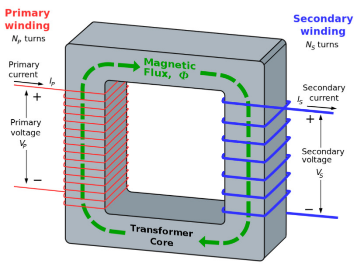
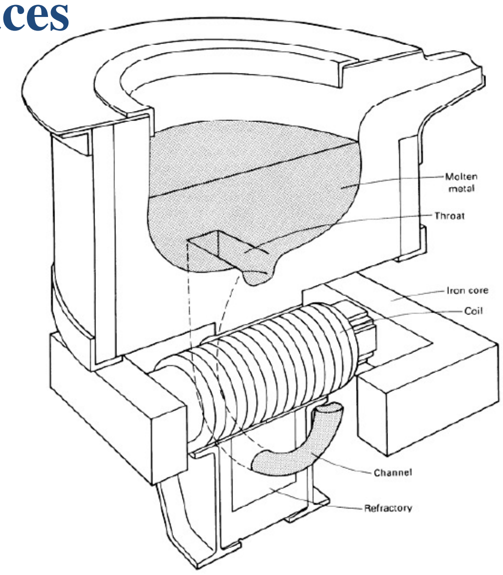
Channel Induction Furnace

Induction Furnaces

Transformer





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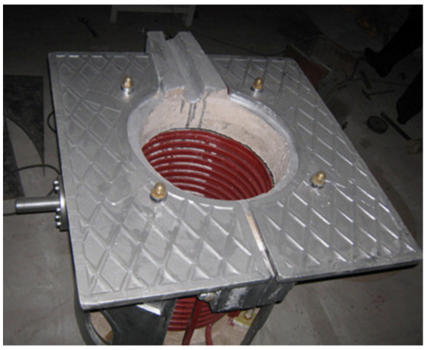
https://wikipedia.org

Fig. 2 A cross section of a channel-type induction furnace showing the water-cooled copper induction coil, which is located inside of a 360° loop formed by the throat and channel portion of the molten metal vessel. It is the channel portion of the loop, which serves as the secondary of the electrical circuit in which the copper coil is the primary.

Coreless Induction Furnace



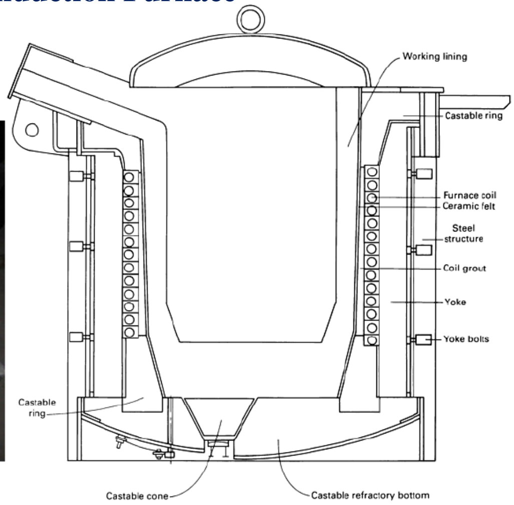


Fig. 1 A cross section of a coreless-type induction furnace showing water-cooled copper induction coil and key structural components. The entire molten metal bath (which serves as the secondary) is surrounded by the coil (the primary) that encircles the working lining.

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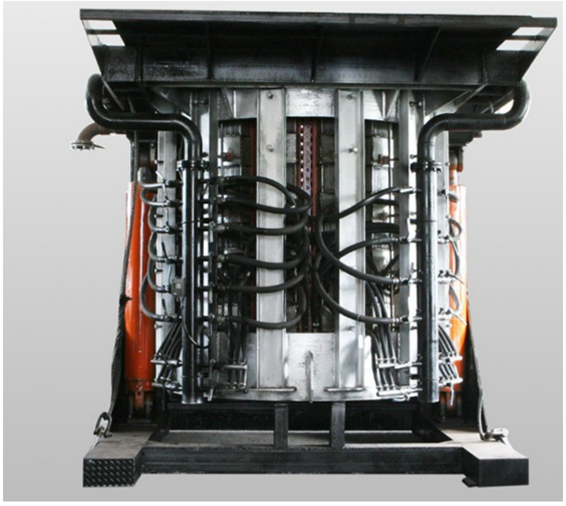
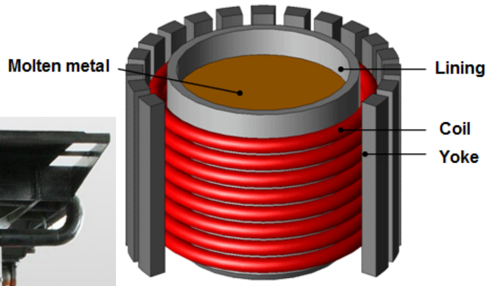
www.psr-magnagroup.com

Coreless Induction Furnace





https://www.jmag-international.com
http://www.semcgroup.com

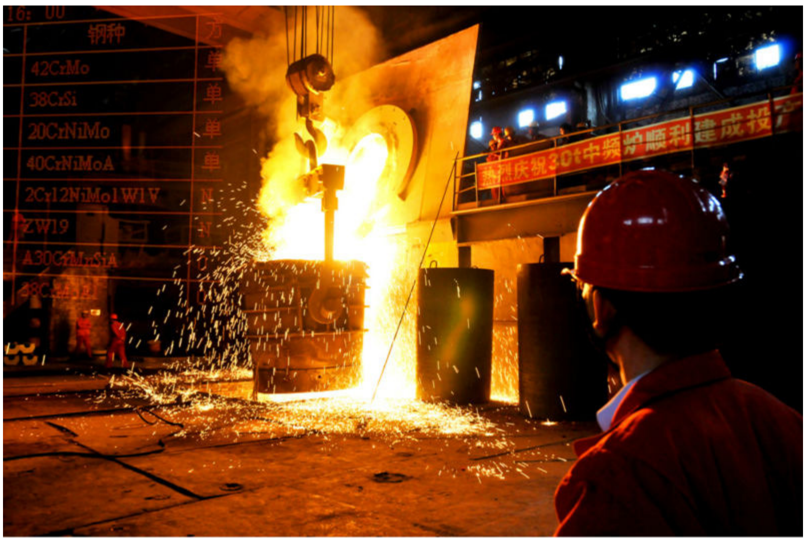
Coreless Induction Furnace

Atl-chatt.org

Coreless Induction Furnace

http://www.tradeindia.com/

Coreless Induction Furnace



http://www.induction-heaters.net/

Coreless Induction Furnace

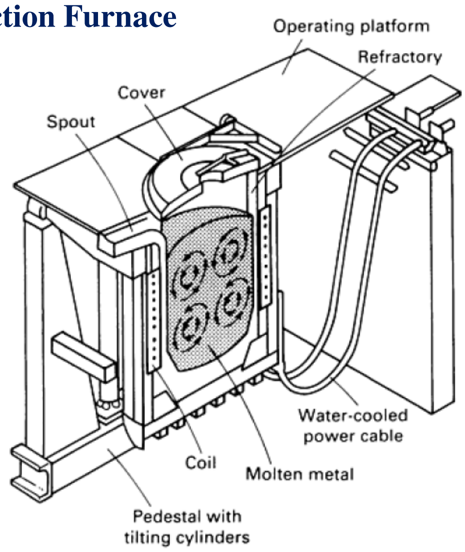


Fig. 3 A cross-sectional view of a coreless-type induction furnace illustrating four-quadrant stirring action, which aids in producing homogeneous melt

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Channel Induction Furnace

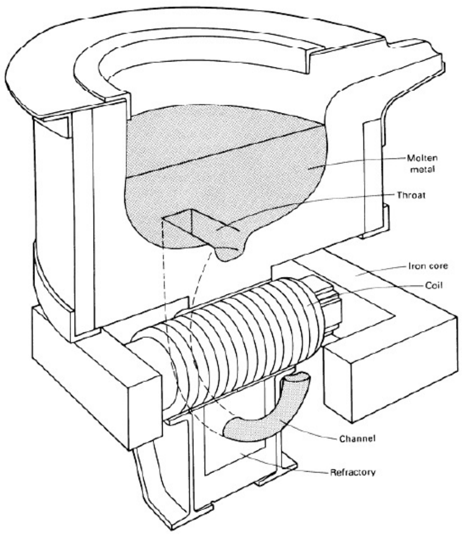

Fig. 2 A cross section of a channel-type induction furnace showing the water-cooled copper induction coil, which is located inside of a 360° loop formed by the throat and channel portion of the molten metal vessel. It is the channel portion of the loop, which serves as the secondary of the electrical circuit in which the copper coil is the primary.

