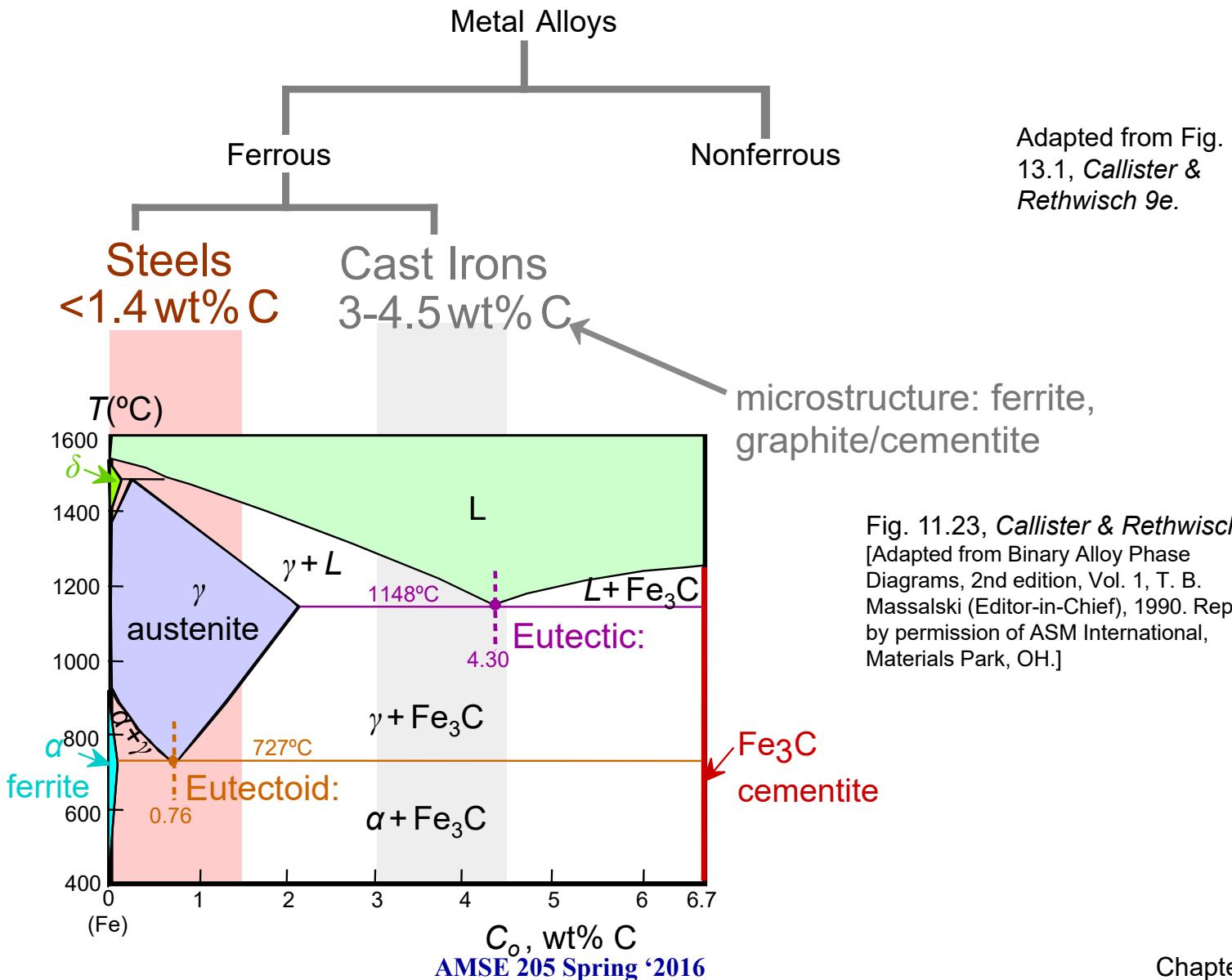


Chapter 13: Properties and Applications of Metals

ISSUES TO ADDRESS...

- How are metal alloys classified and what are their common applications?
- What are the microstructure and general characteristics of cast irons?
- What are the distinctive physical and mechanical properties of nonferrous alloys?

