

Plate Steels: Metallographic Techniques and Microstructures

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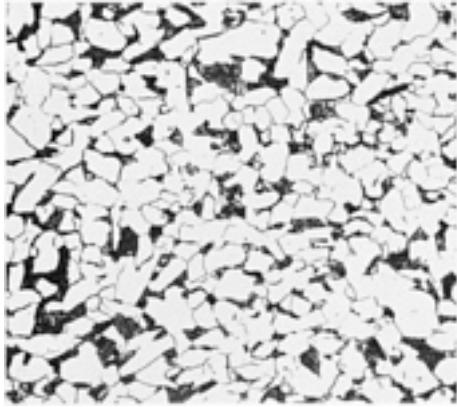


Fig. 1 ASTM A36 steel plate, 9.5 mm ($\frac{3}{8}$ in.) thick, as-rolled. Structure consists of equiaxed ferrite (white areas) and pearlite (black areas). 1% nital. 250 \times

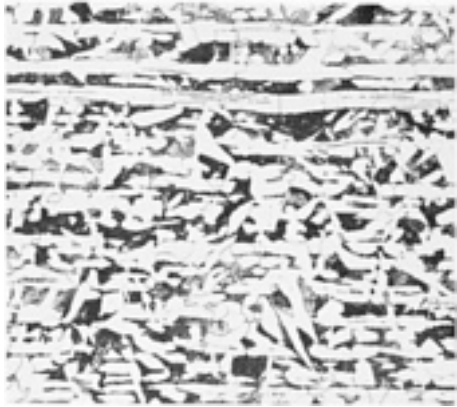


Fig. 2 ASTM A36 steel plate, 25 mm (1 in.) thick, as-rolled. Pearlite (black) and ferrite (white) with small nonmetallic inclusions. 2% nital. 100 \times

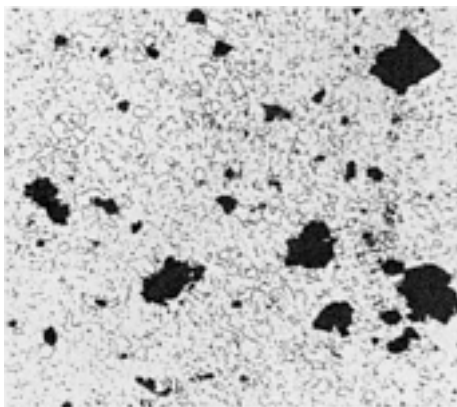


Fig. 3 Graphitization in ASTM A201, Grade A, steel plate after 5 years of service at 595 to 650 °C (1100 to 1200 °F). Structure consists of graphite nodules in a ferrite matrix. Nital. 110 \times

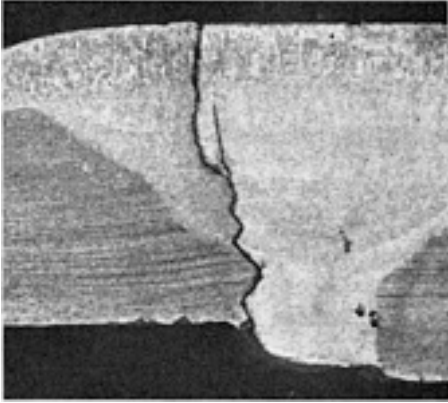


Fig. 4 Crack in a weld in ASTM A201, Grade B, firebox steel plate. The crack was the result of stresses that were induced by poor alignment of the two steel plates. $(\text{NH}_4)_2\text{S}_2\text{O}_8$. 4×

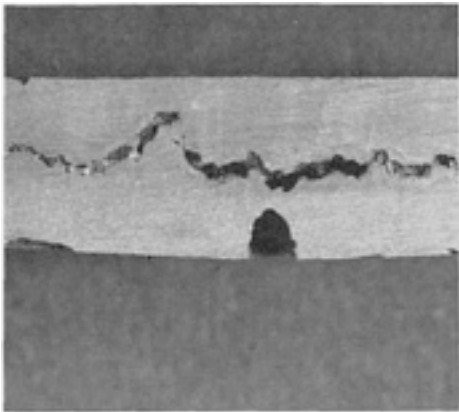


Fig. 5 Crack in ASTM A285, Grade C, firebox steel plate, 9.5 mm ($\frac{3}{8}$ in.) thick. Severe blistering, caused by hydrogen, was followed by cracking in high-carbon areas. $(\text{NH}_4)_2\text{S}_2\text{O}_8$. 3×

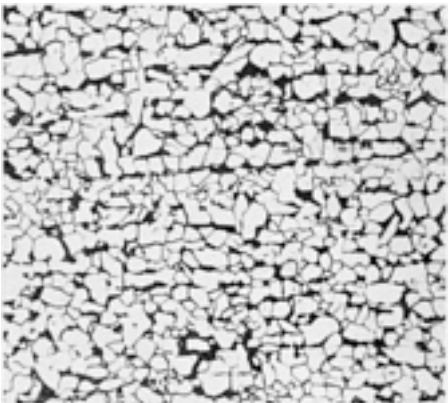


Fig. 6 ASTM A285, Grade C, firebox steel plate, hot rolled, as-received (essentially annealed). The white areas are ferrite, and the black areas are pearlite. 4% nital. 220×