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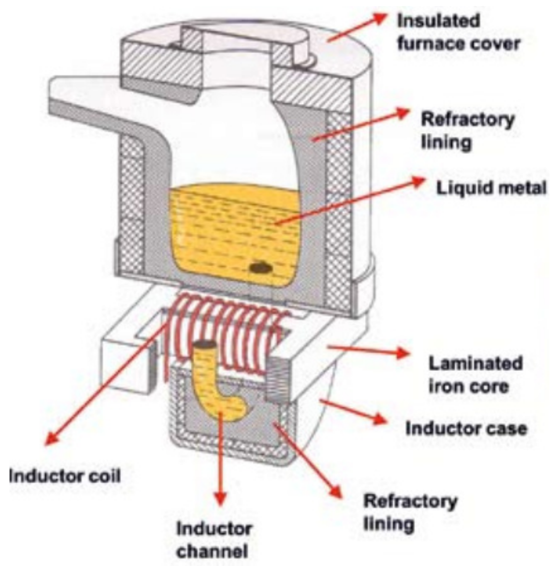
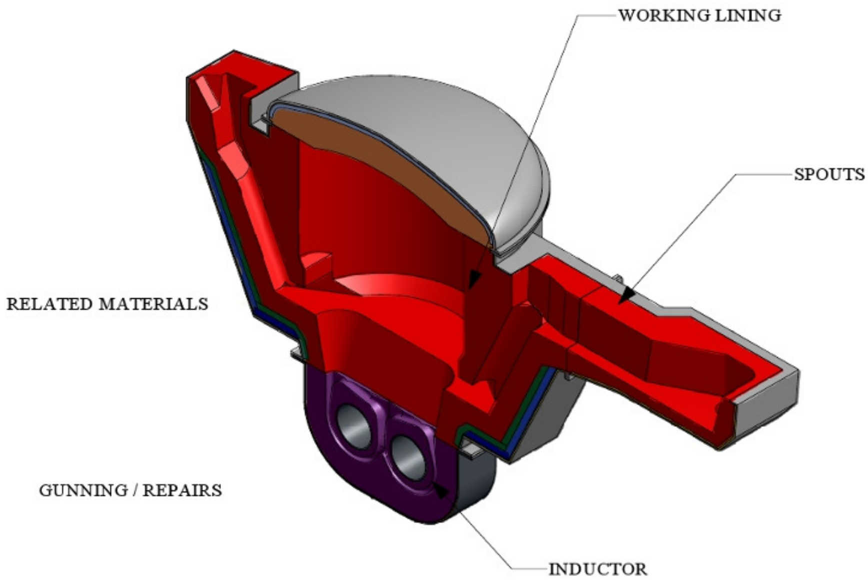
Channel Induction Furnace



http://www.marx-gmbh.de

Channel Induction Furnace (Pressurized)



http://www.alliedmineral.com

Channel Induction Furnace

http://www.erediscabini.com

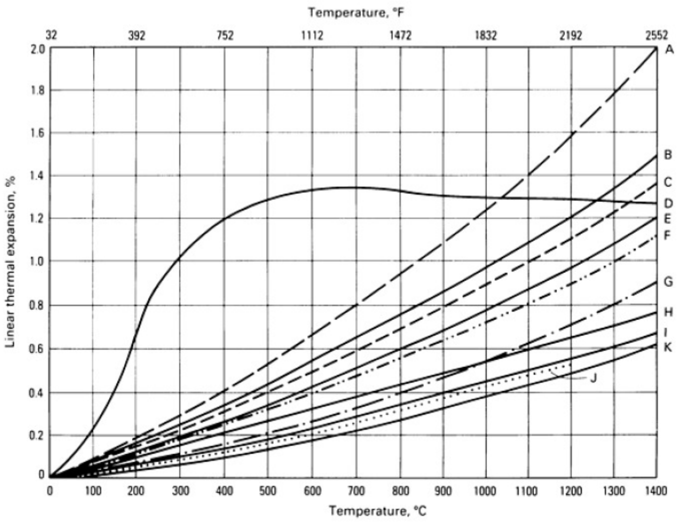


Fig. 7 Thermal expansion curves of various refractory brick oxide materials used for linings in induction furnaces: A, magnesia; B, chrome magnesia; C, chromite; D, silica; E, zirconia; F, corundum 99; G, corundum 90; H, fireclay; I, sillimanite; J, zircon; K, silicon carbide

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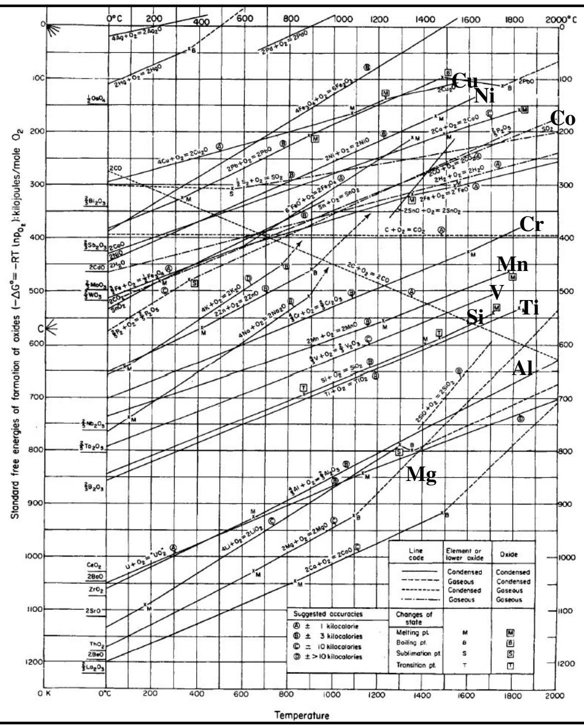

Charge calculation

Table 49

Carbon Content of Iron Versus Casting Wall Thickness

Wall thickness, mm	Carbon content, % in casting iron: into sand molds	into permanent molds: with cores	into permanent molds: without cores	Wall thickness, mm	Carbon content, % in casting iron: into sand molds	into permanent molds: with cores	into permanent molds: without cores
6-10	2.2-2.6	3.0-3.3	2.8-3.0	21-40	1.6-2.0	2.6-2.8	2.2-2.4
11-20	1.8-2.2	2.8-3.0	2.4-2.7	41-80	1.5-1.8	2.4-2.6	2.0-2.4

The mass of gates varies in the range from 20 to 80% for small castings, 15 to 25% for medium-size castings, and 5 to 15% for large castings.

An example of charge calculation by a trial-and-error method. The gray iron used for casting automotive parts must have the following composition: 3.2-3.4% C, 2.0-2.2% Si, 0.6-0.8% Mn, about 0.15% P and 0.12% S. The melting loss in the cupola is 15% Si and 20% Mn; the pickup of sulfur comes to 50%. The chemical composition of charge materials is given in Table 50. The mass of metal charge is 800 kg.

Composition of Charge Components, %

Component	C	Si	Mn	P	S
Pig iron:					
ЛК1	3.5	3.3	0.50	0.11	0.02
ЛК2	3.6	3.0	0.50	0.12	0.03
Foundry returns	3.3	2.1	0.70	0.10	0.09
Steel scrap	0.2	0.3	0.80	0.05	0.05
Briquetted iron chips	3.3	2.1	0.70	0.10	0.09

Pig iron:	Content, kg
ЛК1	200
ЛК2	120
Foundry returns	240
Steel scrap	120
Briquetted iron chips	120
Total	800

Calculation of the Contents of Elements in the Charge

Component	Mass		Element content				
	kg	%	C	Si	Mn	P	S
Pig iron							
ЛК1	200	25	0.25 × 3.5 = 0.875	0.25 × 3.3 = 0.825	0.25 × 0.5 = 0.125	0.25 × 0.11 = 0.027 5	0.25 × 0.02 = 0.005
ЛК2	120	15	0.15 × 3.6 = 0.540	0.15 × 3.3 (3.0) = 0.495 (0.45)	0.15 × 0.5 = 0.075	0.15 × 0.12 = 0.018	0.15 × 0.03 = 0.004 5
Foundry returns	240	30	0.30 × 3.3 = 0.990	0.3 × 2.1 = 0.630	0.3 × 0.7 = 0.210	0.30 × 0.10 = 0.03	0.30 × 0.09 = 0.027
Briquetted chips	120	15	0.15 × 3.3 = 0.495	0.15 × 0.1 (2.1) = 0.015 (0.315)	0.15 × 0.7 = 0.105	0.15 × 0.10 = 0.015	0.15 × 0.09 = 0.013 5
Steel scrap	120	15	0.15 × 0.20 = 0.03	0.15 × 0.30 = 0.045	0.15 × 0.8 = 0.120	0.15 × 0.05 = 0.0075	0.15 × 0.05 = 0.007 5
Total	800	100	2.93	2.01 (2.265)	0.635	0.098	0.057 5 + 0.028 7* = 0.086 2**

* Pickup of sulfur from coke is 50%.
** Sulfur content of iron to be melted will be below the specified value.