Classification of Metal Alloys



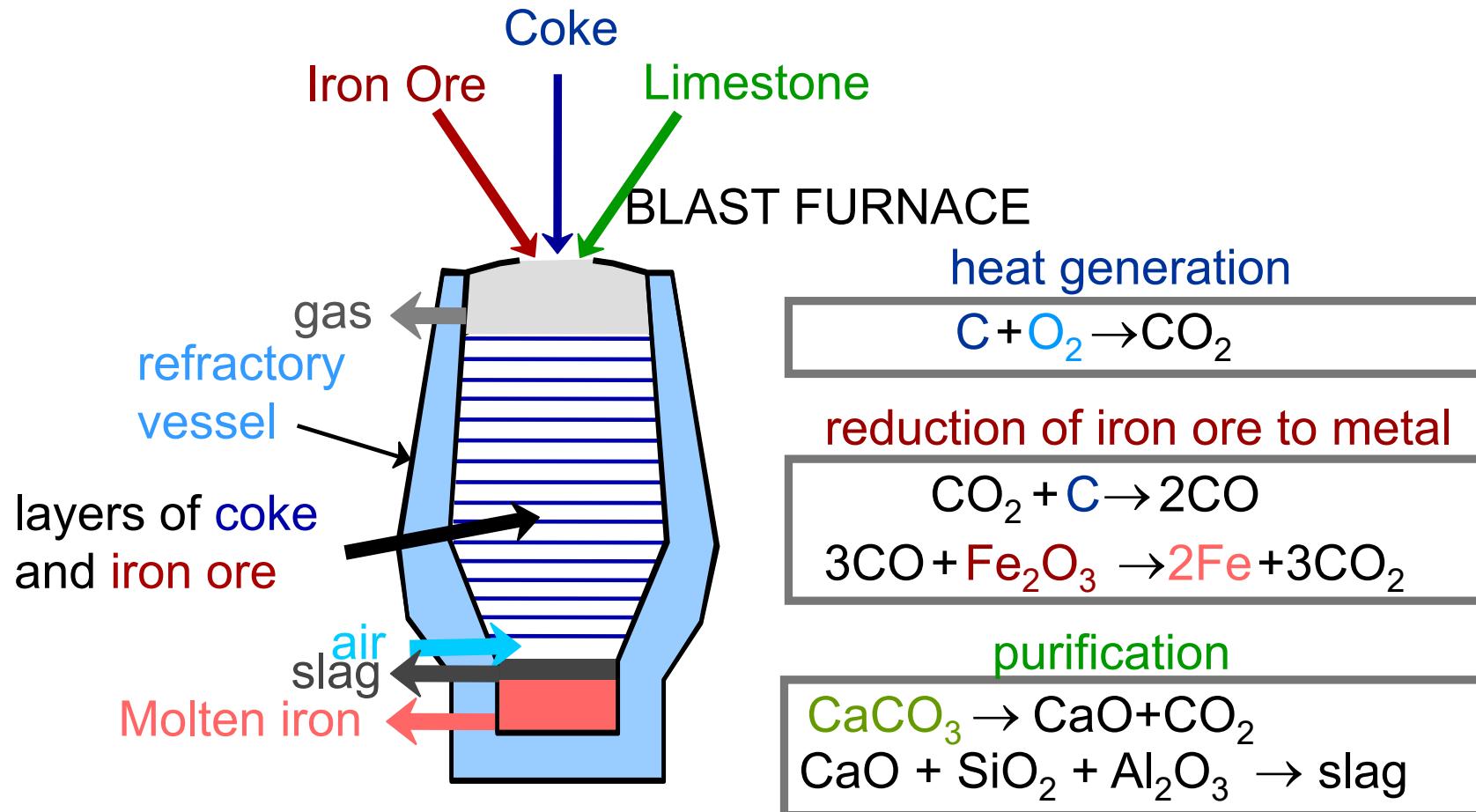
Steels

	Low Alloy			High Alloy			
	low carbon <0.25 wt% C	Med carbon 0.25-0.6 wt% C	high carbon 0.6-1.4 wt% C				
Name	plain	HSLA	plain	heat treatable	plain	tool	stainless
Additions	none	Cr, V Ni, Mo	none	Cr, Ni Mo	none	Cr, V, Mo, W	Cr, Ni, Mo
Example	1010	4310	1040	4340	1095	4190	304, 409
Hardenability	0	+	+	++	++	+++	varies
TS	-	0	+	++	+	++	varies
EL	+	+	0	-	-	--	++
Uses	auto struc. sheet	bridges towers press. vessels	crank shafts bolts hammers	pistons gears wear applic.	wear applic.	drills saws dies	high T applic. turbines furnaces Very corros. resistant

