

Carbon and Low-Alloy Steel Castings: Metallographic Techniques and Microstructures

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Atlas of Microstructures for Carbon and Low-Alloy Steel Castings

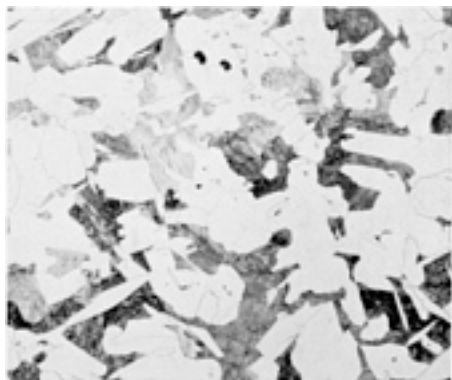


Fig. 1 ASTM A27 steel (0.25% C), 25 mm (1 in.) thick, in as-cast condition. Structure is proeutectoid ferrite (white) at prior austenite grain boundaries, and a mixture of ferrite and pearlite within grains. Nital. 100×

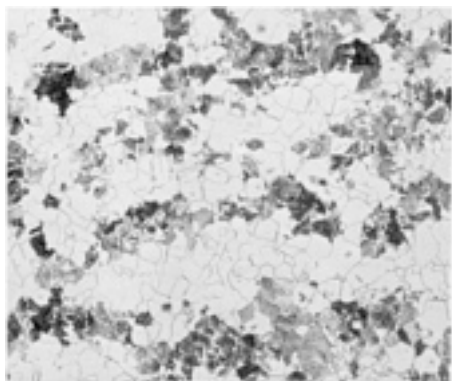


Fig. 2 Same steel as for [Fig. 1](#), 25 mm (1 in.) thick, annealed by austenitizing at 925 °C (1700 °F) for 1 h at temperature and furnace cooling. Ferrite (white) and pearlite (dark) outline the original dendritic structure. Nital. 100×

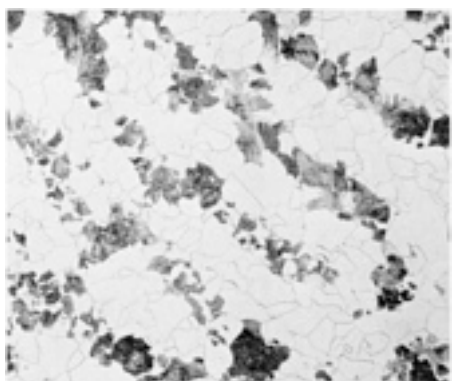


Fig. 3 Same steel as for [Fig. 1](#), 150 mm (6 in.) thick. Heat treatment was the same as for [Fig. 2](#). Structure is essentially the same as for [Fig. 2](#), but grains are coarser because of the greater thickness of the section. Nital. 100×



Fig. 4 Same steel as for [Fig. 1](#), 25 mm (1 in.) thick, quenched and tempered. Austenitized at 925 °C (1700 °F) for 1 h at temperature, quenched in mildly agitated water, tempered at 675 °C (1250 °F) for 2 h. Note fine-grained microstructure of ferrite (white) and pearlite. Nital. 200×

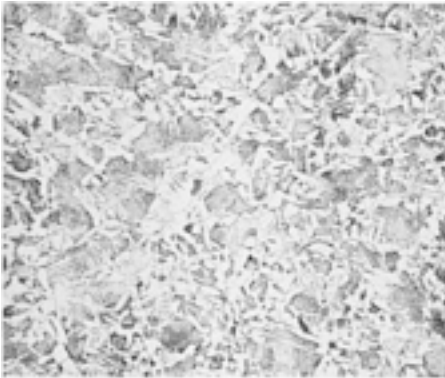


Fig. 5 Same steel as for [Fig. 1](#), 75 mm (3 in.) thick. Quenching and tempering treatment was the same as for [Fig. 4](#). The microstructure is nearly the same as for [Fig. 4](#), but slightly coarser. See [Fig. 6](#) for the structure of a thicker section after the same heat treatment. Nital. 200×

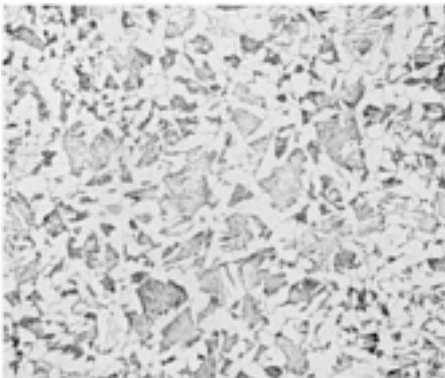


Fig. 6 Same steel as for [Fig. 1](#), 150 mm (6 in.) thick. Quenching and tempering treatment was the same as for [Fig. 4](#). The microstructure consists of the same constituents as [Fig. 4](#) and [5](#), but grains are significantly coarser because of the greater thickness of the section. Nital. 200×



