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An Alternative Route for the Production of Compacted Graphite Irons

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TCS

Elkem Foundry Div., Norway

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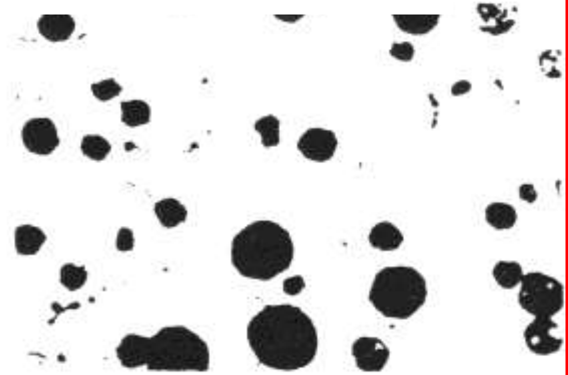
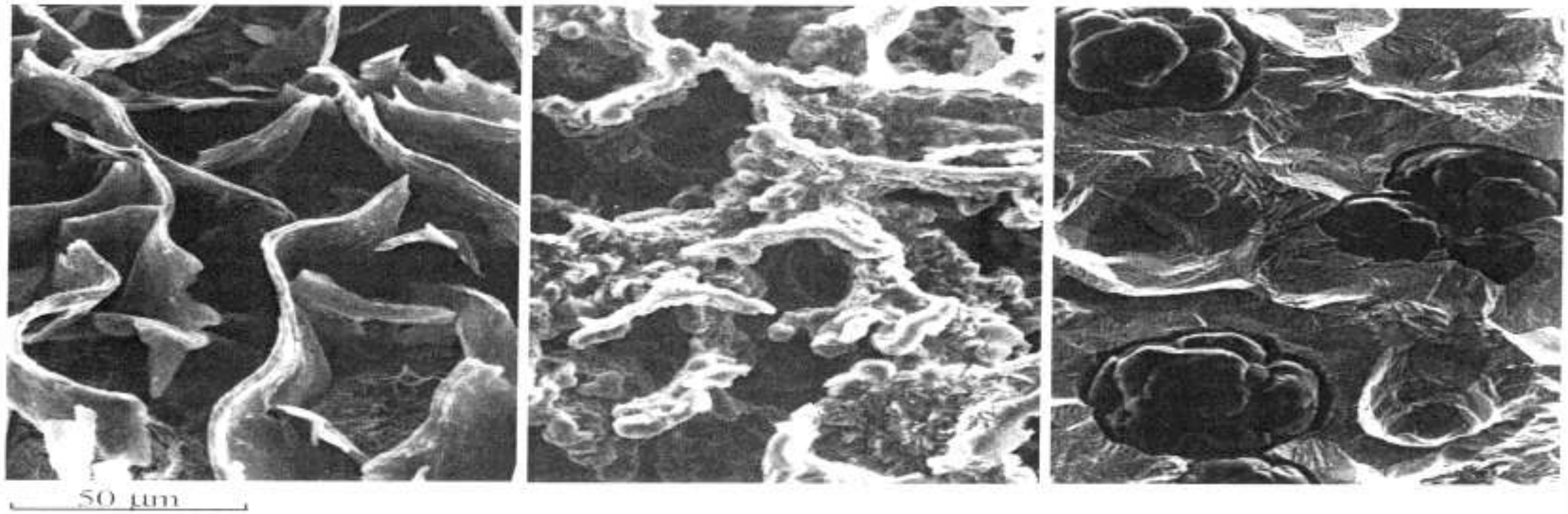
Graphite Structures