increasing strength, cost, decreasing ductility

Based on data provided in Tables 13.1(b), 14.4(b), 13.3, and 13.4, Callister & Rethwisch 9e.

Refinement of Steel from Ore



Ferrous Alloys

Iron-based alloys

- Steels
- Cast Irons

Nomenclature for steels (AISI/SAE)

10xx Plain Carbon Steels

11xx Plain Carbon Steels (resulfurized for machinability)

15xx Mn (1.00 - 1.65%)

40xx Mo (0.20 ~ 0.30%)

43xx Ni (1.65 - 2.00%), Cr (0.40 - 0.90%), Mo (0.20 - 0.30%)

44xx Mo (0.5%)

where xx is wt% C × 100

example: 1060 steel – plain carbon steel with 0.60 wt% C

Stainless Steel >11% Cr

Cast Irons

- Ferrous alloys with > 2.1 wt% C
 - more commonly 3 - 4.5 wt% C
- Low melting – relatively easy to cast
- Generally brittle
- Cementite decomposes to ferrite + graphite
$$\text{Fe}_3\text{C} \rightarrow 3 \text{ Fe } (\alpha) + \text{C } (\text{graphite})$$
 - generally a slow process

Fe-C True Equilibrium Diagram

Graphite formation promoted by

- Si > 1 wt%
- slow cooling

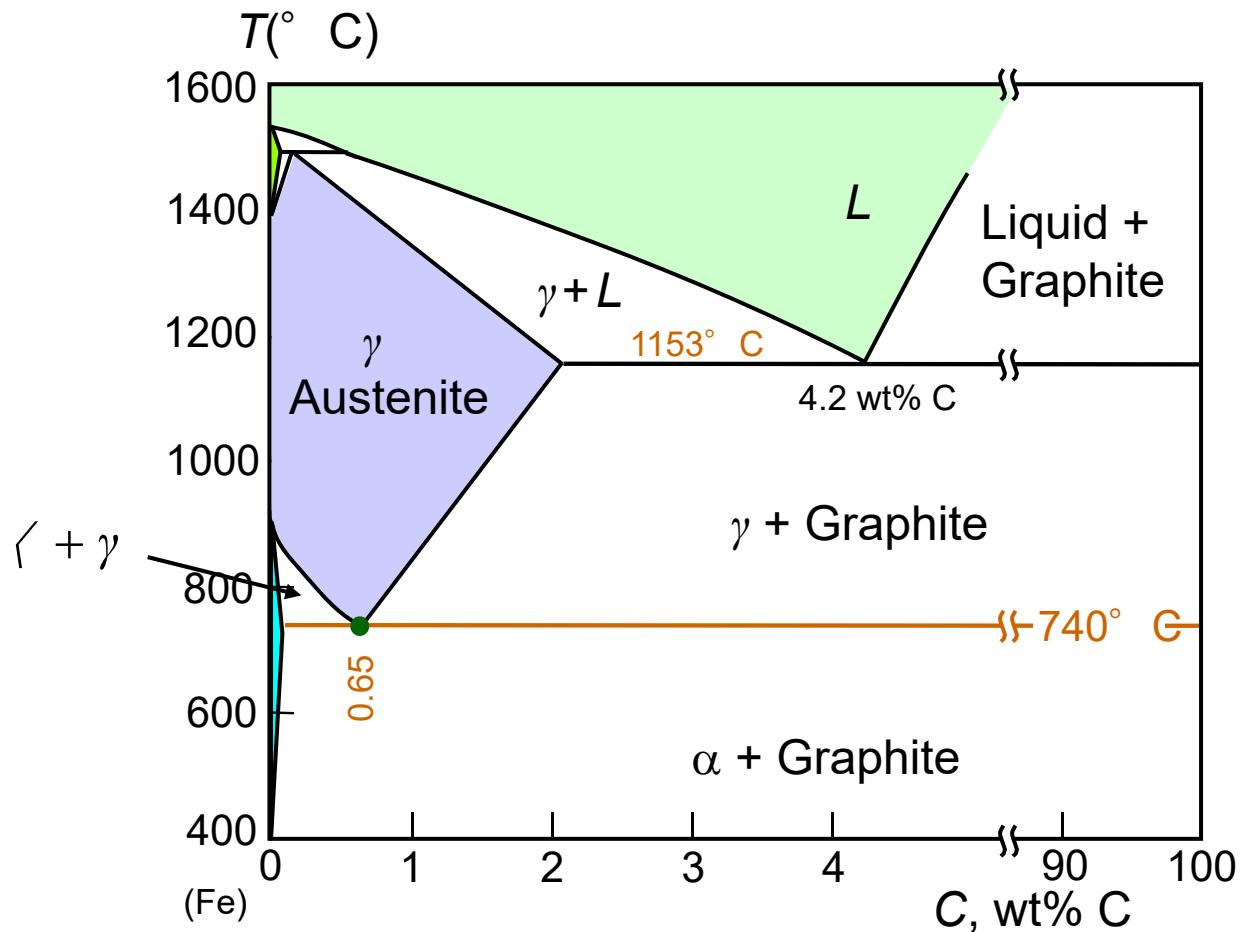


Fig. 13.2, Callister & Rethwisch 9e.
[Adapted from *Binary Alloy Phase Diagrams*, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]

Types of Cast Iron

Gray iron

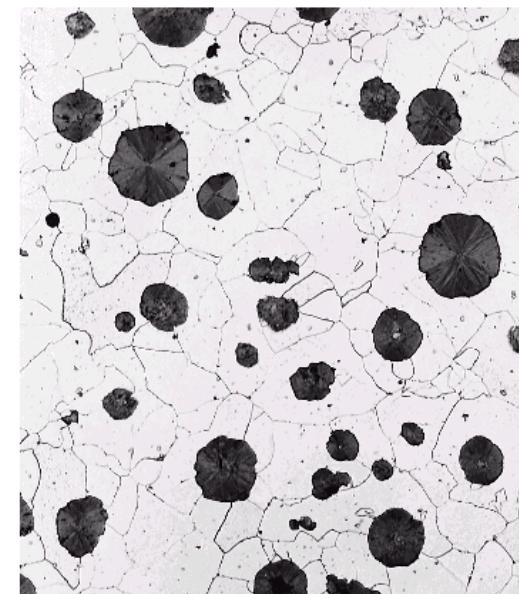
- graphite flakes
- weak & brittle in tension
- stronger in compression
- excellent vibrational dampening
- wear resistant

Figs. 13.3(a) & (b),
*Callister &
Rethwisch 9e.*
[Courtesy of C. H.
Brady and L. C. Smith,
National Bureau of
Standards, Washington,
DC (now the National
Institute of Standards
and Technology,
Gaithersburg, MD)]



Ductile iron

- add Mg and/or Ce
- graphite as nodules not flakes
- matrix often pearlite – stronger but less ductile

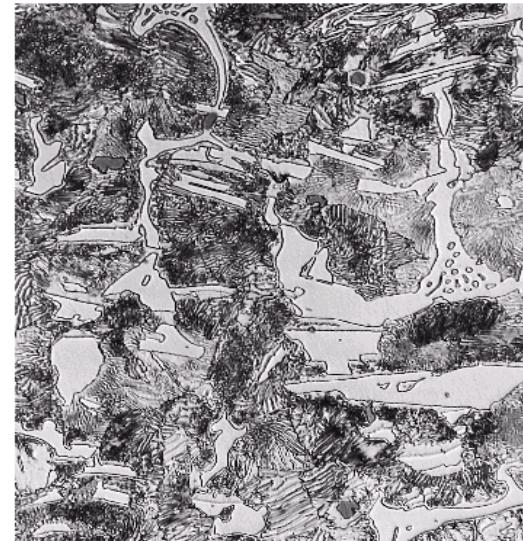


Types of Cast Iron (cont.)