Fig. 7 ASTM A27 steel, grade 70-36 (0.26% C, 0.71 % Mn), 25-mm (1-in.) cube, normalized by austenitizing at 1205 °C (2200 °F) for 30 min and air cooling. Widmanstätten pattern of proeutectoid ferrite in a matrix of ferrite and pearlite. 4% Nital. 250×



Fig. 8 ASTM A27 steel, grade 70-36 (0.30 to 0.40% C), 25 mm (1 in.) thick, as cast. Ferrite (white) and pearlite (dark). Higher carbon content than that of steel in [Fig. 1](#) results in a greater proportion of pearlite. Nital. 250×

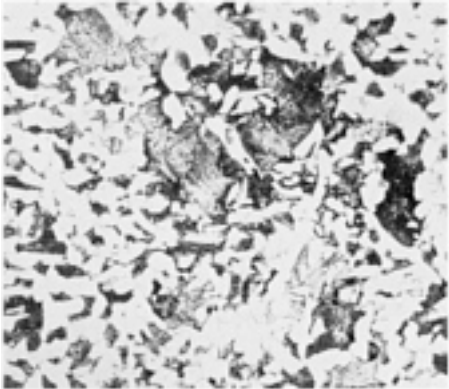


Fig. 9 Same steel as for [Fig. 8](#), 25 mm (1 in.) thick, but after being normalized by austenitizing at 900 °C (1650 °F) for 1 h and air cooling. Structure consists of ferrite (white constituent) and pearlite (dark constituent). Nital. 250×

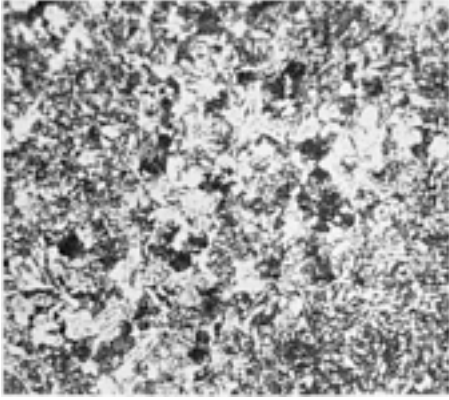


Fig. 10 Same steel as for [Fig. 8](#), 25 mm (1 in.) thick, quenched and tempered. Austenitized at 900 °C (1650 °F) for 1 h, water quenched, tempered at 620 °C (1150 °F) for 2 h. Structure is tempered martensite and ferrite (white). Nital. 250×

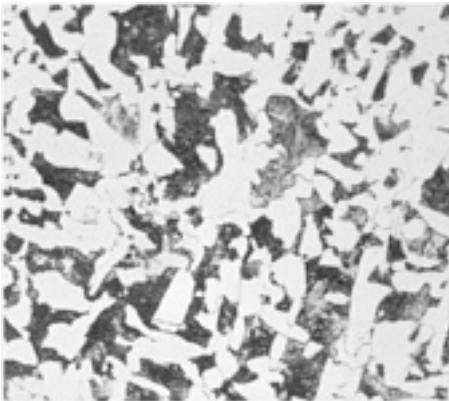


Fig. 11 Same steel as for [Fig. 8](#), 75 mm (3 in.) thick, but after being normalized by austenitizing at 900 °C (1650 °F) for 3 h and air cooling. The structure consists of pearlite (dark constituent) and ferrite (light constituent). Nital. 250×

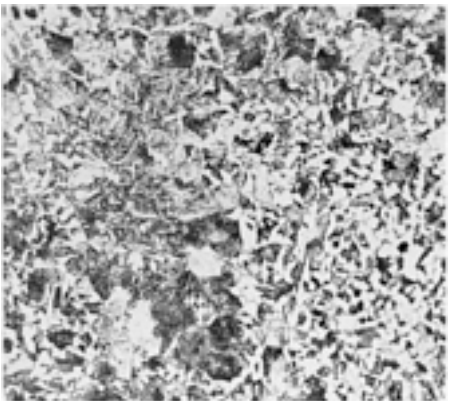


Fig. 12 Same steel as for [Fig. 8](#), 75 mm (3 in.) thick, quenched and tempered. Austenitized at 900 °C (1650 °F) for 3 h, water quenched, tempered at 620 °C (1150 °F) for 4 h. Structure: tempered martensite, pearlite, and ferrite. Nital. 250×