Grey Iron	CGI	Ductile Iron
		
Flake Graphite	*Compacted or Vermicular Graphite*	*Nodular Graphite*



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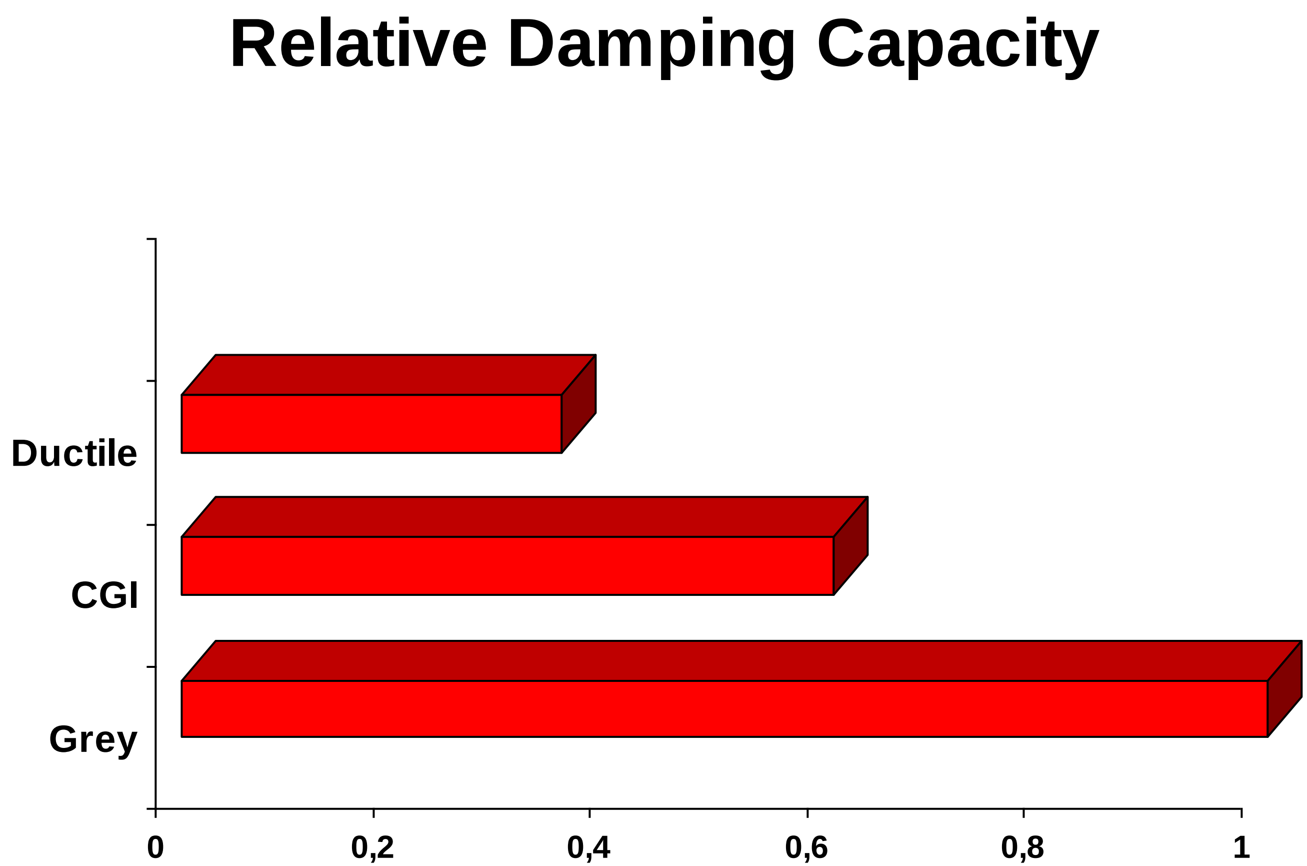
Relative Damping Capacity



Mechanical Properties of Cast Iron

	Matrix	Tensile [MPa]	Modulus [GPa]	Fatigue [MPa]	Therm.Cond. [W/Km]	Hardness [HB]	Elongation [%]
Grey Iron	Pearlitic	200 - 270	105 - 115	95 - 110	44 - 52	175 - 230	0 – 1
CG Iron	Ferritic	330 - 410	130 - 150	155 - 185	40 - 45	130 - 190	5 – 10
	Pearlitic	420 - 580	130 - 155	190 - 225	31 - 40	200 - 250	2 - 5
Ductile	Ferritic	400 - 600	155 - 165	185 - 210	32 - 38	140 - 200	15 – 25
	Pearlitic	600 - 700	160 - 170	245 - 290	25 - 32	240 - 300	3 – 10

Note: ***Ferritic CG iron shows comparable thermal conductivity to pearlitic grey iron, but has a much better tensile strength***