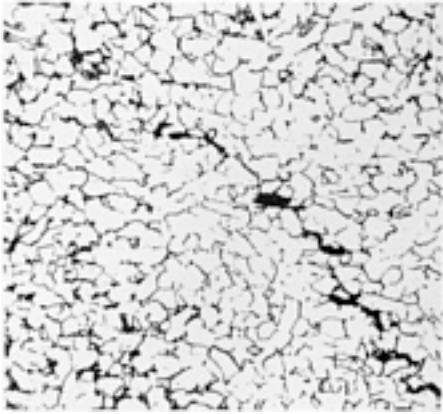


Fig. 7 Fissures in ASTM A285, Grade C, steel plate, exposed to hydrogen at 540 °C (1000 °F) and 5 MPa (700 psi) for 348 h. Hydrogen combined with carbon to form methane. 2% nital. 220×

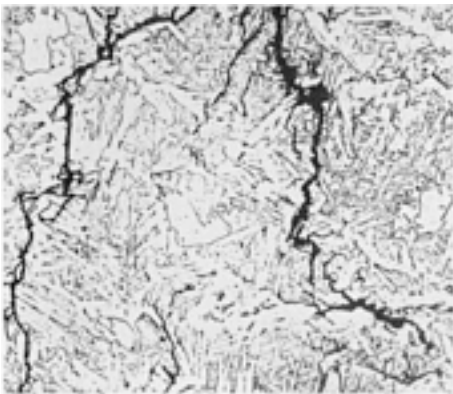


Fig. 8 Cracks in weld metal in ASTM A285, Grade C, steel plate. The cracks, which resulted from caustic embrittlement, are transgranular and inter-granular. Nital. 275×

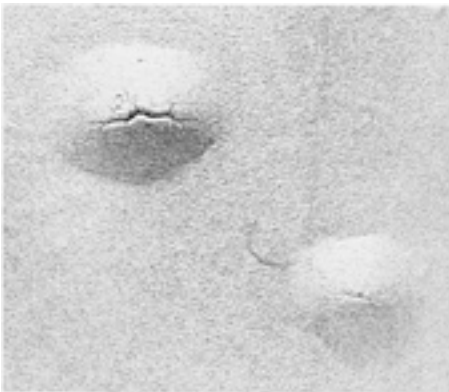


Fig. 9 Blisters, caused by hydrogen penetration in 9.5-mm ($\frac{3}{8}$ -in.) thick ASTM A285, Grade C, steel plate that had been in service one year at 480 °C (900 °F) in a refinery vessel. See also [Fig. 10](#). Not polished, not etched. 1.5 ×

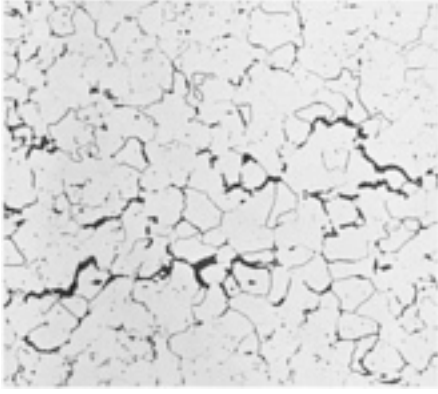


Fig. 10 Same as [Fig. 9](#). Wide black lines are fissures caused by hydrogen penetration. Ferrite with only a few carbide particles--a result of hydrogen decarburization in service. Nital. 275×

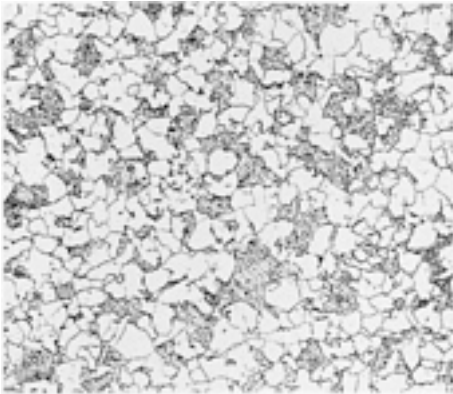


Fig. 11 ASTM A387, Grade D, steel plate, 200 mm (8 in.) thick, normalized and tempered. Austenitized at 955 °C (1750 °F) for 8 h, air cooled, tempered at 675 °C (1250 °F) for 8 h. Structure is ferrite and probably upper bainite (dark). Saturated picral. 100×

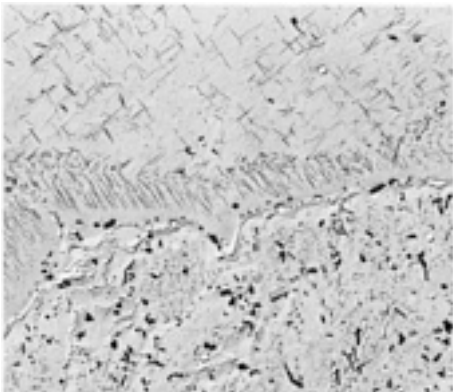


Fig. 12 Same structures as in [Fig. 11](#), but shown by a replica electron micrograph. Upper portion shows ferrite containing acicular and fibrous carbide particles; lower portion, probably upper bainite with fine acicular carbide. Saturated picral. 3600×