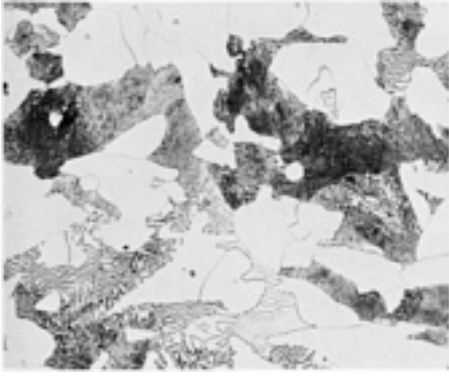


Fig. 13 Same steel as for [Fig. 8](#), 150 mm (6 in.) thick, normalized by austenitizing at 900 °C (1650 °F) for 6 h and air cooling. The microstructure consists of lamellar pearlite (gray and black) and ferrite (white). Nital. 250×

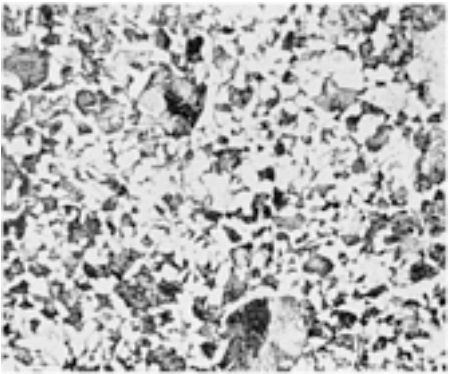


Fig. 14 Same steel as for [Fig. 8](#), 150 mm (6 in.) thick, quenched and tempered. Austenitized at 900 °C (1650 °F) for 6 h, water quenched, tempered at 620 °C (1150 °F) for 6 h. Structure is fine pearlite and ferrite (white). Nital. 250×



Fig. 15 ASTM A148 steel, grade 90-60 (0.30% C, 1.65% Mn), 25 by 25 by 13 mm (1 by 1 by 0.5 in.), in the as-cast condition. The microstructure consists of ferrite (white) in a matrix of pearlite (dark). 4% nital. 100×

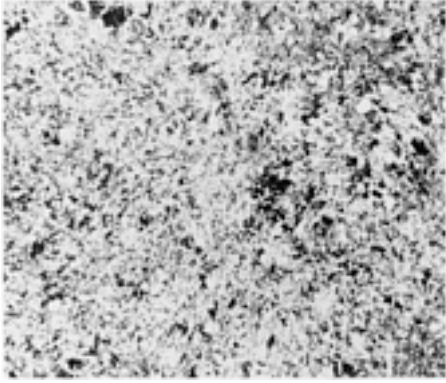


Fig. 16 Same steel and size as for [Fig. 15](#), normalized by austenitizing at 900 °C (1650 °F) for 20 min and air cooling. Structure: a fine-grained aggregate of ferrite and pearlite. 4% nital. 100×

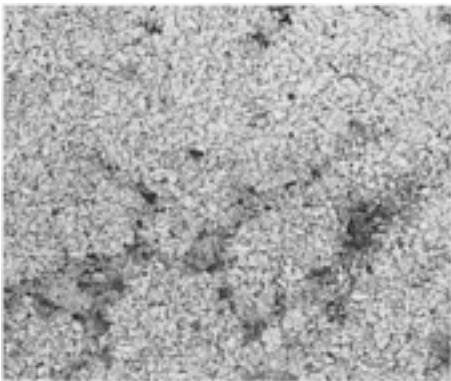


Fig. 17 ASTM A148 steel, grade 90-60 (0.27% C, 0.80% Mn, 0.51 % Si, 0.35% Mo), 25 mm (1 in.) thick, normalized and tempered. Austenitized at 925 °C (1700 °F) for 1 h, air cooled, tempered at 705 °C (1300 °F) for 3 h. Structure is fine-grained ferrite and pearlite. 5% nital. 100×

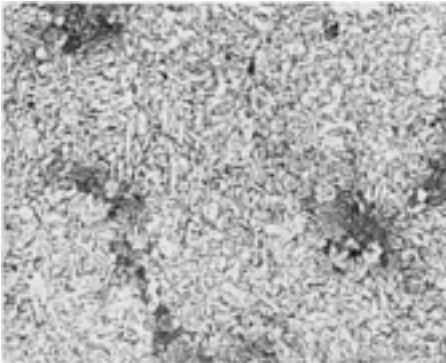


Fig. 18 Same steel as for [Fig. 17](#), 150 mm (6 in.) thick, normalized and tempered. Austenitized at 925 °C (1700 °F) for 6 h, air cooled, tempered at 705 °C (1300 °F) for 4 h. Structure: fine-grained aggregate of ferrite and pearlite. Note dendritic segregation of carbon and manganese. 5% nital. 100×