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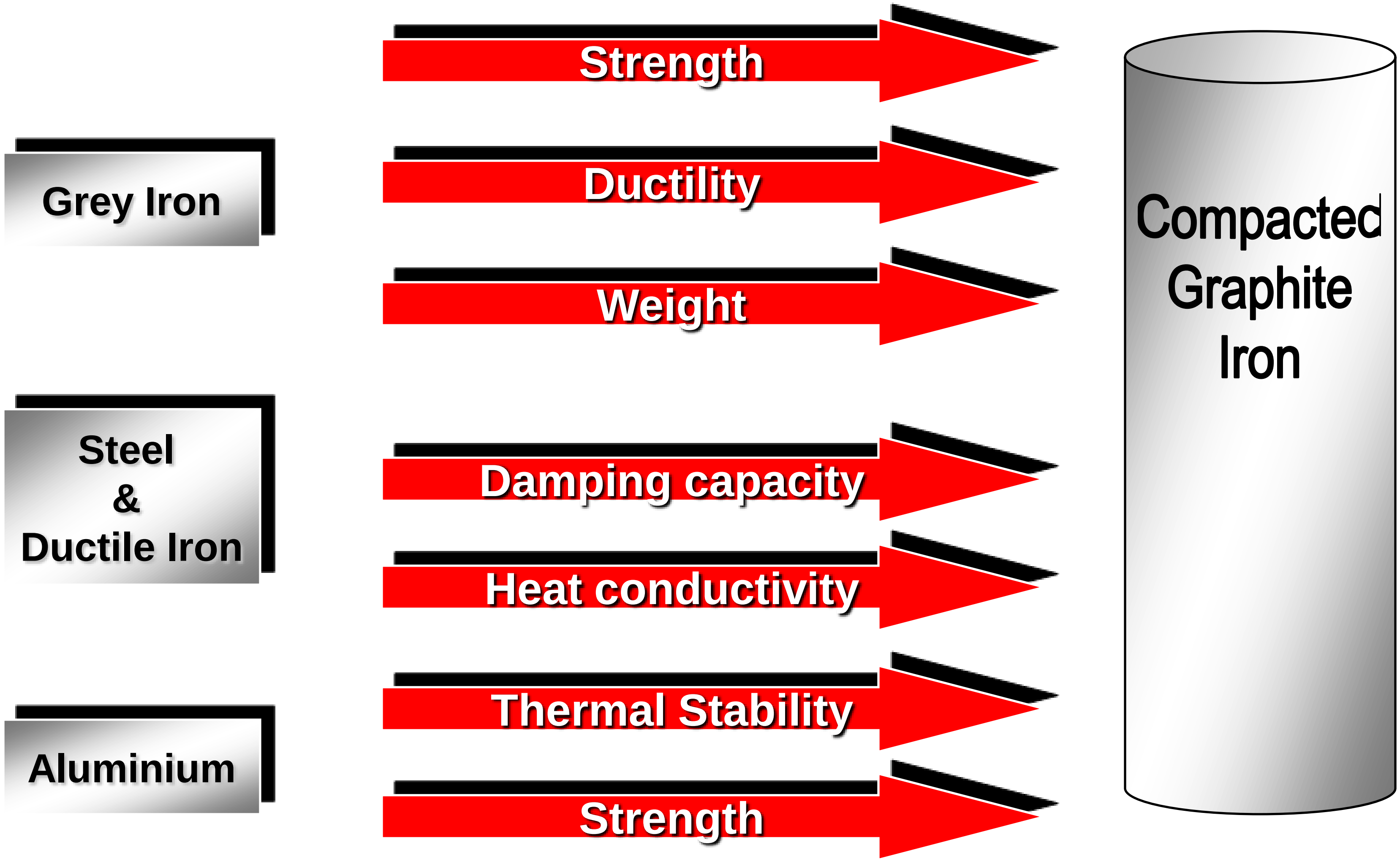
CGI replaces….