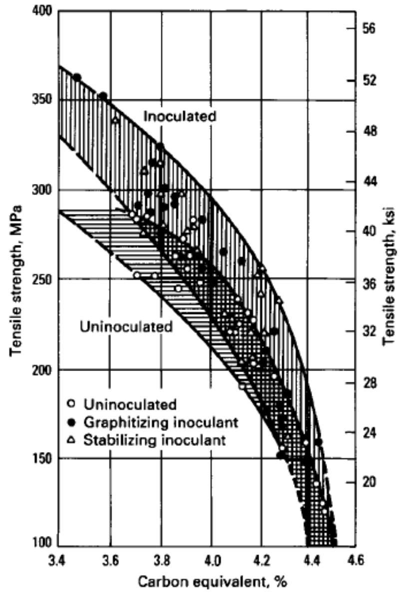

Fig. 6 Influence of inoculation on tensile strength of gray irons as a function of carbon equivalent for 30 mm (1.2 in.) diam bars. Source: Ref 7

ASM International, Alloying: Understanding the Basics, 2001

Table 2 Effects, levels, and sources of some trace elements in gray iron

Element	Trace level, %	Effects	Sources
Aluminum	≤0.03	Promotes hydrogen pinhole defects, especially when green sand molds are used and at levels above 0.005%. Neutralizes nitrogen	Deliberate addition, ferrous alloys, inoculants, scrap contaminated with aluminum components
Antimony	≤0.02	Promotes pearlite. Addition of 0.01% reduces the amount of ferrite sometimes found adjacent to cored surfaces	Vitreous enameled scrap, steel scrap, white metal bearing shells, deliberate addition
Arsenic	≤0.05	Promotes pearlite. Addition of 0.05% reduces the amount of ferrite sometimes found adjacent to cored surfaces	Pig iron, steel scrap
Bismuth	≤0.02	Promotes carbides and undesirable graphite forms that reduce tensile properties	Deliberate addition, bismuth-containing molds and core coatings
Boron	≤0.01	Promotes carbides, particularly in light-section parts. Effects become significant above about 0.001%	Deliberate addition, vitreous enameled scrap
Chromium	≤0.2	Promotes chill in thin sections	Alloy steel, chromium plate, some refined pig iron
Copper	≤0.3	Trace amounts have no significant effect and can be ignored	Copper wire, nonferrous alloys, steel scrap, some refined pig iron
Hydrogen	≤0.0004	Produces subsurface pinholes and (less often) fissures or gross blowing through a section. Mild chill promoter. Promotes inverse chill when insufficient manganese is present. Promotes coarse graphite	Damp refractories, mold materials, and additions
Lead	≤0.005	Results in Widmanstätten and "spiky" graphite, especially in heavy sections with high hydrogen. Can reduce tensile strength 50% at low levels (≥0.0004%). Promotes pearlite	Some vitreous enamels, paints, free-cutting steels, nonferrous alloys, terne plate, white metal, solder, some pig irons
Molybdenum	≤0.05	Promotes pearlite	Some refined pig iron, steel scrap
Nickel	≤0.01	Trace amounts have no major effect and can be ignored	Refined pig iron, steel scrap
Nitrogen	≤0.02	Compacts graphite and increases strength. Promotes pearlite. Increases chill. Can cause pinhole and fissure defects. Can be neutralized by aluminum or titanium	Coke, carburizers, mold and core binders, some ferroalloys, steel scrap
Tellurium	≤0.003	Not usually found, but a potent carbide former	Free-cutting brasses, mold and core coatings, deliberate addition
Tin	≤0.15	Strong pearlite promoter; sometimes deliberately added to promote pearlitic structures	Solder, steel scrap, nonferrous alloys, refined pig iron, deliberate addition
Titanium	≤0.15	Promotes undercooled graphite. Promotes hydrogen pinholing when aluminum is present. Combines with nitrogen to neutralize its effects	Some pig irons, steel scrap, some vitreous enamels and paints, deliberate addition
Tungsten	≤0.05	Promotes pearlite	Tool steel
Vanadium	≤0.08	Forms carbides; promotes pearlite	Steel scrap; some pig irons

ASM International, Alloying: Understanding the Basics, 2001

Table 3 Effects of alloying elements on the mechanical and physical properties of gray iron

Alloying element	Effect of alloying element on: Chill propensity	Pearlite stability	Machinability	Wear resistance	Hardness level	Hardenability	Strength
Silicon	Decreases	Decreases	Increases	Decreases	Decreases	Decreases	Decreases
Manganese	...	Increases	...	...	Increases	Increases	Increases
Chromium	Increases	Increases	Decreases	Increases	Increases	Increases	Increases
Molybdenum	...	...	...	Increases	Increases	Increases	Increases
Nickel	Decreases	Increases	Increases	Increases	Increases	Increases	Increases
Copper	...	Increases	Increases	Increases	Increases	...	Increases
Vanadium	Increases	...	...	...	Increases	Increases	Increases

Table 4 Compositions of ferrosilicon inoculants for gray cast iron

Performance category of inoculant	Composition, %(a) Si	Al	Ca	Ba	Ce	TRE(b)	Ti	Mn	Sr	Others
Standard	46–50	0.5–1.25	0.60–0.90	...	...	...	...	...	...	...
	74–79	1.25 max	0.50–1.0	...	...	...	...	...	...	...
	74–79	0.75–1.5	1.0–1.5	...	...	...	...	...	...	...
Intermediate	46–50	1.25 max	0.75–1.25	0.75–1.25	...	...	...	1.25 max	...	...
	60–65	0.8–1.5	1.5–3.0	4–6	...	...	...	7–12	...	...
	70–74	0.8–1.5	0.8–1.5	0.7–1.3	...	...	...	...	...	...
				0.75–1.25						
	42–44	...	0.75–1.25	...	...	...	9–11	...	...	...
	50–55	...	5–7	...	...	...	9–11	...	...	...
	50–55	...	0.5–1.5	...	...	...	9–11	...	...	...
High	36–40	...	...	...	9–11	10.5–15	...	...	...	...
	46–50	0.50 max	0.10 max	...	...	...	...	...	0.60–1.0	...
	73–78	0.50 max	0.10 max	...	...	...	...	...	0.60–1.0	...
Stabilizing	6–11	0.50 max	0.50 max	...	...	...	...	...	...	48–52 Cr

(a) All compositions contain balance of iron. (b) TRE, total rare earth elements

ASM International, Alloying: Understanding the Basics, 2001

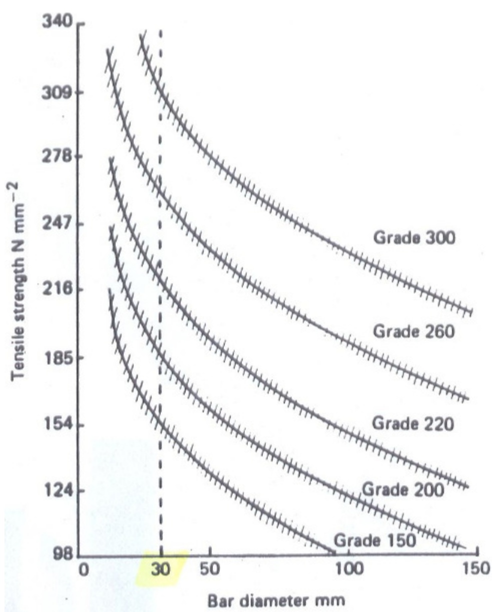

Figure 1.6 Variation of tensile strength with section thickness for grey flake irons

