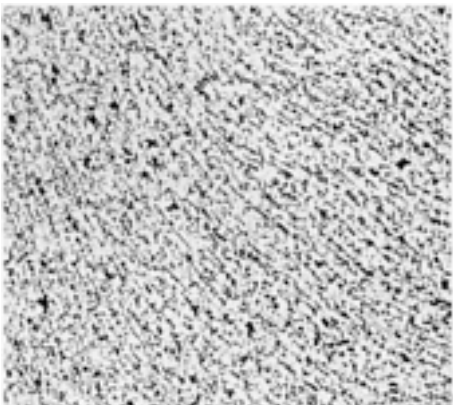


Fig. 43 1018 steel tubing, showing a transverse section near the longitudinal seam after welding and normalizing. Note flow pattern. Nital. 100×

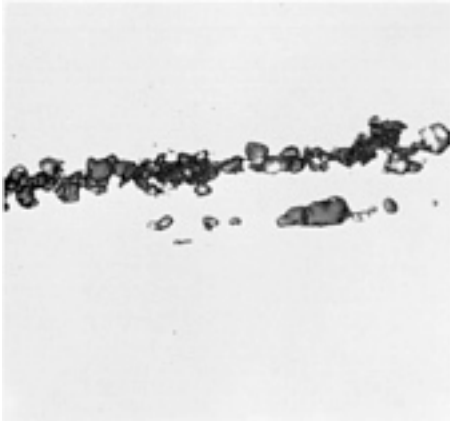


Fig. 44 Aluminate inclusion (longitudinal) in 1025 cold drawn steel tube. As-polished. 500×



Fig. 45 Segmented sulfide inclusion (longitudinal) in 1215 cold drawn steel tube. As-polished. 1000×

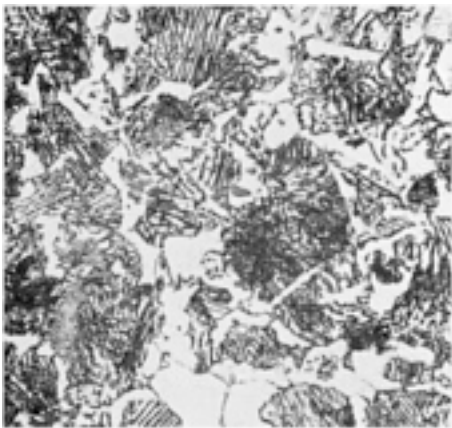


Fig. 46 4140 steel tube, annealed by austenitizing at 845 °C (1550 °F), for 3 h, furnace cooling to 620 °C (1150 °F), and air cooling to room temperature. Structure is ferrite and pearlite. Nital. 1000×



Fig. 47 4140 steel tube, austenitized at 830 °C (1525 °F) for 1 h, oil quenched, tempered at 595 °C (1100 °F) for 2 h. The structure consists of some ferrite (white) in tempered martensite. Nital. 1000×

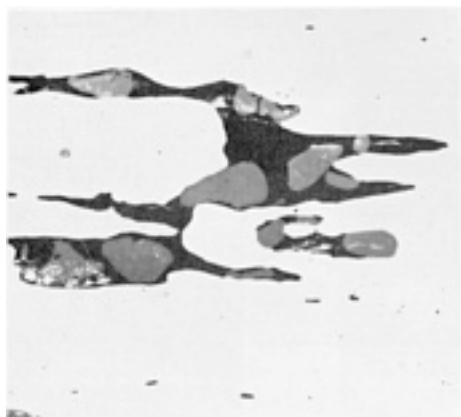


Fig. 48 Silicate (black) and sulfide (gray) inclusions in 4620 steel tube. As-polished. 500×

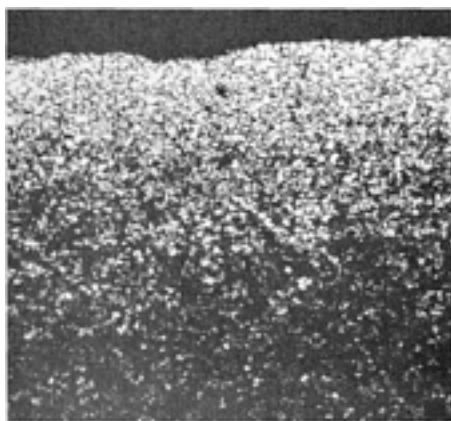


Fig. 49 Decarburization at the surface of 5048 steel seamless tube (transverse). Nital. 100×



Fig. 50 Large silicate inclusion (longitudinal) in 8620 steel tube. As-polished. 250×

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