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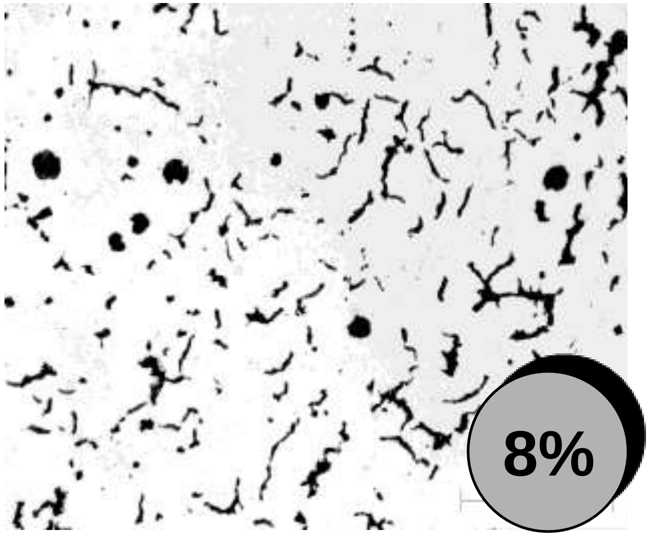
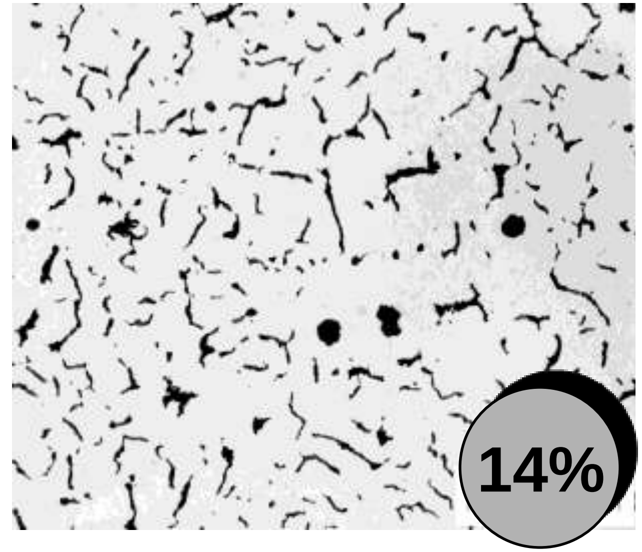
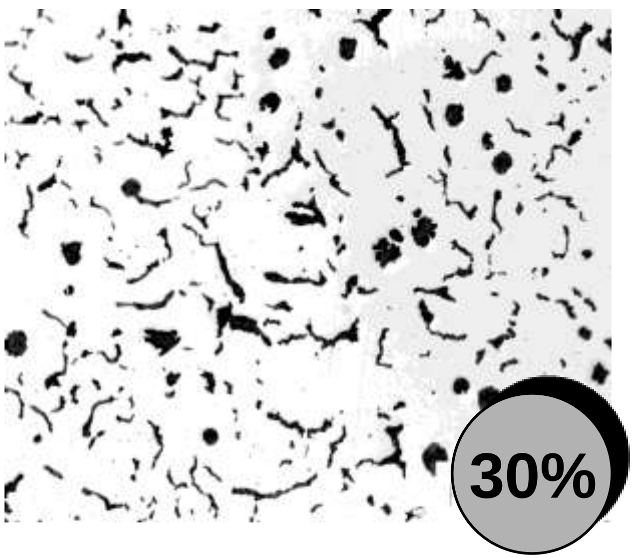
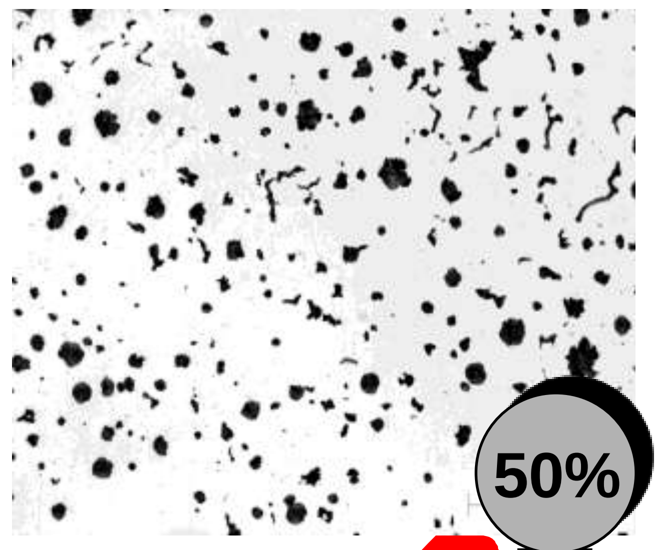
Proportion of nodular graphite in CG-Iron