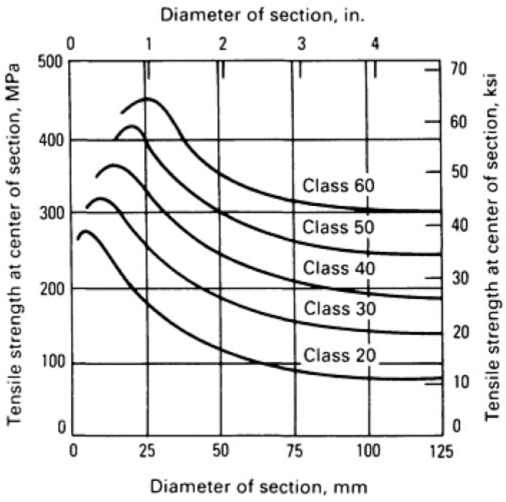

Fig. 12 Effect of section size on tensile strength of specimens cast from five classes of gray iron

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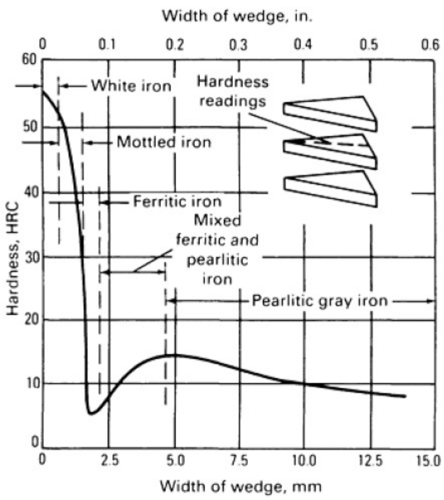

Fig. 11 Effect of section thickness on the hardness and microstructure of gray iron. Hardness readings were taken at increasing distance from the tip of a cast wedge (see inset). Iron composition was Fe-3.52C-2.55Si-1.01Mn-0.215P-0.086S.

International Comparison of Standard — مقایسه بین‌المللی در استاندارد

Sweden Reference (SS) — رفرنس بیس از کشور سوئد (SS)

لیست معادل‌گیری در پاره‌ای چدنهای ریخته‌گری
Material cross reference list

Country: Great Britain انگلستان	Sweden سوئد	USA امریکا	Germany آلمان		France فرانسه	Italy ایتالیا	Spain اسپانیا	Japan ژاپن
Standard: BS	**SS**	**AISI/SAE**	**W.-nr.**	**DIN**	**AFNOR**	**UNI**	**UNE**	**JIS**
Gray cast iron / چدن ریخته‌گری خاکستری								
	0100							
	0110	No 20B		GG 10	Ft 10 D			FC 100
Grade 150	0115	No 25B	0.6015	GG 15	Ft 15 D	G 15	FG 15	FC 150
Grade 220	0120	No 30B	0.6020	GG 20	Ft 20 D	G 20		FC 200
Grade 260	0125	No 35B	0.6025	GG 25	Ft 25 D	G 25	FG 25	FC 250
		No 40B } A 48						
Grade 300	0130	No 45B	0.6030	GG 30	Ft 30 D	G 30	FG 30	FC 300
Grade 350	0135	No 50B	0.6035	GG 35	Ft 35 D	G 35	FG 35	FC 350
Grade 400	0140	No 55B	0.6040	GG 40	Ft 40 D			
L-NiCuCr 202	0523	A 436 Type 2	0.6660	GGL-NiCr 202	L-NC 202			
Nodular cast iron / چدن ریخته‌گری باگرافیت کروی (ندولار)								
SNG 420/12	0717-02	60-40-18	0.7040	GGG 40	FCS 400-12	GS 370-17	FGE 38-17	FCD 400
SNG 370/17	0717-12	—		GGG 40.3	FGS 370-17			
—	0717-15	—	0.7033	GGG 35.3	—			
SNG 500/7	0727-02	80-55-06	0.7050	GGG 50	FGS 500 - 7	GS 500	FGE 50-7	FCD 500
Grade S6	0776	A43D2	0.7660	GGG-NiCr 202	S-NC 202	—	—	
SNG 600/3	0732-03	—		GGG 60	FGS 600-3			FCD 600
SNG 700/2	0737-01	100-70-03	0.7070	GGG 70	FGS 700-2	GS 700-2	FGS 70-2	FCD 700

Type of iron	Total carbon, %	Silicon, %
Class 20 ...	3.40–3.60	2.30–2.50
Class 30 ...	3.10–3.30	2.10–2.30
Class 40 ...	2.95–3.15	1.70–2.00
Class 50 ...	2.70–3.00	1.70–2.00
Class 60 ...	2.50–2.85	1.90–2.10

Table 7 As-cast mechanical properties of standard gray iron test bars

Class	Tensile strength		Torsional shear strength		Compressive strength		Reversed bending fatigue limit		Transverse load on test bar		Hardness, HB
	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	kgf	lbf	
20	152	22	179	26	572	83	69	10	839	1850	156
25	179	26	220	32	669	97	79	11.5	987	2175	174
30	214	31	276	40	752	109	97	14	1145	2525	210
35	252	36.5	334	48.5	855	124	110	16	1293	2850	212
40	293	42.5	393	57	965	140	128	18.5	1440	3175	235
50	362	52.5	503	73	1130	164	148	21.5	1633	3600	262
60	431	62.5	610	88.5	1293	187.5	169	24.5	1678	3700	302

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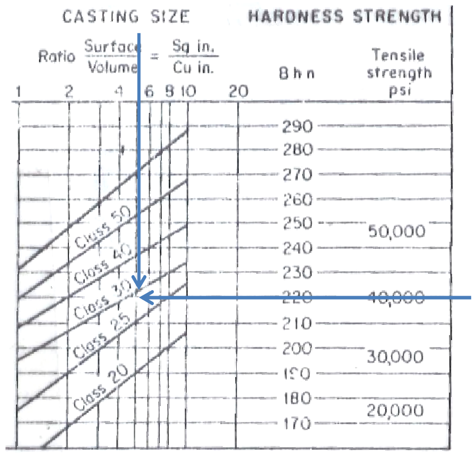

Fig. 20.8 **Relationship of ASTM class number, tensile strength, hardness, and machinability of gray iron to ratio of casting surface area to volume.**

Table 2 Hardness ranges for various combinations of gray iron microstructures

Microstructure	Hardness, HB
Ferrite + graphite	110–140
Pearlite + graphite	200–260
Pearlite + graphite + massive carbides	300–450
Bainite + graphite	260–350
Tempered martensite + graphite	350–550
Austenite + graphite	140–160

Table 6 Typical pouring temperatures for some classes of gray iron

Class	Approximate liquidus temperature		Pouring temperature: Small castings, Thin sections		Small castings, Thick sections		Large castings, Thin sections		Large castings, Thick sections	
	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
30	1150	2100	1400	2550	1370	2500	1345	2450	1315	2400
35	1175	2150	1425	2600	1400	2550	1370	2500	1345	2450
40	1200	2190	1450	2640	1420	2590	1395	2540	1365	2490
45	1220	2230	1470	2680	1445	2630	1415	2580	1390	2530

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Table 3 Minimum recommended section sizes for unalloyed gray irons

Class	Minimum section thickness mm	in.	Volume-to-surface-area ratio(a) mm	in.
20	3.2	1/8	1.5	0.06
25	6.4	1/4	3.0	0.12
30	9.5	3/8	4.3	0.17
35	9.5	3/8	4.3	0.17
40	15.9	5/8	7.1	0.28
50	19.0	3/4	8.4	0.33
60	25.4	1	10.7	0.42

(a) Volume-to-surface-area ratios are for square plates.