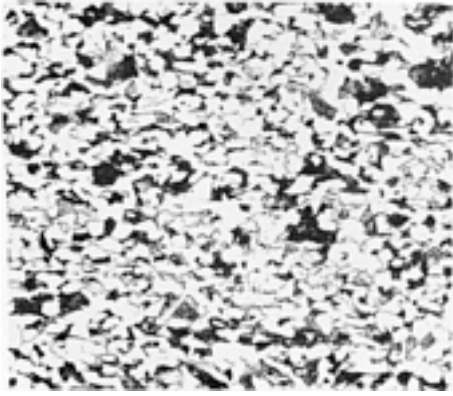


Fig. 13 ASTM A515, Grade 70, steel plate, 32 mm (1.25 in.) thick, in the as hot rolled condition. The structure consists of ferrite (light constituent) and pearlite (dark constituent); note that grains are somewhat elongated. 1% nital. 100×

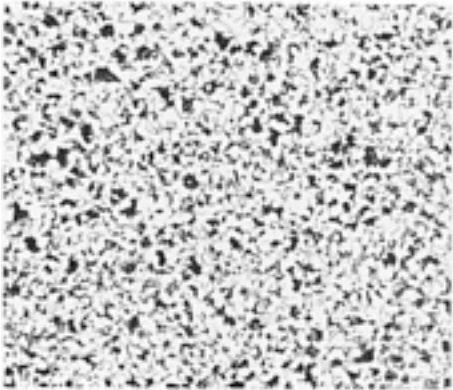


Fig. 14 Same steel and plate thickness as for [Fig. 13](#). Normalized by austenitizing at 900 °C (1650 °F) for 1 h and cooling in air. Light areas are ferrite, and dark areas are pearlite. Compare with [Fig. 15](#), which shows effect of overheating. 1% nital. 100×



Fig. 15 Overheated ASTM A515, Grade 70, steel plate, 38 mm (1.5 in.) thick. Normalized by austenitizing at 1125 °C (2060 °F) for 1.5 h and air cooling. Note ferrite at prior austenite grain boundaries and within grains. 1% nital. 100×

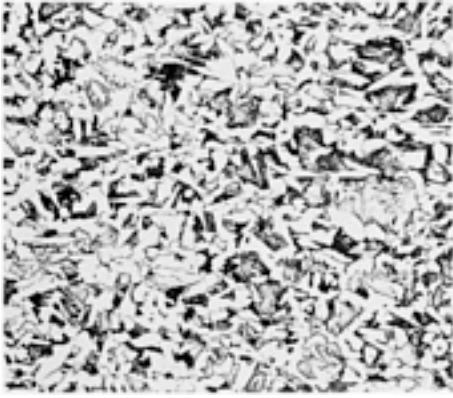


Fig. 16 ASTM A516, Grade 70, steel plate, 17 mm ($\frac{11}{16}$ in.) thick, in the as hot rolled condition. The structure consists of ferrite (light constituent) and pearlite (dark constituent); note that grains are somewhat elongated. 1% nital. 100×

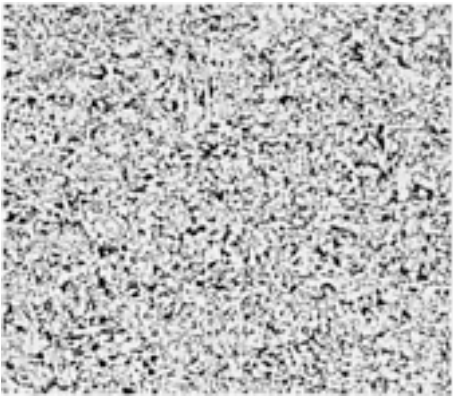


Fig. 17 Same steel and plate thickness as for [Fig. 16](#). Normalized by austenitizing at 900 °C (1650 °F) for 1 h and cooling in air. Structure consists of ferrite and pearlite. Compare with [Fig. 18](#), which shows effect of overheating. 1% nital. 100×

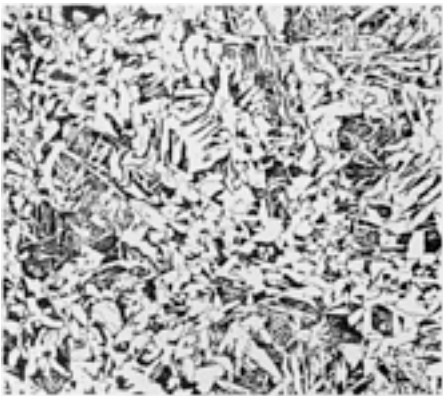


Fig. 18 Overheated ASTM A516, Grade 70, steel plate, 38 mm (1.5 in.) thick. Normalized by austenitizing at 1125 °C (2060 °F) for 1.5 h and air cooling. Structure consists of ferrite, pearlite (dark), and probably bainite. 1% nital. 100×