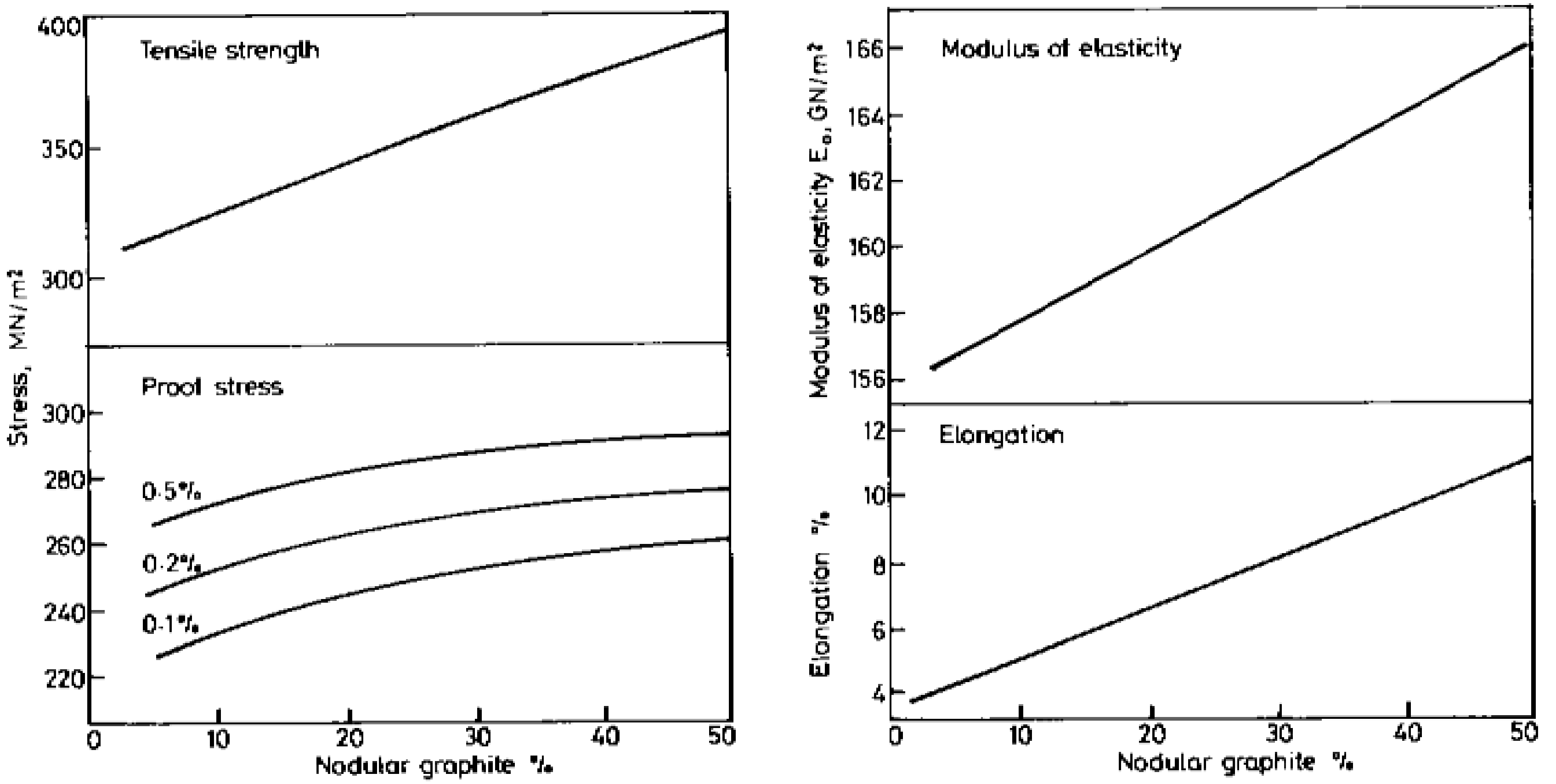








Effect of nodular graphite on mechanical properties



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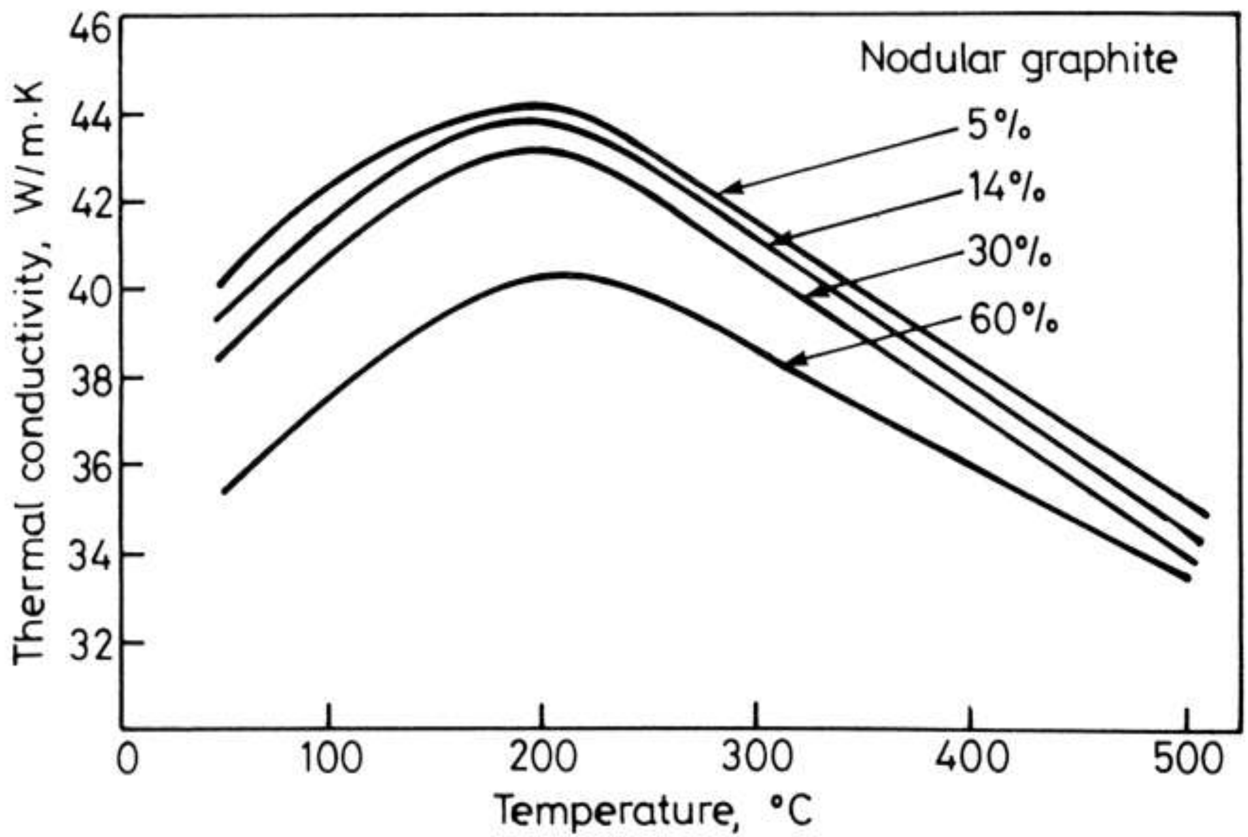
Thermal conductivity