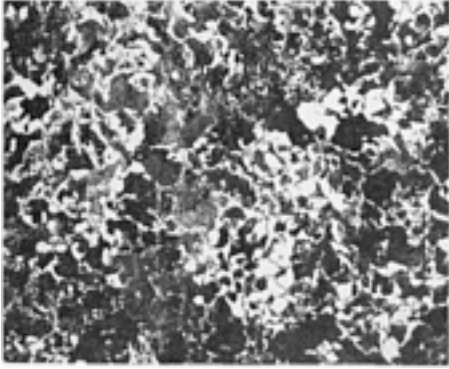


Fig. 19 ASTM A148 steel (0.45% C), 75 mm (3 in.) thick, annealed by austenitizing at 900 °C (1650 °F) for 5 h and furnace cooling to room temperature in 10 h. Structure consists of blocky ferrite and ferrite at prior austenite grain boundaries in a matrix of pearlite (dark). 5% nital. 100×

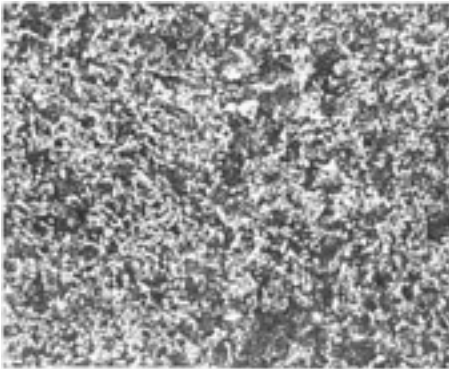


Fig. 20 Same steel as for [Fig. 19](#), 150 mm (6 in.) thick, quenched and tempered. Austenitized at 900 °C (1650 °F) for 3 h to temperature and held 5 h, water quenched, tempered at 595 °C (1100 °F) for 4 h to temperature and held 6 h, air cooled. Very fine ferrite and spheroidized pearlite. 5% nital. 100×



Fig. 21 ASTM A148 steel, grade 105-85 (0.27% C, 0.80% Mn, 0.51 % Si, 0.35% Mo), 150 mm (6 in.) thick, quenched and tempered. Austenitized at 925 °C (1700 °F) for 4 h, water quenched, tempered at 650 °C (1200 °F) for 4 h. Proeutectoid ferrite (white) in a matrix of tempered martensite. 5% nital. 500×

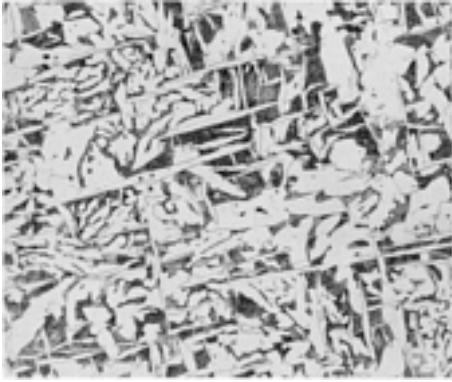


Fig. 22 ASTM A216 steel, grade WCA (0.21 % C, 0.60% Mn, 0.49% Si), 25 mm (1 in.) thick, as-cast. The microstructure consists of pearlite (dark constituent), blocky ferrite, and Widmanstätten platelets of ferrite. 2% nital. 100×

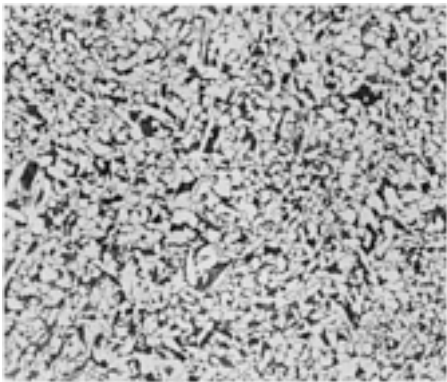


Fig. 23 Same steel as for [Fig. 22](#), 25 mm (1 in.) thick, normalized and tempered. Austenitized at 925 °C (1700 °F) for 1 h, air cooled, tempered at 705 °C (1300 °F) for 3 h. The structure consists of fine pearlite in a matrix of ferrite (white). 2% nital. 100×

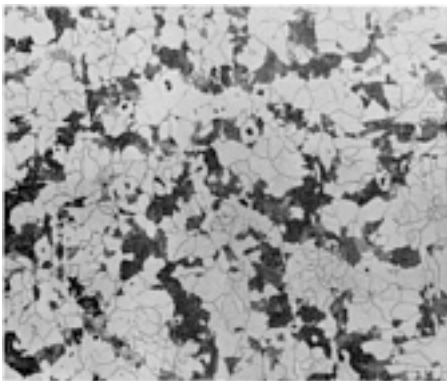


Fig. 24 Same steel as for [Fig. 22](#), 25 mm (1 in.) thick, annealed by austenitizing at 925 °C (1700 °F) for 1 h, and furnace cooling. Structure consists of ferrite (light) and pearlite (dark). Pattern of pearlite reflects primary dendritic segregation of carbon and manganese. 2% nital. 100×