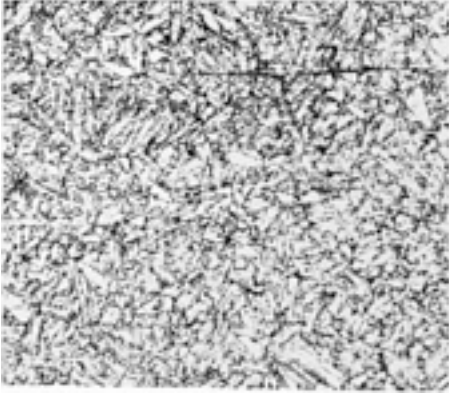


Fig. 19 ASTM A517, Grade B, steel plate, 6 mm (0.25 in.) thick, austenitized 1 h at 900 °C (1650 °F), water quenched, tempered 1 h at 620 °C (1150 °F). Structure is tempered martensite. Saturated picral. 500×

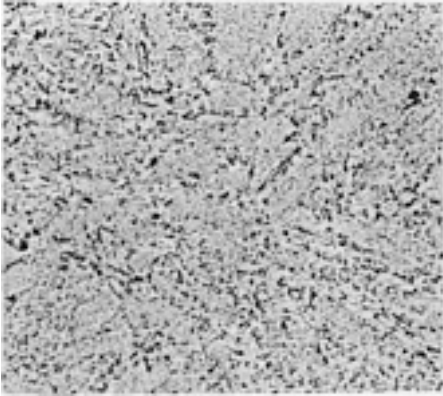


Fig. 20 Same steel and heat treatment as for [Fig. 19](#), but shown by a replica electron micrograph. Structure is mainly tempered martensite, but a dispersion of fine carbide is now resolved. Saturated picral. 3000×

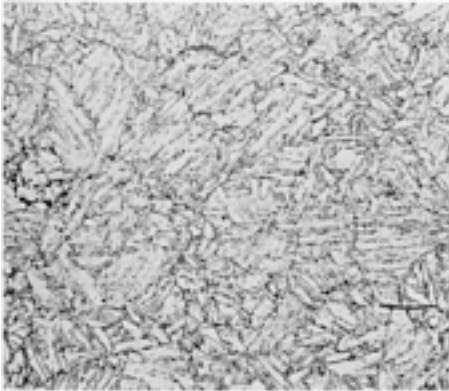


Fig. 21 ASTM A517, Grade M, steel plate, 50 mm (2 in.) thick, quenched and tempered. Austenitized at 900 °C (1650 °F), water quenched, tempered at 645 °C (1190 °F). Specimen was taken from the surface. 2% nital. 500×

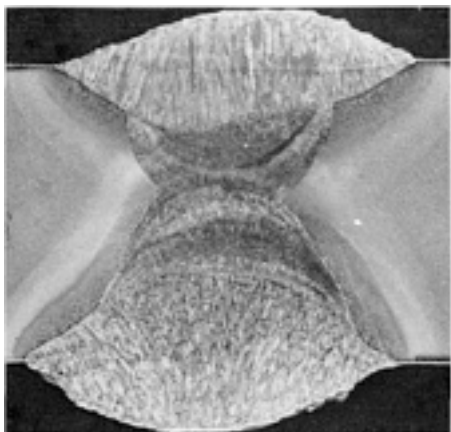


Fig. 22 Cross-sectional view of a butt welded joint between two 13-mm ($\frac{1}{2}$ -in.) thick plates of ASTM A517, Grade J, steel. Arc welding and a joint of double-V-groove design were used. Note the columnar structure of the weld metal in the outer portion of the weld. The heat-affected zone is also apparent. 2% nital. 4×



Fig. 23 ASTM A533, Grade B, steel plate, 300 mm (12 in.) thick. Austenitized at 915 °C (1675 °F) for 12 h, water quenched, re-austenitized at 855 °C (1575 °F) for 12 h, water quenched, tempered at 665 °C (1225 °F) for 12 h, air cooled, and stress relieved twice: 40 h at 605 °C (1125 °F) and 42 h at 550 °C (1025 °F). See also [Fig. 24](#). Saturated picral. 250×

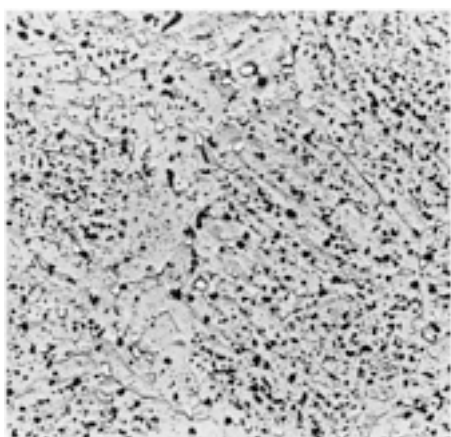


Fig. 24 Same steel and heat treatment as for [Fig. 23](#), but shown by a replica electron micrograph. Specimen was taken from the surface, as was specimen for [Fig. 23](#). Structure in [Fig. 23](#) is identifiable only as tempered martensite, but is resolved here as tempered martensite that contains a dispersion of carbide particles. Saturated picral. 3000×