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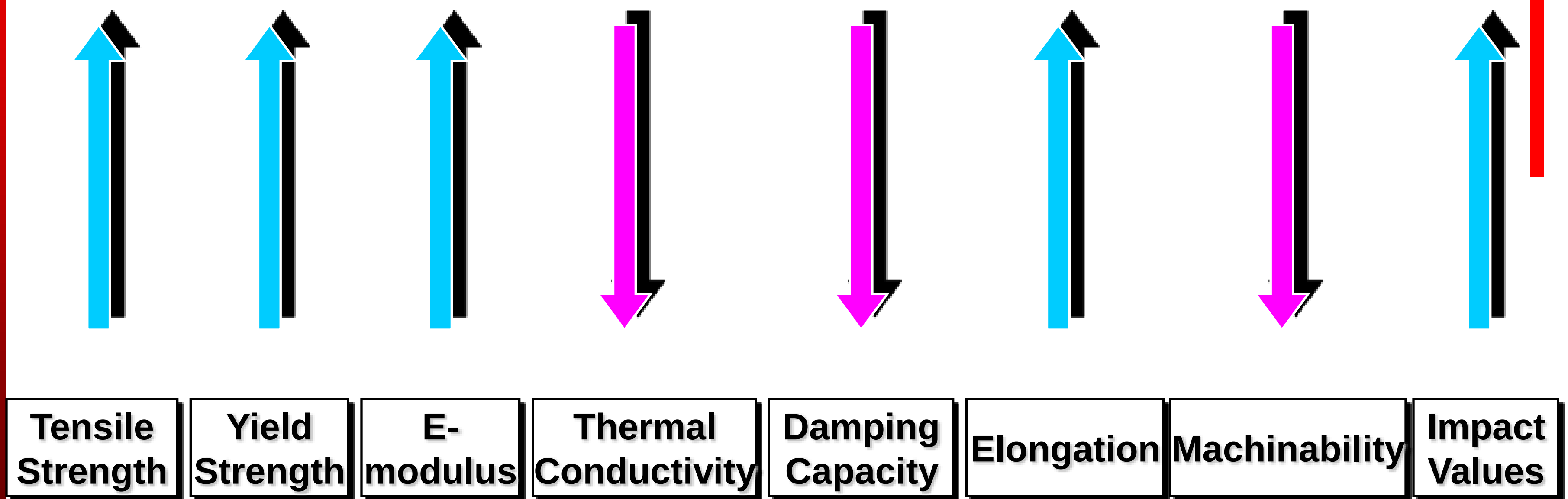
Effects of nodular graphite in CGI

An increase in nodular graphite content in CG iron have the following effects ….