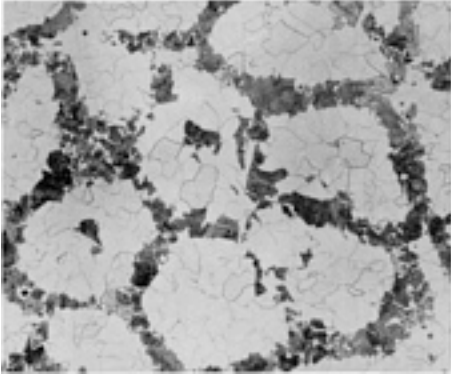


Fig. 25 ASTM A216 steel, grade WCA (0.21 % C, 0.60% Mn, 0.49% Si), 75 mm (3 in.) thick, annealed by austenitizing at 925 °C (1700 °F) for 6 h, and furnace cooling. Same structure as [Fig. 24](#), but "cell" size of carbon and manganese segregation is larger, because the section is thicker. 2% nital. 100×

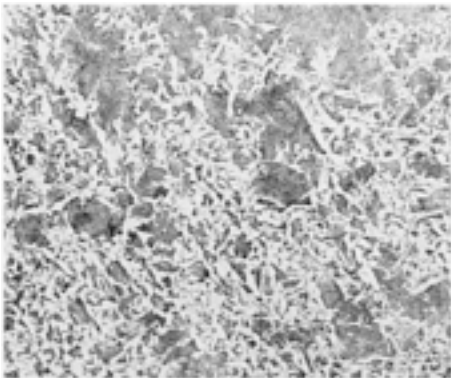


Fig. 26 Same steel as for [Fig. 25](#), 75 mm (3 in.) thick, quenched and tempered. Austenitized at 925 °C (1700 °F) for 3 h, water quenched, tempered at 650 °C (1200 °F) for 4 h. Structure consists of fine pearlite and probably some upper bainite (dark) in a matrix of ferrite (white). 2% nital. 100×

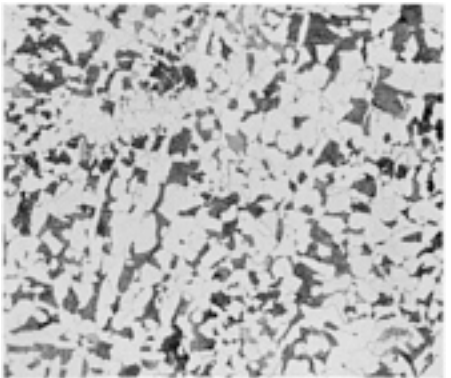


Fig. 27 Same steel as for [Fig. 25](#), 150 mm (6 in.) thick, normalized and tempered. Austenitized at 925 °C (1700 °F) for 6 h, air cooled, tempered at 705 °C (1300 °F) for 4 h. Structure consists of fine pearlite in a matrix of blocky ferrite (light) with platelets of Widmanstätten ferrite. 2% nital. 100×

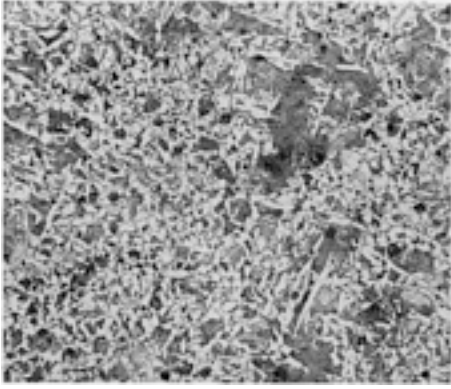


Fig. 28 Same steel as for [Fig. 25](#), 150 mm (6 in.) thick, quenched and tempered. Austenitized at 925 °C (1700 °F) for 6 h, water quenched, tempered at 650 °C (1200 °F) for 4 h. Structure is fine-grained ferrite with some platelets of Widmanstätten ferrite and fine pearlite (dark). 2% nital. 100×

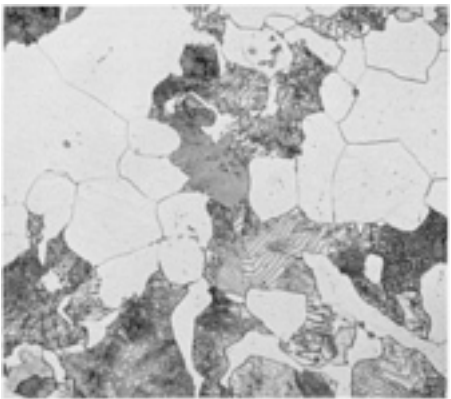


Fig. 29 ASTM A216, grade WCB (0.27% C), 25 mm (1 in.) thick, annealed by austenitizing at 870 °C (1600 °F) for 8 h and furnace cooling. Structure consists of blocky pearlite (dark) and blocky ferrite (white). 2% nital. 500×