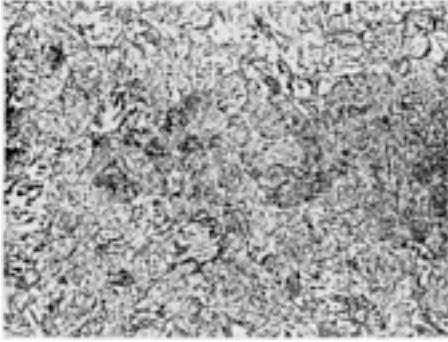


Fig. 25 Same steel and heat treatment as for [Fig. 23](#), but specimen was taken at one quarter of plate thickness. Structure is mainly tempered bainite; dark constituent is probably tempered martensite. Saturated picral. 250×

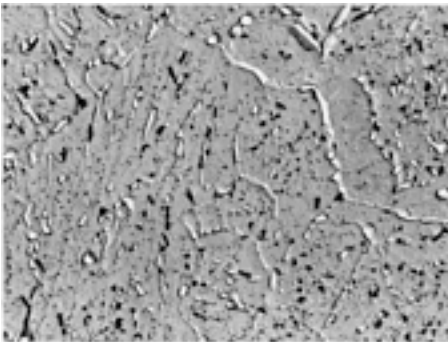


Fig. 26 Same as [Fig. 25](#), but a replica electron micrograph. Tempered bainite and probably martensite with carbide particles replicated (white) or extracted from specimen surface when plastic replica was stripped (black). Saturated picral. 3000×



Fig. 27 Same steel and heat treatment as for [Fig. 23](#), but specimen was taken from center of plate. Structure is largely tempered bainite; some proeutectoid ferrite (more equiaxed light gray constituent) is evident. Saturated picral. 250×

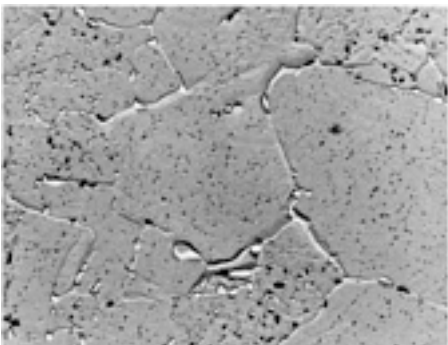


Fig. 28 Same steel, heat treatment, and location of specimen as for [Fig. 27](#), but shown by a replica electron micrograph. The structure consists of proeutectoid ferrite and bainite containing particles of carbide. Saturated picral. 3000×

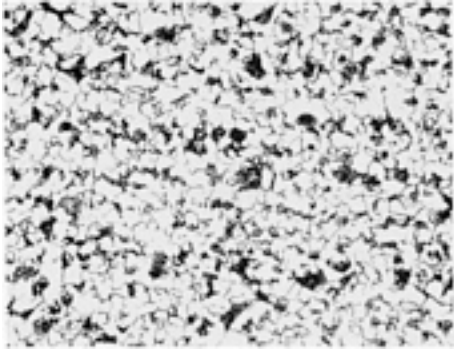


Fig. 29 ASTM A537, Grade A, steel plate, 13 mm (0.5 in.) thick, that was normalized by austenitizing at 900 °C (1650 °F) for 30 min and cooling in air. The microstructure consists of ferrite and pearlite. Some banding is apparent. 1% nital. 250×

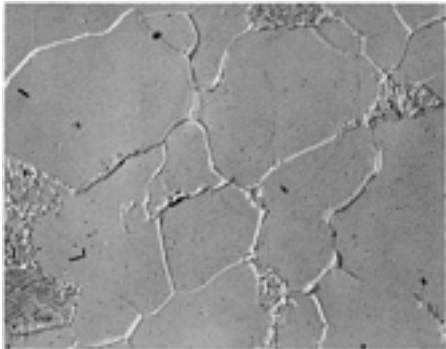


Fig. 30 Same steel and heat treatment as for [Fig. 29](#), but shown by a replica electron micrograph. Smooth areas in structure are ferrite, lamellar areas are pearlite, and fine black particles are aluminum nitride. 1% nital. 3000×

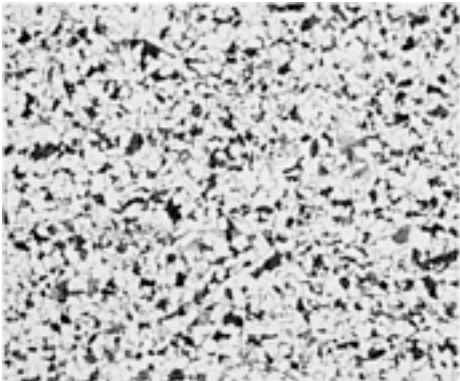


Fig. 31 ASTM A537, Grade A, steel plate, 50 mm (2 in.) thick. Normalized by austenitizing at 910 °C (1670 °F) and cooling in air. Specimen was taken near the plate surface. Light areas are ferrite; dark areas, pearlite. 2% nital. 100×