Nodularity may be manipulated to enhance special properties

Possible Production Routes

- By Magnesium
- By Cerium
- By Nitrogen
- By Titanium
- By (Mg,RE)-Alloy

Possible Production Routes

Mg	Ce	N	Ti

Typical Characteristics

Mg
- 0.005 - 0.03 % Mg
- regular Mg-alloys
- narrow Mg-range
- flakes in heavy sections
- nodules in thin sections
- difficult to control

Ce
- 0.02 - 0.05 % Ce
- medium inocula-tion effect required
- carbides in thin sections
- tendency to nodular graphite in thin sections

N
- 0.01 - 0.015 % N
- nitrided FeMn
- mild compaction in thin sections
- strong compaction in heavy sections
- neutralised by Ti or Al
- may cause porosity

Ti
- 0.08 - 0.15 % Ti
- 0.035 - 0.15 % Mg
- (Mg,Ti,Ce)-alloys
- CG in both thin and heavy sections
- Ti-contamination of returns
- poor machinability

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Production by high RE-MgFeSi

- Rare earth's are reported to have beneficial effects on section sensitivity
- High rare earth is easier to control than Magnesium
- Improves fading resistance
- The entire treatment is done in one go - treatment alloy with balanced total composition
- Rare earth's may be an attractive alternative to the use of Titanium especially when it comes to machining

Production by CompactMag™ Alloy

CompactMag™

Si	**44 – 48**	**%**
Mg	**5.0 – 6.0**	**%**
Ca	**1.8 – 2.3**	**%**
RE	**5.5 – 6.5**	**%**
Al	**Max 1.0**	**%**
	Balance Iron	

- Ladle treatment or in the mould
- 0.30 - 0.45 wt% alloy addition *depending on base sulphur level*
- 0.1 - 0.5 wt % *mild* inoculant addition may be needed

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Alloy Addition Rates

- Alloy addition rates depend on the base metal composition and treatment process:
  - Undertreatment: 0.4 - 1 wt% MgFeSi
  - Titanium: 1 - 2 wt% MgFeSi + 0.1 - 0.6 wt% Ti
  - CompactMag™: 0.3 - 0.4 wt%
- Inoculant should be added from 0 to 0.8 wt%