White iron

- < 1 wt% Si
- pearlite + cementite
- very hard and brittle

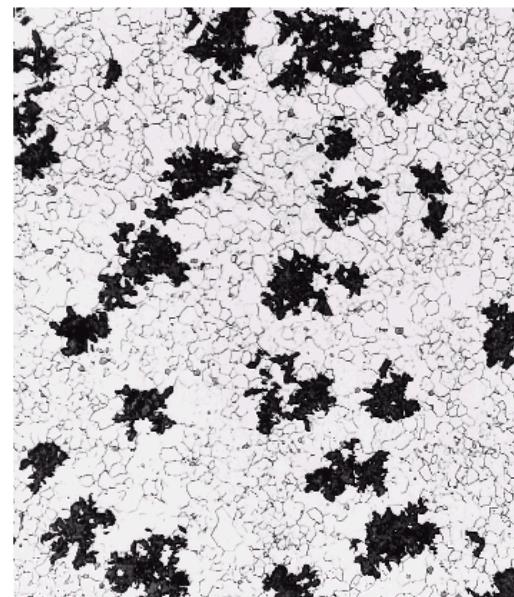
Figs. 13.3(c) & (d),
Callister &
Rethwisch 9e.



Courtesy of Amcast Industrial Corporation

Malleable iron

- heat treat white iron at 800-900°C
- graphite in rosettes
- reasonably strong and ductile

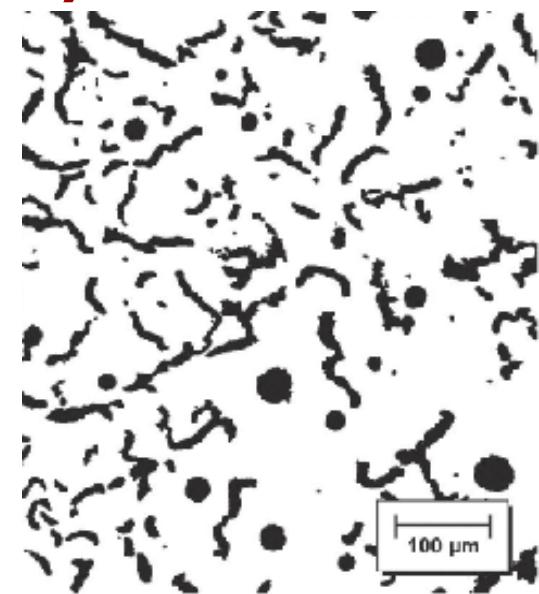


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Iron Castings Society, Des Plaines, IL

Types of Cast Iron (cont.)

Compacted graphite iron

- relatively high thermal conductivity
- good resistance to thermal shock
- lower oxidation at elevated temperatures