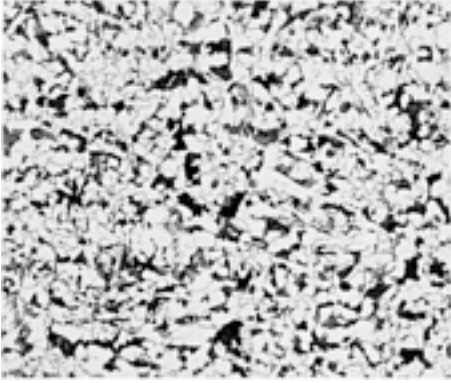


Fig. 32 Same steel and heat treatment as for [Fig. 31](#), but the specimen was taken from the center of the plate. Note that the grains are larger than those shown in the specimen taken from near the plate surface. 2% nital. 100×

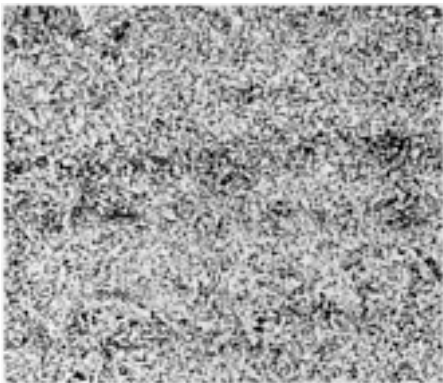


Fig. 33 ASTM A537, Grade B, steel plate, 13 mm (0.5 in.) thick, quenched and tempered. Austenitized at 900 °C (1650 °F) for 30 min, water quenched, tempered at 595 °C (1100 °F) for 1 h. Structure is carbide particles in tempered martensite. Saturated picral. 250×

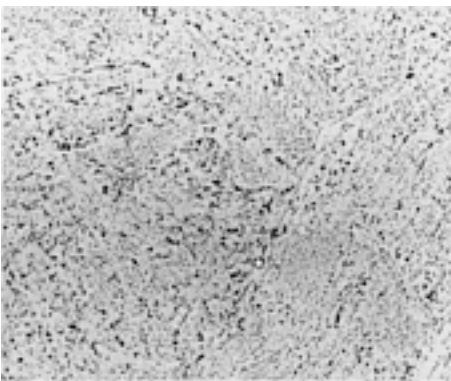


Fig. 34 Same steel and heat treatment as for [Fig. 33](#), but shown by a replica transmission electron micrograph. The carbide particles now appear as small black dots. The matrix (gray) is tempered martensite. Saturated picral. 3000×

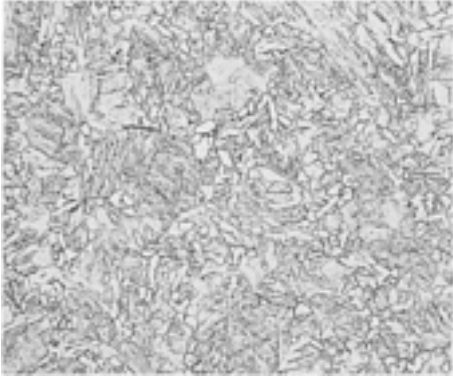


Fig. 35 ASTM A537, Grade B, steel plate, 19 mm (0.75 in.) thick, quenched and tempered. Austenitized at 925 °C (1700 °F), water quenched, tempered at 640 °C (1180 °F). The structure consists of tempered martensite. 2% nital. 500×

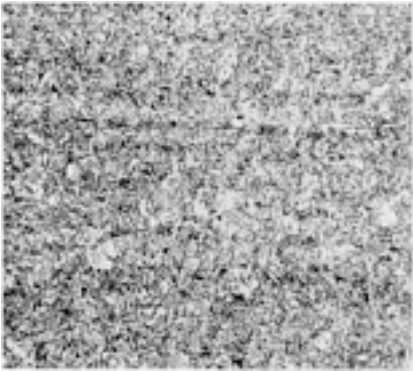


Fig. 36 ASTM A542, Class 2, steel plate, 25 mm (1 in.) thick, quenched and tempered. Austenitized at 955 °C (1750 °F), water quenched, tempered at 675 °C (1250 °F) for 1 h. Structure is probably tempered bainite. Saturated picral. 100×

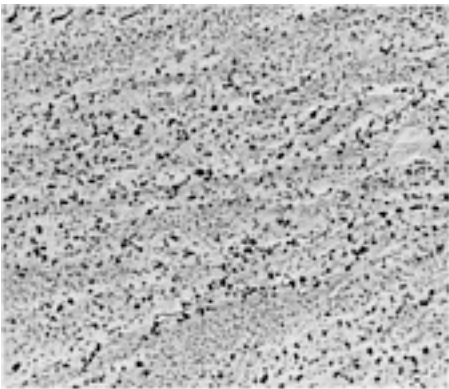


Fig. 37 Same steel and heat treatment as for [Fig. 36](#), but a replica electron micrograph that resolves a general distribution of fine carbide particles (see [Fig. 26](#) for explanation). Matrix is probably tempered bainite. Saturated picral. 3600×

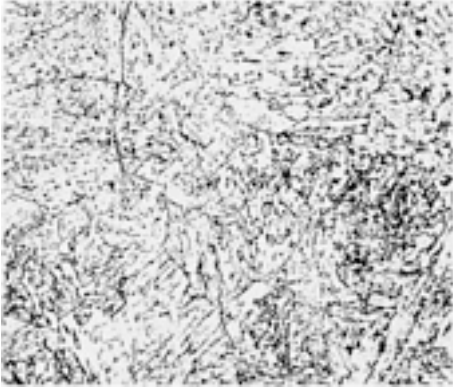


Fig. 38 ASTM A542, Class 2, steel plate, 116 mm (4.575 in.) thick, austenitized 4 h at 955 °C (1750 °F), quenched in agitated brine, tempered 4 h at 565 °C (1050 °F). Specimen from midthickness. Structure is tempered bainite. Nital. 275×