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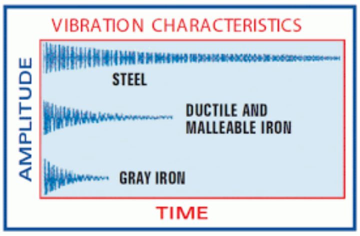
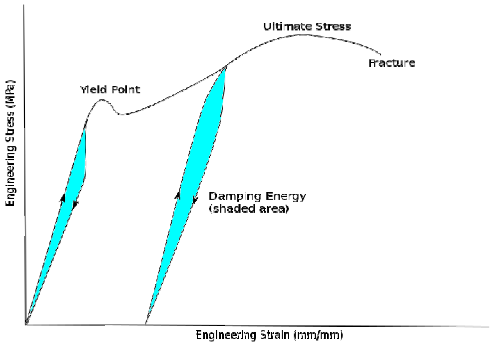
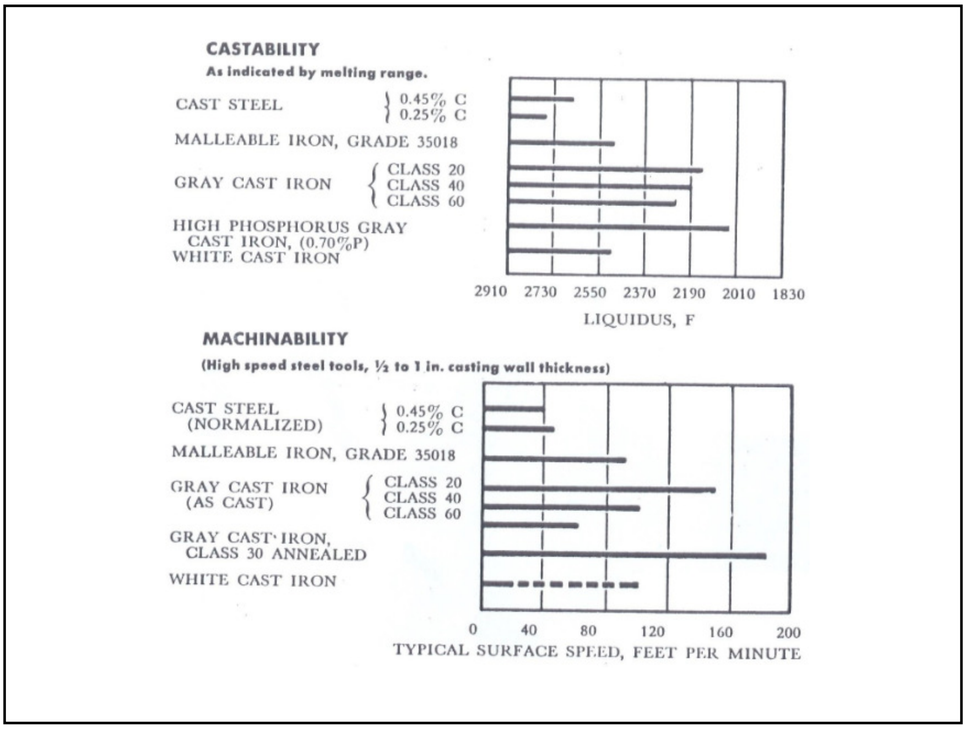
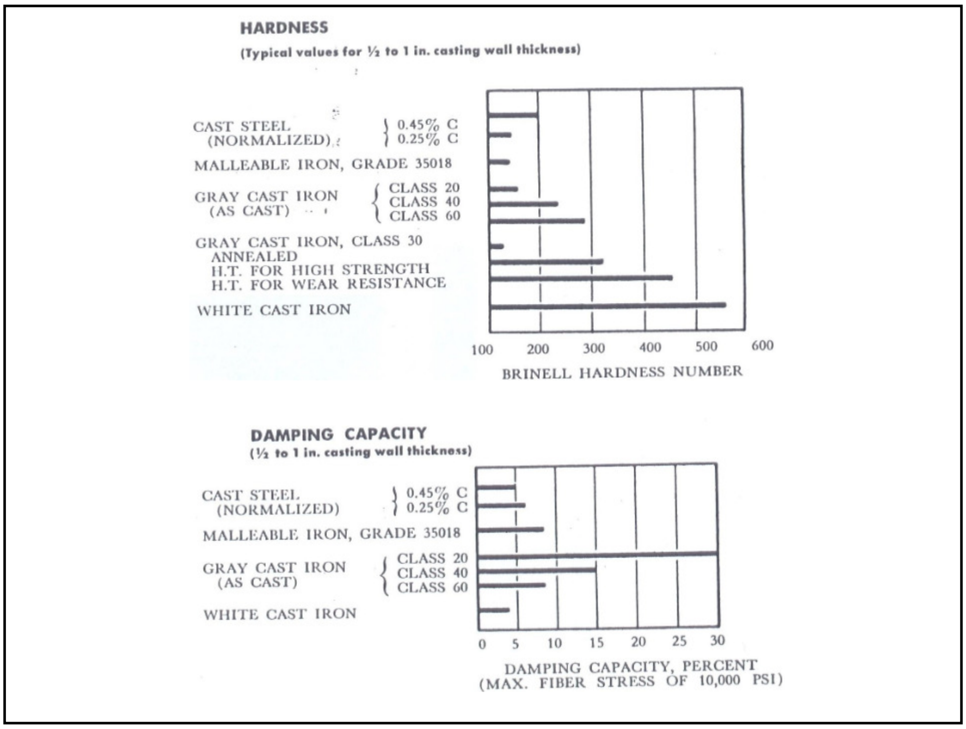
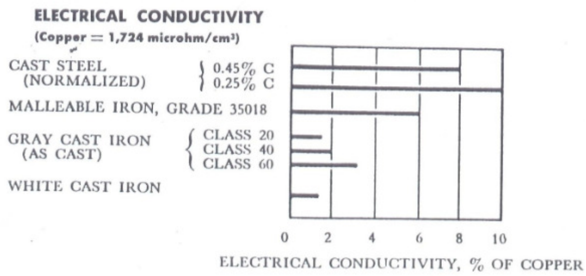




Material	Relative damping capacity
White iron	2–4
Malleable iron	8–15
Ductile iron	5–20
Gray iron, fine flake	20–100
Gray iron, coarse flake	100–500
Eutectoid steel	4
Armco iron	5
Aluminum	0.4


CASTABILITY
As indicated by melting range.
CAST STEEL
0.45% C
0.25% C
MALLEABLE IRON, GRADE 35018
GRAY CAST IRON
CLASS 20
CLASS 40
CLASS 60
HIGH PHOSPHORUS GRAY CAST IRON, (0.70%P)
WHITE CAST IRON
2910 2730 2550 2370 2190 2010 1830
LIQUIDUS, F
MACHINABILITY
(High speed steel tools, ½ to 1 in. casting wall thickness)
CAST STEEL (NORMALIZED)
0.45% C
0.25% C
MALLEABLE IRON, GRADE 35018
GRAY CAST IRON (AS CAST)
CLASS 20
CLASS 40
CLASS 60
GRAY CAST IRON, CLASS 30 ANNEALED
WHITE CAST IRON
0 40 80 120 160 200
TYPICAL SURFACE SPEED, FEET PER MINUTE


HARDNESS
(Typical values for ½ to 1 in. casting wall thickness)
CAST STEEL (NORMALIZED)
0.45% C
0.25% C
MALLEABLE IRON, GRADE 35018
GRAY CAST IRON (AS CAST)
CLASS 20
CLASS 40
CLASS 60
GRAY CAST IRON, CLASS 30
ANNEALED
H.T. FOR HIGH STRENGTH
H.T. FOR WEAR RESISTANCE
WHITE CAST IRON
100 200 300 400 500 600
BRINELL HARDNESS NUMBER
DAMPING CAPACITY
(½ to 1 in. casting wall thickness)
CAST STEEL (NORMALIZED)
0.45% C
0.25% C
MALLEABLE IRON, GRADE 35018
GRAY CAST IRON (AS CAST)
CLASS 20
CLASS 40
CLASS 60
WHITE CAST IRON
0 5 10 15 20 25 30
DAMPING CAPACITY, PERCENT
(MAX. FIBER STRESS OF 10,000 PSI)



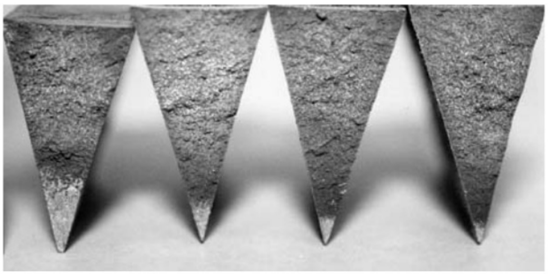


Fig. 2. Fractured W 3 ½ chill wedges illustrated various levels of clear chill and total chill. (magnification – 0.85x)

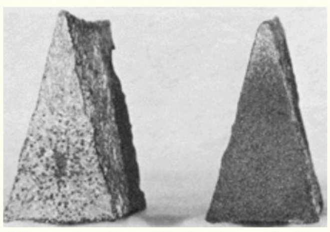


Figure 1, The effect of inoculation on chill in grey iron. Wedge on the left uninoculated. Wedge on the right inoculated.