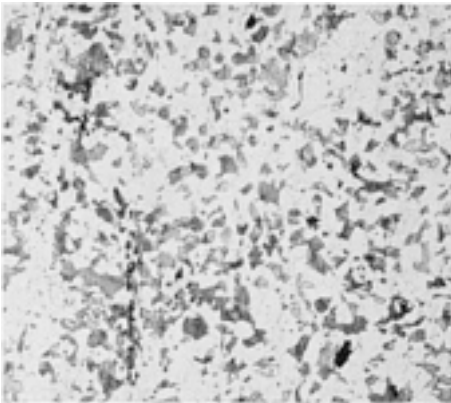


Fig. 30 Same steel as for [Fig. 29](#), 75 mm (3 in.) thick, normalized by austenitizing at 925 °C (1700 °F) and air cooling. Structure consists of fine pearlite in a matrix of ferrite (light). 3% nital. 75×

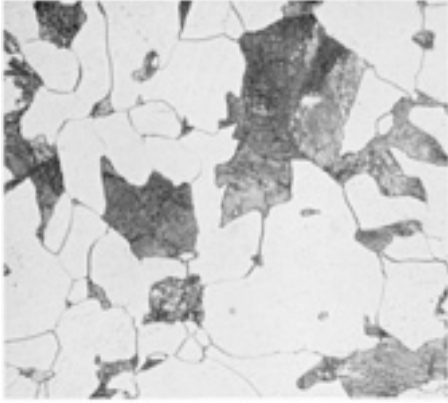


Fig. 31 Same steel and heat treatment as for [Fig. 30](#), but at a higher magnification. White grains (note distinct boundaries) are blocky ferrite; dark areas are fine, lamellar pearlite. 2% nital. 500×

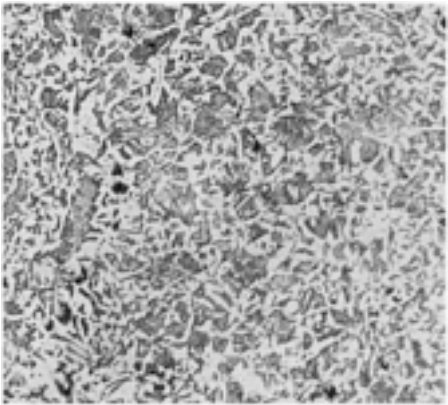


Fig. 32 Same steel as for [Fig. 29](#), 75 mm (3 in.) thick, as-quenched condition. Austenitized at 925 °C (1700 °F) and quenched in oil. The structure consists of fine pearlite in a matrix of ferrite. 3% nital. 75×

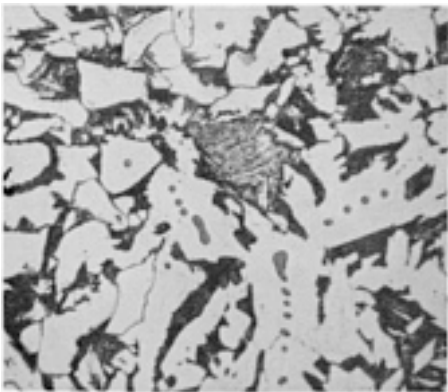


Fig. 33 ASTM A216, grade WCB (0.27% C) 75 mm (3 in.) thick, heat treated as for [Fig. 32](#), but shown at higher magnification. Fine pearlite in a ferrite matrix. Note MnS inclusions (globular). 2% nital. 500×

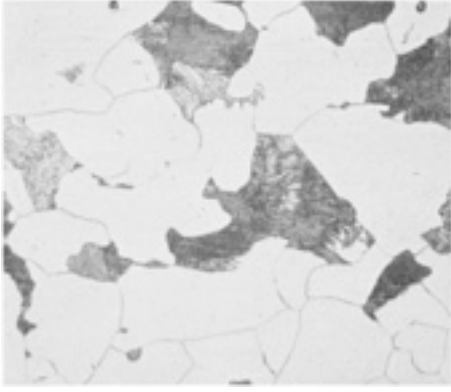


Fig. 34 Same steel as for [Fig. 33](#), 150 mm (6 in.) thick, normalized by austenitizing at 925 °C (1700 °F) and air cooling. Structure: fine and coarse pearlite in a coarse-grained ferrite matrix. 2% nital. 500×