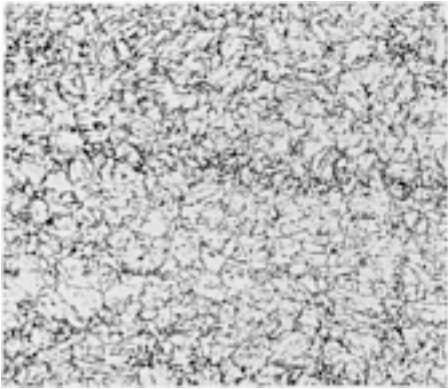


Fig. 39 ASTM A553, Grade A, steel plate, 13 mm (0.5 in.) thick, quenched and tempered. Austenitized at 800 °C (1475 °F) for 1 h, water quenched, tempered at 605 °C (1125 °F) for 1 h and cooled in air. Tempered martensite. 1% nital. 250×

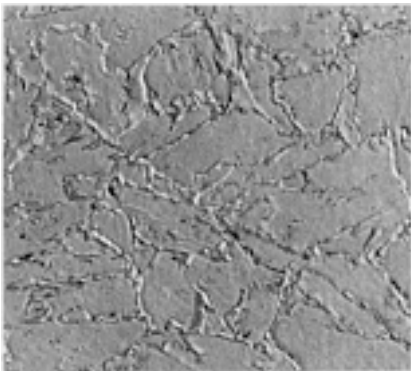


Fig. 40 Same steel and heat treatment as for [Fig. 39](#), but shown by a replica electron micrograph. Structure is tempered martensite; carbide particles are present, mainly at grain boundaries. 1% nital. 3000×



Fig. 41 ASTM A562 steel plate, 25 mm (1 in.) thick. Normalized by austenitizing at 900 °C (1650 °F) for 1 h and cooling in air. The microstructure consists largely of ferrite, with small particles of titanium carbide. 1% nital. 100×

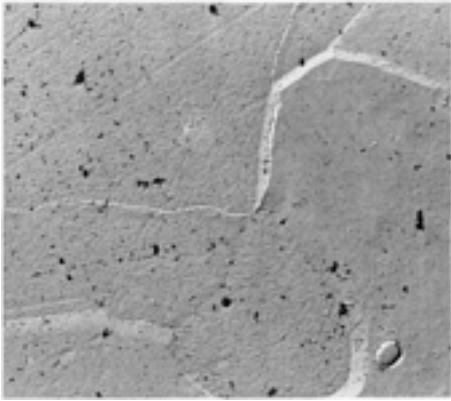


Fig. 42 Same steel and heat treatment as for [Fig. 41](#), but shown by a replica electron micrograph. The titanium carbide particles (black constituent) are well resolved at the higher magnification. 1% nital. 3000×

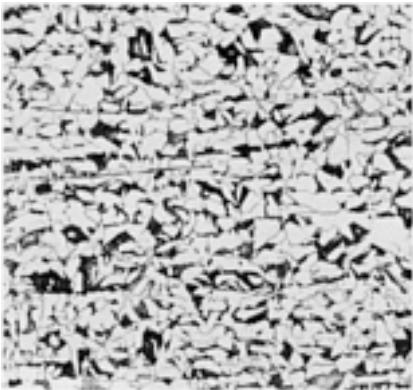


Fig. 43 ASTM A572, Grade 55, steel plate, 19 mm (0.75 in.) thick, as hot rolled. The structure is ferrite and pearlite. Note presence of a few nonmetallic stringers in the ferrite. 2% nital. 100×

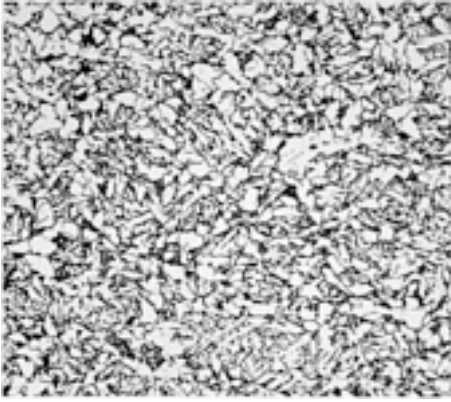


Fig. 44 ASTM A572, Grade 65, steel plate, 6 mm (0.25 in.) thick, as hot rolled. The microstructure consists of ferrite and pearlite (dark), with possibly some bainite. 1% nital. 250×