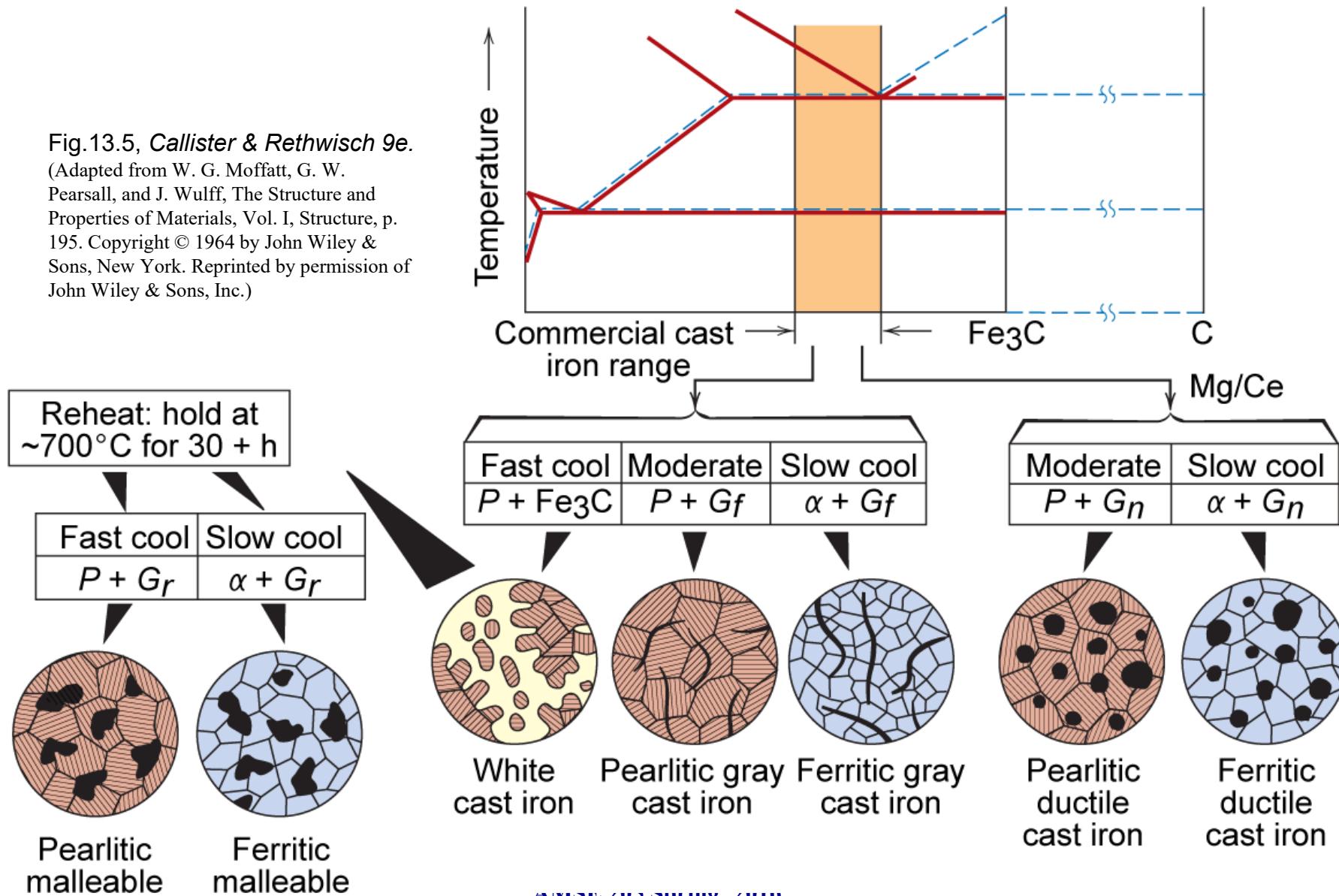


Courtesy of Sinter-Cast, Ltd.

Fig. 13.3(e), Callister & Rethwisch 9e.

Production of Cast Irons

Fig.13.5, Callister & Rethwisch 9e.
 (Adapted from W. G. Moffatt, G. W. Pearsall, and J. Wulff, The Structure and Properties of Materials, Vol. I, Structure, p. 195. Copyright © 1964 by John Wiley & Sons, New York. Reprinted by permission of John Wiley & Sons, Inc.)



Limitations of Ferrous Alloys

- 1) Relatively high densities
- 2) Relatively low electrical conductivities
- 3) Generally poor corrosion resistance

Nonferrous Alloys

- Cu Alloys

Brass: Zn is subst. impurity
(costume jewelry, coins,
corrosion resistant)

Bronze : Sn, Al, Si, Ni are
subst. impurities
(bushings, landing
gear)

Cu-Be:
precip. hardened
for strength

- Ti Alloys

-relatively low ρ : 4.5 g/cm³

vs 7.9 for steel

-reactive at high T 's

-space applic.

- Al Alloys

-low ρ : 2.7 g/cm³
-Cu, Mg, Si, Mn, Zn additions
-solid sol. or precip.
strengthened (struct.
aircraft parts
& packaging)

- Mg Alloys

-very low ρ : 1.7 g/cm³
-ignites easily
-aircraft, missiles

- Refractory metals

-high melting T 's
-Nb, Mo, W, Ta

- Noble metals

-Ag, Au, Pt
-oxid./corr. resistant

Summary

- Ferrous alloys:
 - steels
 - cast irons
- Non-ferrous alloys:
 - Cu, Al, Ti, and Mg alloys; refractory alloys; and noble metals