http://www.asi-alloys.com/
http://www.ceesvandevelde.eu

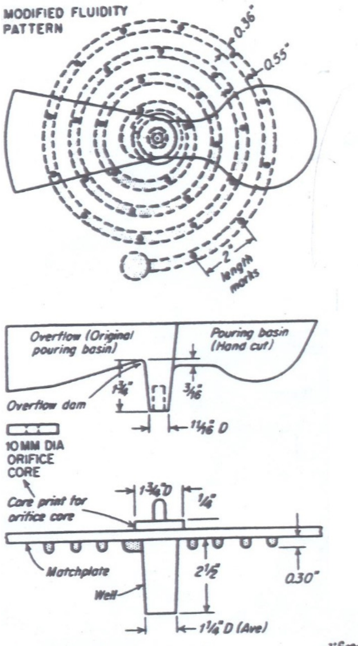
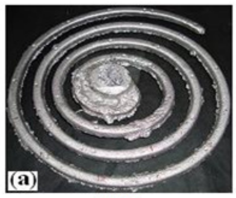
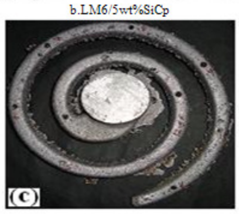


Fig. 21.7 Fluidity-spiral pattern, a modification of the fluidity test of Saeger and Krynitsky. (*From L. F. Porter and P. C. Rosenthal.*)



a. LM6

b.LM6/5wt%SiCp



c. LM6/12.5wt%SiCp

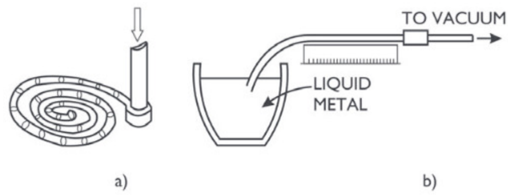
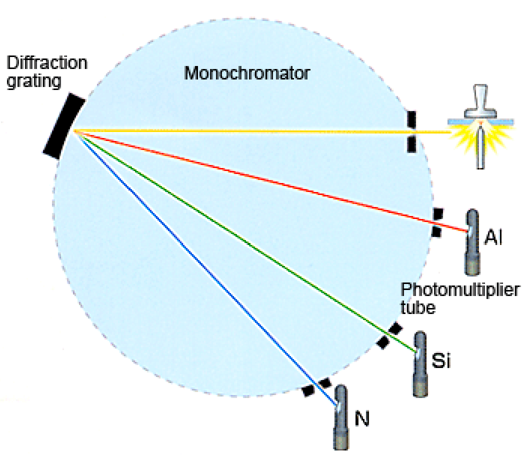
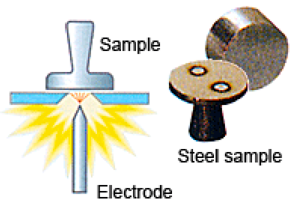


Fig. 3: Scheme of two fluidity tests: a) spirals test: the molten metal is poured in a spiral-shaped mould; b) vacuum test: the molten metal is sucked through a tube by a vacuum pump [2]

Spark optical emission spectrometer

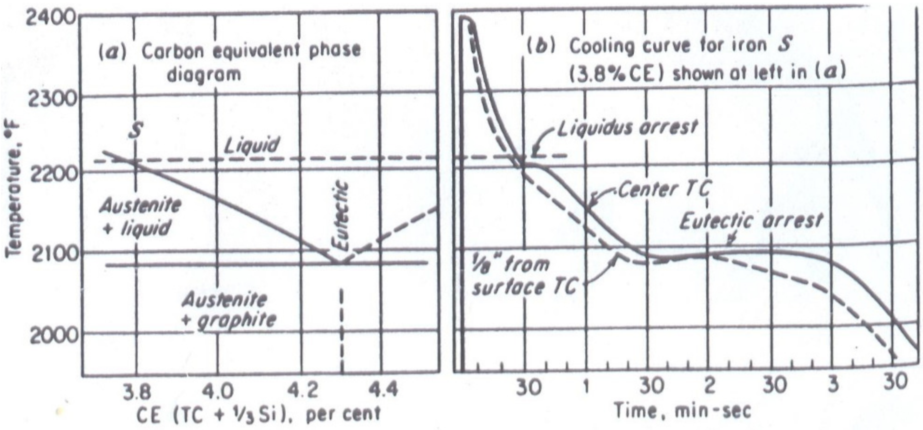
Spark optical emission spectrometer





http://www.shimadzu.com

Thermal analysis

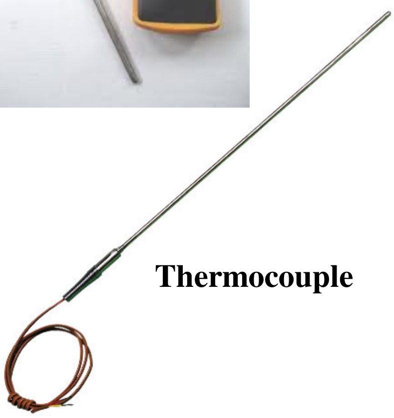


The relationship of the carbon-equivalent phase d[...]m in (a) to the[...]al arrests on the cooling curve in (b).

Thermometer

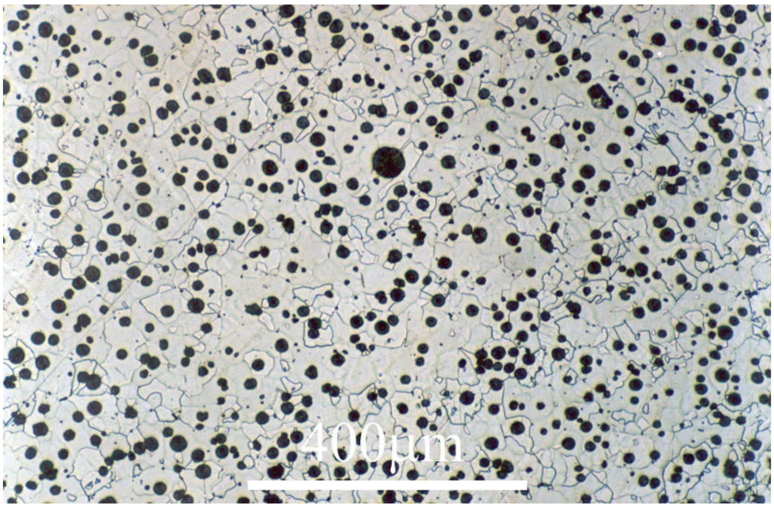
-50 ~ 900C
-58~1652F

Pyrometer



Thermocouple

Ductile cast Iron



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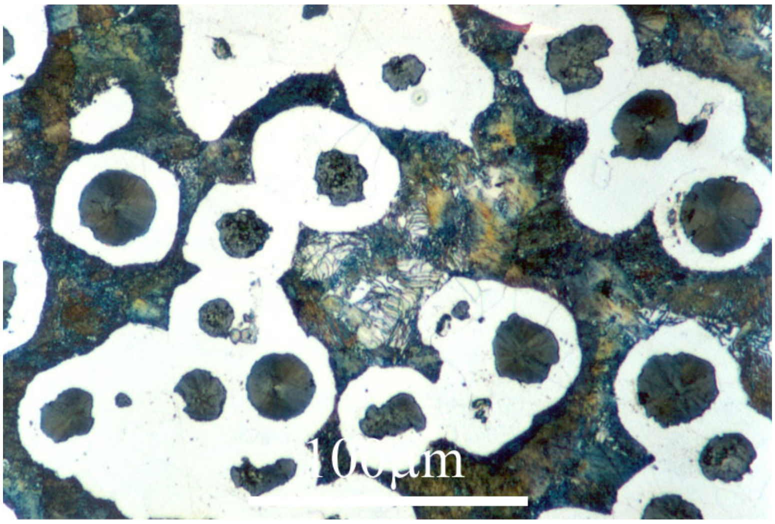
http://www.doitpoms.ac.uk/miclib/index.php