Fig. 35 Same steel as for [Fig. 33](#), 150 mm (6 in.) thick, in the as-quenched condition. Austenitized at 925 °C (1700 °F) and oil quenched. Pearlite (dark), randomly dispersed in ferrite (white). Note the gray MnS inclusion at the left. 2% nital. 500×

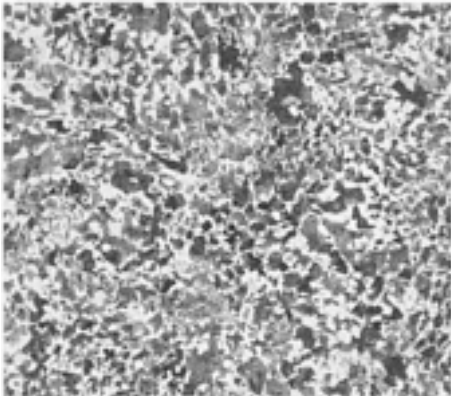


Fig. 36 Cast steel with 0.45% C, 0.70% Mn, 0.40% Si, normalized by austenitizing at 955 °C (1750 °F) for 30 min and cooling in air. Structure is a mixture of ferrite (white) and pearlite (dark), which is not well resolved. 4% nital. 100×

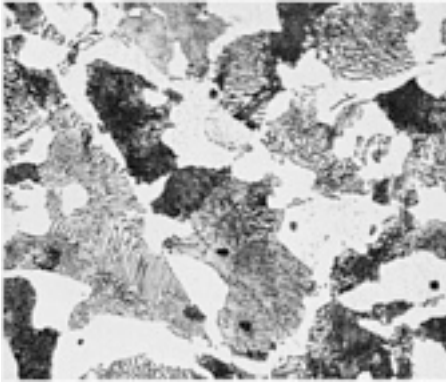


Fig. 37 Same area as for [Fig. 36](#), but at a still higher magnification. Parallel plate structure of the pearlite is now well resolved. A magnification of 500× (as here) is often best for this structure and grain size. 4% nital.

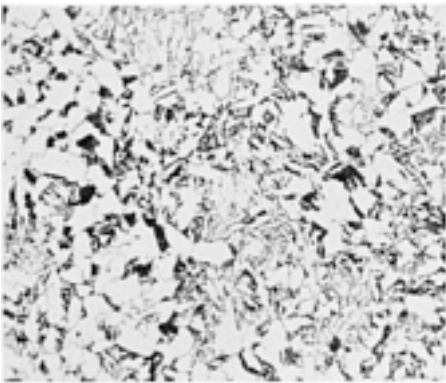


Fig. 38 ASTM A487 steel, class 2, 25 mm (1 in.) thick, normalized by austenitizing at 900 °C (1650 °F) and air cooling. The structure consists of pearlite and ferrite. See [Fig. 39](#) and [40](#) for influence of alternate heat treatment and section size. 4% nital. 250×

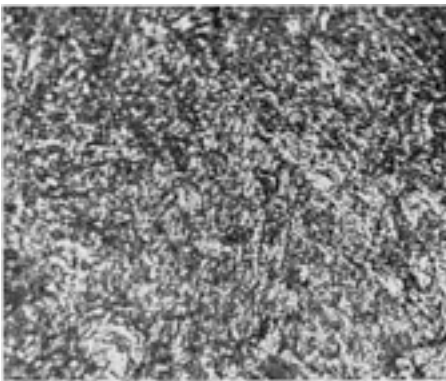


Fig. 39 ASTM A487 steel, 25 mm (1 in.) thick, normalized by austenitizing at 955 °C (1750 °F) for 3 h, held 5 h, air cooled, tempered at 660 °C (1225 °F) for 4 h to temperature, and held 6 h. The lighter areas are fine ferrite; the darker areas are probably bainite delineating prior austenite grain boundaries. 5% nital. 1000×

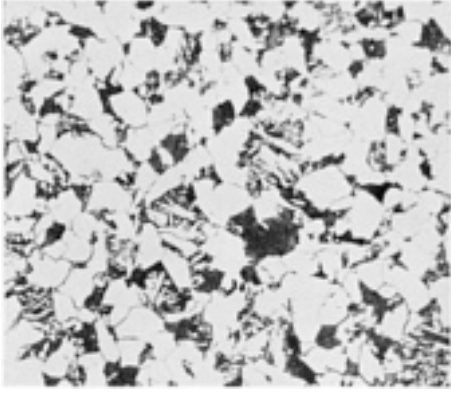


Fig. 40 Same steel as for [Fig. 38](#), but 75 mm (3 in.) thick, normalized by austenitizing at 900 °C (1650 °F) and cooling in air. The structure consists of ferrite (light constituent) and pearlite (dark constituent). Some martensite may be present in dark areas of the structure. 4% nital. 250×