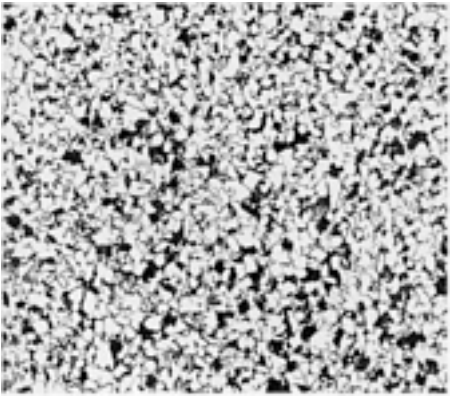


Fig. 45 ASTM A572, Grade 65, steel plate, 6 mm (0.25 in.) thick. Normalized by austenitizing at 900 °C (1650 °F) for 1 h and cooling in air. Structure is ferrite and pearlite (dark). 1% nital. 250×

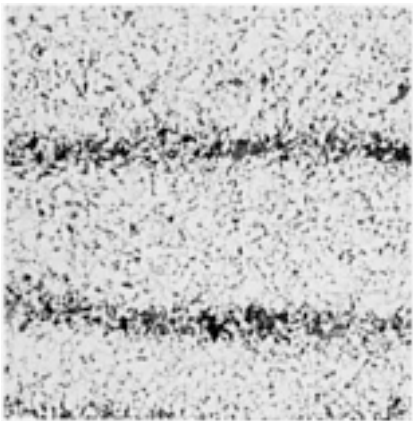


Fig. 46 ASTM A633, Grade C, 100-mm (4-in.) thick plate. Austenitized at 900 °C (1650 °F) and air cooled (normalized). Fine, polygonal ferrite and fine, partially banded pearlite. Nital plus picral. 200×

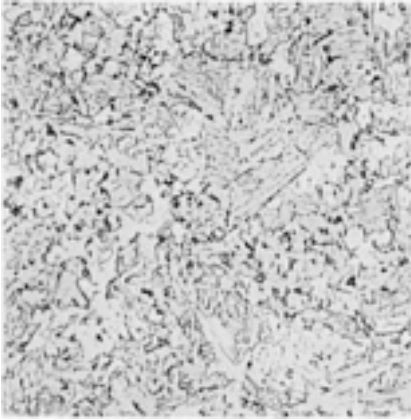


Fig. 47 ASTM A710, Grade A, Class 3, 25-mm (1-in.) thick plate. Austenitized at 900 °C (1650 °F), water-spray quenched, and aged at 650 °C (1200 °F). Predominantly acicular ferrite with fine, tempered carbides. Nital plus picral. 500×

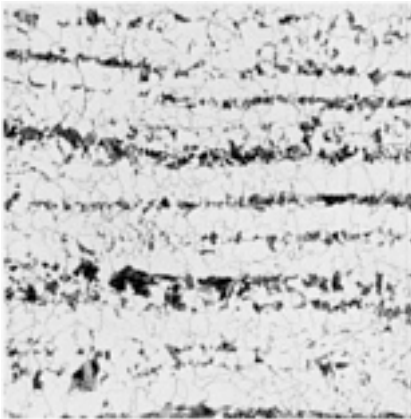


Fig. 48 ASTM A737, Grade B, 38-mm (1.5-in.) thick plate. Austenitized at 900 °C (1650 °F) and air-cooled normalized. Fine, polygonal ferrite and banded pearlite. Nital plus picral. 200×

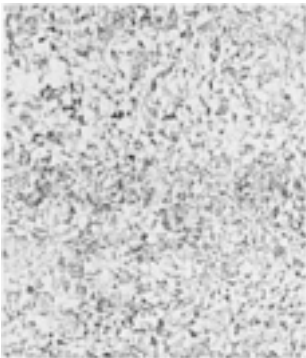


Fig. 49 Same as [Fig. 48](#), but austenitized at 900 °C (1650 °F), water-spray quenched, and tempered at 595 °C (1100 °F). Mixed fine polygonal and acicular ferrite with tempered carbides. Nital plus picral. 200×

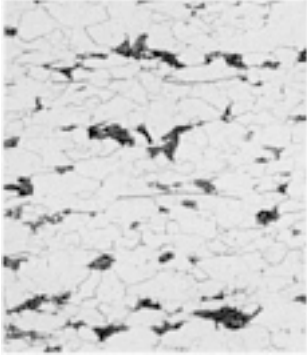


Fig. 50 ASTM A808, 8-mm ($\frac{5}{16}$ -in.) thick plate, as-rolled condition. Fine-grain, slightly elongated ferrite-pearlite. Several thin, elongated MnS inclusions are evident. Nital plus picral. 500×



Fig. 51 Same as [Fig. 50](#), but 50-mm (2-in.) thick as-rolled plate. Structure consists of polygonal ferrite-pearlite. Note effect of gage dimension on grain size (compare with [Fig. 50](#)). Nital plus picral. 500×

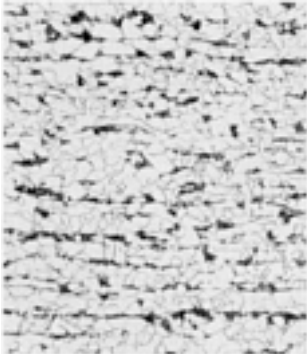


Fig. 52 API X60, 10-mm (0.4-in.) thick plate (skelp) for line-pipe, control-rolled. Fine-grain, polygonal ferrite; moderately banded pearlite. Nital plus picral. 200×

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