Ductile cast Iron



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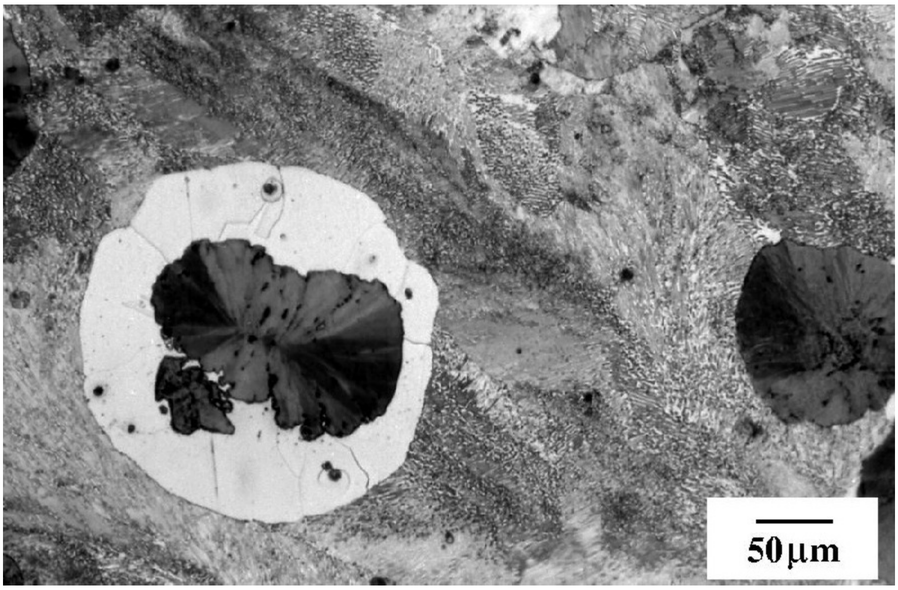
Ductile cast Iron



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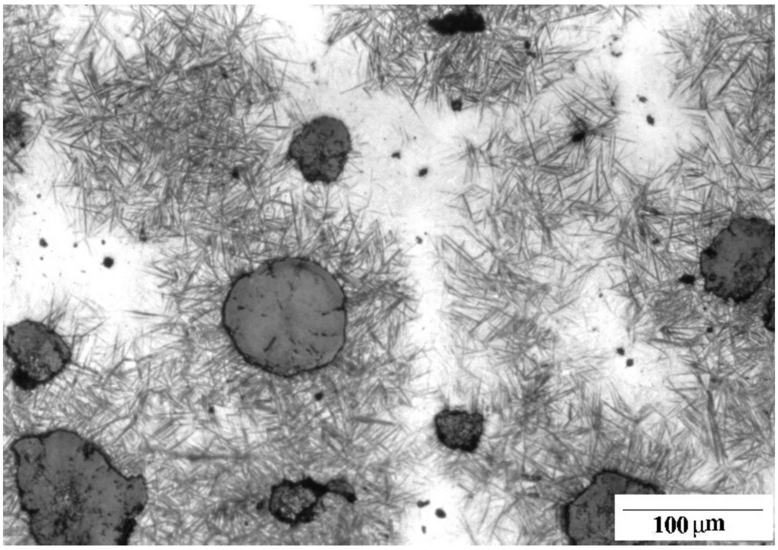
Austempered Ductile Iron (ADI)



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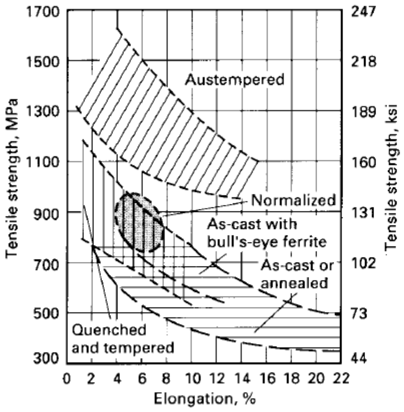
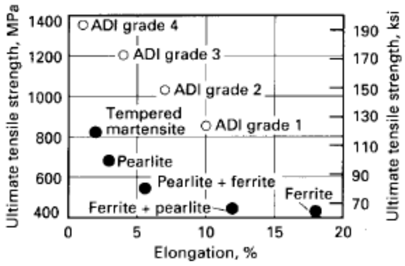
http://www.doitpoms.ac.uk/miclib/index.php

Ductile cast Iron



Range of tensile strength and elongation values for as-cast and heat-treated ductile irons.



Effect of matrix microstructure on the minimum values of tensile strength and elongation of ductile irons. The ADI matrix microstructure consists of acicular (bainitic) ferrite and austenite (see Fig. 2).

ASM International, Alloying: Understanding the Basics, 2001

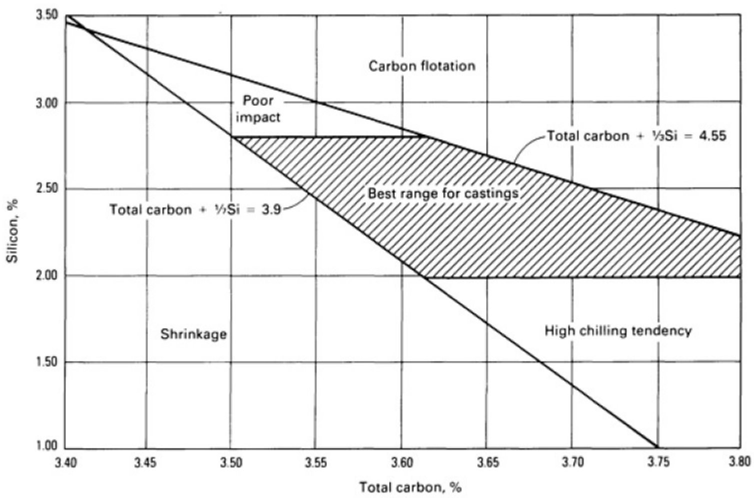


Fig. 1 Typical carbon and silicon ranges for ductile iron castings. Source: Ref 1

Metals Handbook, Vol. 15

Table 2 Mechanical properties and typical applications for standard grades of ductile iron

Specification No.	Grade or class	Hardness, HB(a)	Tensile strength, min(b) MPa	Tensile strength, min(b) ksi	Yield strength, min(b) MPa	Yield strength, min(b) ksi	Elongation in 50 mm (2 in.) (min), % (b)	Typical applications
ASTM A395; ASME SA395	60-40-18	143–187	414	60	276	40	18	Valves and fittings for steam and chemical plant equipment
ASTM A476(c); SAE AMS 5316	80-60-03	201 min	552	80	414	60	3	Paper mill dryer rolls
ASTM A536	60-40-18	...	414	60	276	40	18	Pressure-containing parts, such as valve and pump bodies
	65-45-12	...	448	65	310	45	12	Machine components subject to shock and fatigue loads
	80-55-06	...	552	80	379	55	6	Crankshafts, gears, and rollers
	100-70-03	...	689	100	483	70	3	High-strength gears and machine components
	120-90-02	...	827	120	621	90	2	Pinions, gears, rollers, and slides
SAE J434	D4018	170 max	414	60	276	40	18	Steering knuckles
	D4512	156–217	448	65	310	45	12	Disk brake calipers
	D5506	187–255	552	80	379	55	6	Crankshafts
	D7003	241–302	689	100	483	70	3	Gears
	DQ&T	(c)	(d)	(d)	(d)	(d)	(d)	Rocker arms
SAE AMS 5315C	Class A	190 max	414	60	310	45	15	Electric equipment, engine blocks, pumps, housings, gears, valve bodies, clamps, and cylinders

Note: For compositions, descriptions, and uses, see Table 1. (a) Measured at a predetermined location on the casting. (b) Determined using a standard specimen taken from a separately cast test block, as set forth in the applicable specification. (c) Range specified by mutual agreement between producer and purchaser. (d) Value must be compatible with minimum hardness specified for production castings.