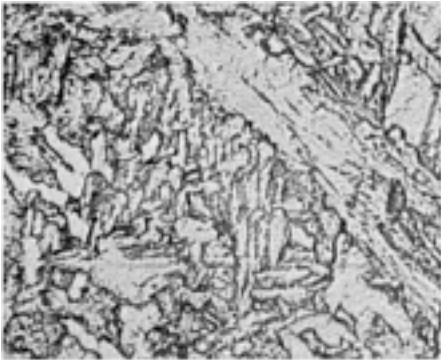


Fig. 41 ASTM A352 steel, grade LC3, 25 mm (1 in.) thick. Austenitized at 900 °C (1650 °F) for 3 h to temperature, held 5 h, water quenched, tempered at 620 °C (1150 °F) for 4 h to temperature, and held 6 h. The microstructure consists of fine, acicular ferrite (light constituent), some pearlite (dark), and minute particles of cementite. 5% nital. 1000×

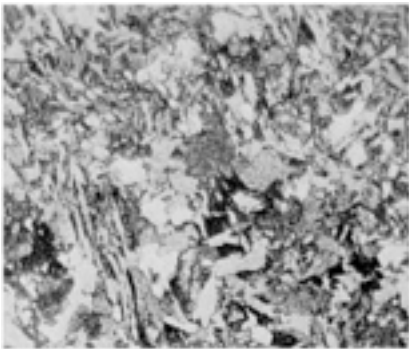


Fig. 42 Aluminum deoxidized low-alloy steel casting, 50 mm (2 in.) thick, normalized at 900 °C (1650 °F) for 30 min, air cooled, then tempered at 565 °C (1050 °F) for 2 h, air cooled. Fine-grained uniform ferrite and pearlite with bainite transformed during moderately rapid cooling rate. 4% nital. 500×. (L.L. Bright)

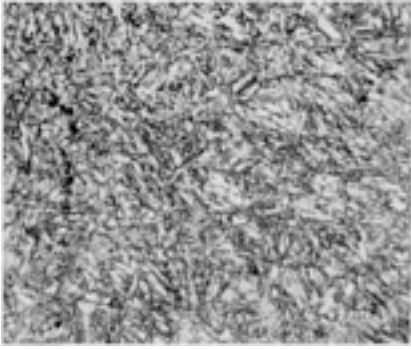


Fig. 43 Same steel as for [Fig. 42](#), 50 mm (2 in.) thick, quenched and tempered. Austenitized at 900 °C (1650 °F) for 30 min, water quenched, and tempered at 565 °C (1050 °F) for 2 h, air cooled. Structure consists of tempered martensite-bainite. 4% nital. 500×. (L.L. Bright)

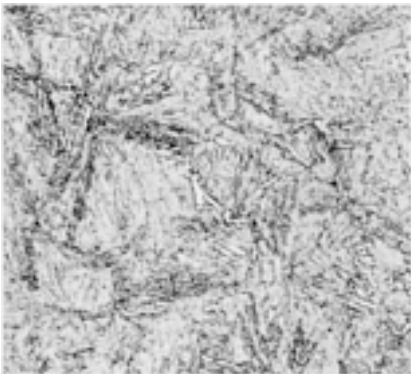


Fig. 44 Low-alloy cast steel (0.28C-0.55Mn-1.3Si-1.00Ni-1.5Cr-0.40Mo), normalized at 925 °C (1700 °F), hardened by water quench from 900 °C (1650 °F), and tempered at 290 °C (550 °F) to ~500 HB. Tempered martensite with some bainite. 2% nital. 100×. (D. Subramanyam)



Fig. 45 Low-alloy cast steel (0.32C-0.85Mn-0.80Ni-0.80Cr-0.32Mo), annealed at 870 °C (1600 °F). Structure consists of ferrite (light areas) and pearlite (dark areas). 5% nital. 100×. (G.J. Wiskow)

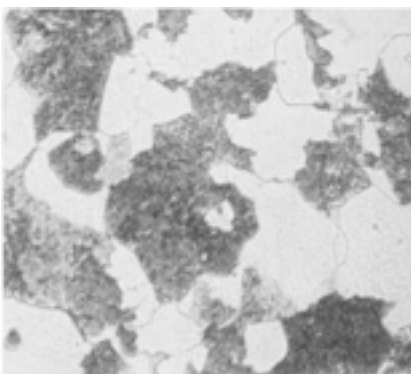


Fig. 46 Same low-alloy cast steel as for [Fig. 45](#), annealed at 870 °C (1600 °F), except at higher

magnification. Structure consists of ferrite (light areas) and pearlite (dark areas). 5% nital. 400×.
(G.J. Wiskow)

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