Table 3 Hardness, toughness, and tensile properties at room temperature for austempered ductile iron grades specified in ASTM A 897 and A 897M (metric)

Grade	Minimum tensile strength MPa	Minimum tensile strength ksi	Minimum yield strength MPa	Minimum yield strength ksi	Minimum elongation, %	Unnotched Charpy impact energy J	Unnotched Charpy impact energy ft · lbf	Typical hardness, HB
125/80/10 (Grade 1)	850	125	550	80	10	100	75	269–321
150/100/7 (Grade 2)	1050	150	700	100	7	80	60	302–363
175/125/4 (Grade 3)	1200	175	850	125	4	60	45	341–444
200/155/1 (Grade 4)	1400	200	1100	155	1	35	25	388–477
230/185/- (Grade 5)	1600	230	1300	185	...	...	...	444–555

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Table 4 Summary of the effects of various elements found in ductile irons

Element	Typical amount	Maximum for matrix: Ferrite	Maximum for matrix: Pearlite	Positive effects	Deleterious effects
Spheroidizing elements					
Mg	0.02–0.08%	Sufficient to ensure spheroidal graphite		Lowers sulfur and oxygen contents; causes graphite to form spheroids	Excess promotes carbides
Rare earths	0–0.30%	About 0.035%	About 0.035%	Promotes nodule count and quality in combination with magnesium; neutralizes subversive elements	Excess promotes carbides in thin sections and chunky graphite in heavy sections
Ca	Not detected	Essentially insoluble	Essentially insoluble	Increases nodule count and improves nodule quality; optimizes inoculation	Excess promotes carbides
Ba	Not detected	Essentially insoluble	Essentially insoluble	Increases nodule count; optimizes inoculation	...
Primary elements					
C	3.00–4.00%	3.00–4.00%	3.00–4.00%	Present as spheroids or carbides	Excess results in graphite formation
Si	1.80–3.00%	1.80–3.00%	1.80–2.75%	Promotes graphitization during solidification and matrix formation	Hardens and strengthens ferrite; increases nil-ductility temperatures
P	About 0.02%	0.035% max	0.05% max	Kept as low as possible	Forms intercellular carbide network; promotes pearlite
S	0.01–0.02%	0.02% max	0.02% max	Combines with magnesium and rare earths	Limits efficiency of magnesium treatment process
Mn	0.00–1.20%	0.20%	0.80% max	Promotes pearlite in as-cast and normalized iron	Intercellular carbides when over 0.70%
Alloying elements					
Ni	0.01–2.00%	As low as possible for as-cast	To specification	Employed for hardenability (e.g., pearlitic)	...
Mo	0.01–0.75%	0.03% max	To specification	Promotes hardenability	Excess promotes intercellular carbides
Cu	0.01–0.90%	0.03% max	To specification	Promotes pearlitic hardenability	No significant effect on nodule count or quality
Tramp elements					
Te	<0.005%	0.02% max	0.02% max	Used to control pinholes	Promotes spheroid degeneration in absence of rare earths
Pb	...	0.002% max	0.002% max	Kept as low as possible	Promotes intercellular flake graphite
Ti	<0.07%	0.03% max	0.07% max	Kept as low as possible	Promotes vermicular graphite
Al	0.003–0.06%	0.05% max	0.05% max	Used in ferroalloys to suppress chill	Promotes vermicular graphite effect—greater in heavy sections; promotes pinholes

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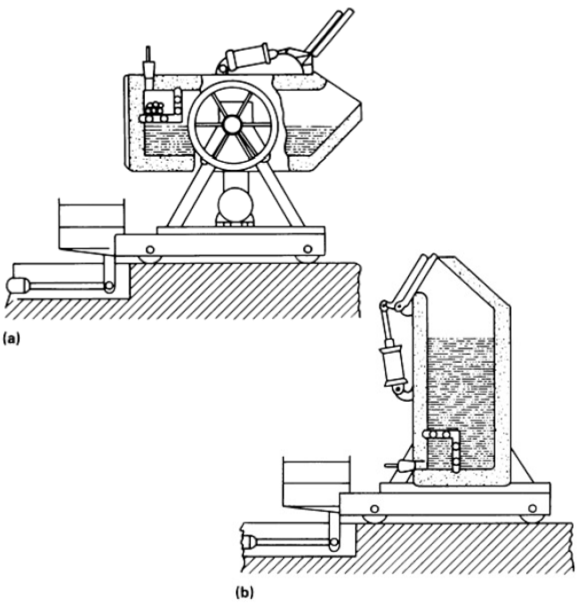
Ductile cast Iron

Sb	<0.005%	0.001% max	0.001% max	Strong pearlite former; counteracts chunky graphite in heavy sections	Nodule degeneration at high levels when rare earths are not present
Bi	<0.01%	0.002% max	0.002% max	Increases nodule count and quality when rare earths are present	Promotes vermicular graphite in absence of rare earths
Zr	<0.01%	0.10% max	0.10% max	Kept as low as possible	Promotes vermicular graphite
Carbide- and pearlite-forming elements					
Cr	0.02–0.15%	0.04% max	0.10% max	Very powerful carbide former	Carbides resistant to annealing
B	<0.0005%	0.002% max	0.002% max	Kept as low as possible	Forms intercellular carbides that resist annealing
Sn	<0.10%	0.01% max	0.08% max	Very potent pearlite former	At <0.10%, forms intercellular structure with flake graphite
As	0.01% max	0.02% max	0.05% max	About 0.08% required for pearlitic matrix	...
V	<0.04%	0.04% max	0.05% max	Forms very stable carbides	Retards annealing
Gaseous elements					
O	<0.005%	About 0.003%	About 0.003%	Kept as low as possible	Combines with magnesium
H	0.0002–0.0015%	About 0.0003%	About 0.0003%	Kept as low as possible	Promotes centerline carbides and inverse chill; promotes pinholes
N	...	...	...	Kept as low as possible	Mild carbide-forming tendency; may contribute to porosity

Source: Ref 1

ASM International, Alloying: Understanding the Basics, 2001



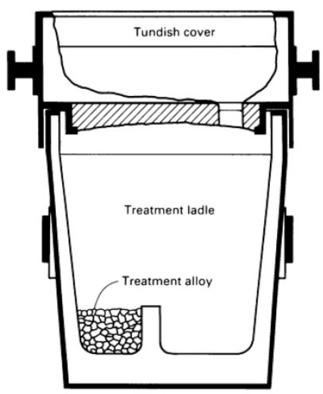


Fig. 3 Treatment ladle with tundish cover used in the magnesium treatment of ductile iron

Fig. 2 Schematic of the Fischer converter. (a) Vessel in filling position. (b) Vessel in treating position

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Compacted Graphite cast Iron

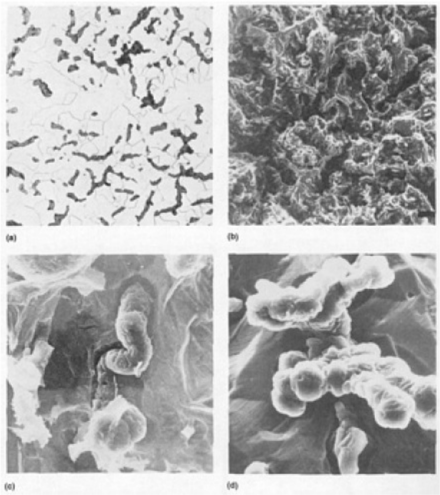

Fig. 1 Typical microstructures of CG irons. (a) Optical micrograph. Etched with nital. (b) Tensile load fracture surface. Overall view. Ion bombardment etched. SEM, 65×. (c) and (d) Examples of true shape of graphite in CG irons. Full deep etch. SEM, 395×. Courtesy of Austrian Foundry Research Institute

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Compacted Graphite cast Iron

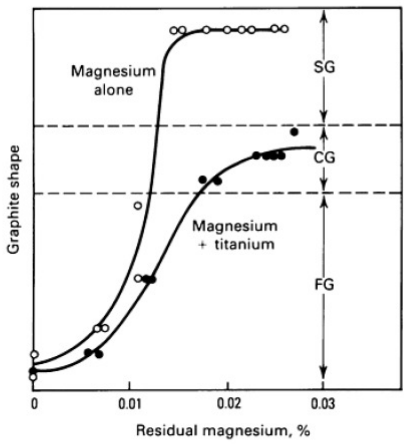

Fig. 6 Range of residual magnesium that produces compacted graphite. Source: Ref 5

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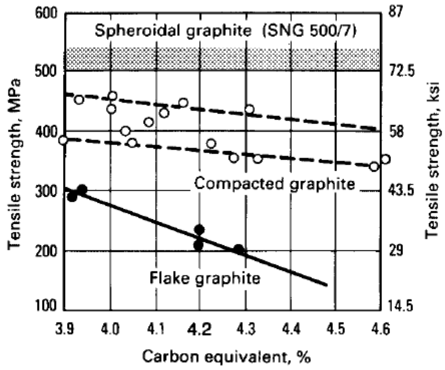

Fig. 6 Effect of carbon equivalent on the tensile strength of flake, compacted, and spheroidal graphite irons cast in 30 mm (1.2 in.) diam bars

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