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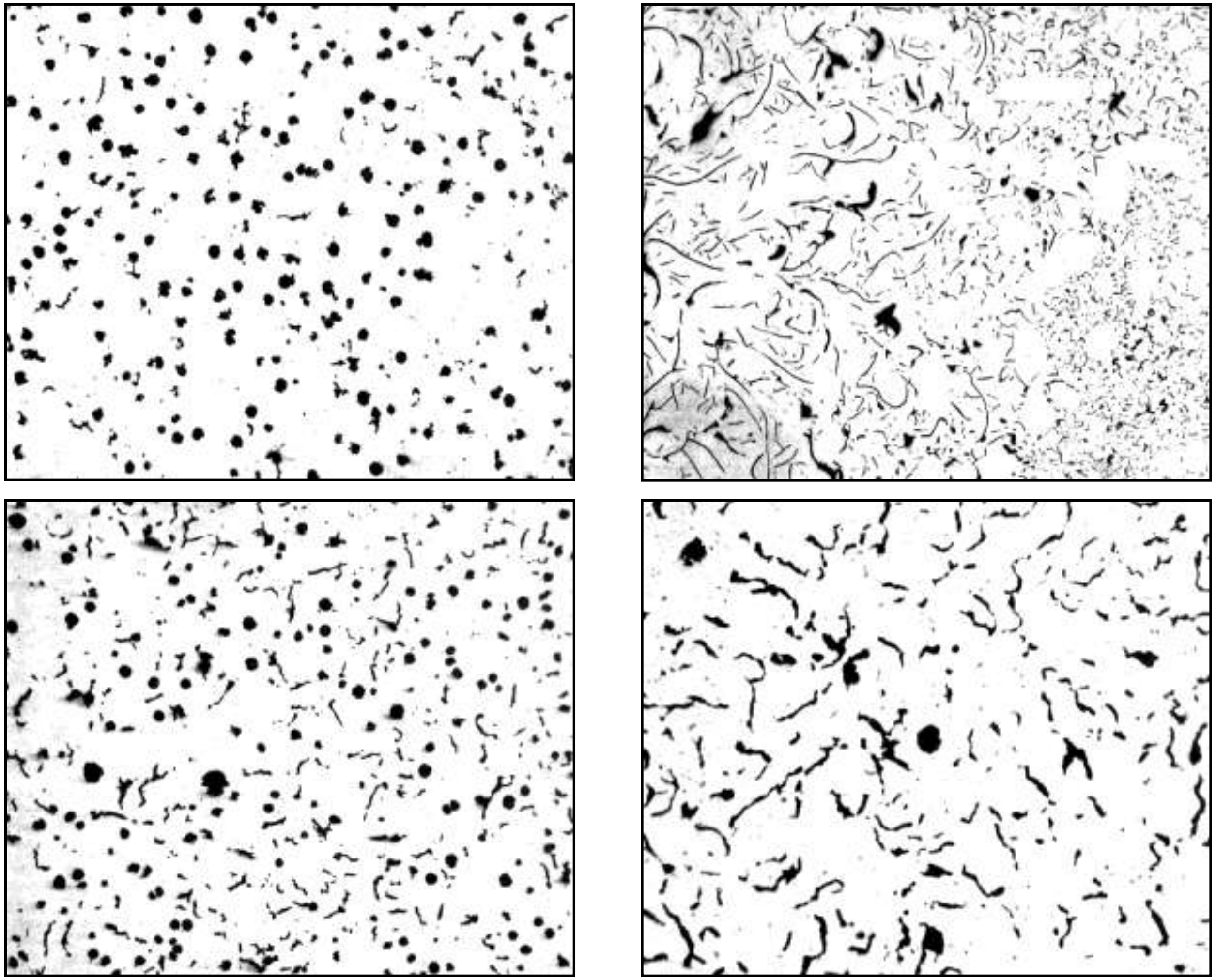
MgFeSi Undertreatment vs. CompactMag™



MgFeSi (1%RE)

Addition: 0.8wt%

CompactMag™

Addition: 0.35wt%

5 mm

35 mm

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Typical Mechanical Properties

Property	Grey Iron (ISO 100)	Example Compacted by Titanium	Example Compacted by CompactMag™	Ductile Iron (ISO 400-12)
Yield strength [MPa]	-	290	330	min. 250
Tensile Strength [MPa]	min. 100	365	380	min. 400
Elongation [%]	ca. 0.5	4.5	5	min. 15

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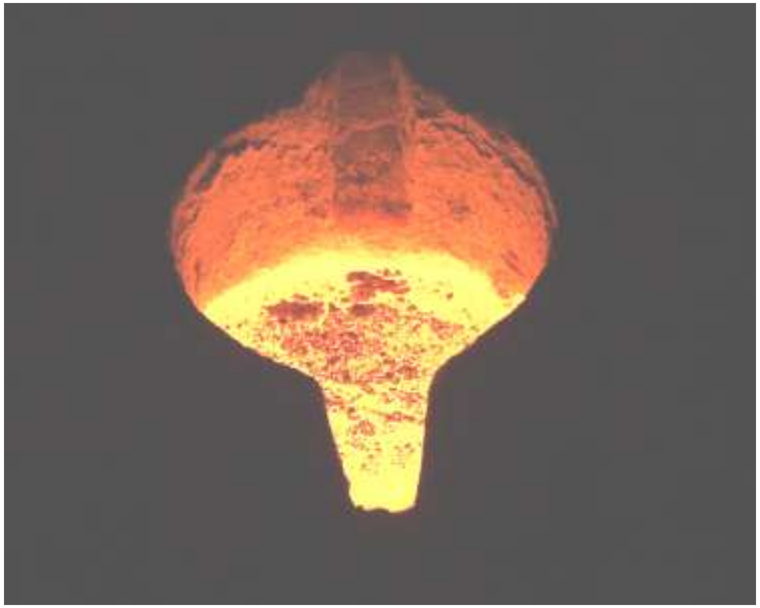
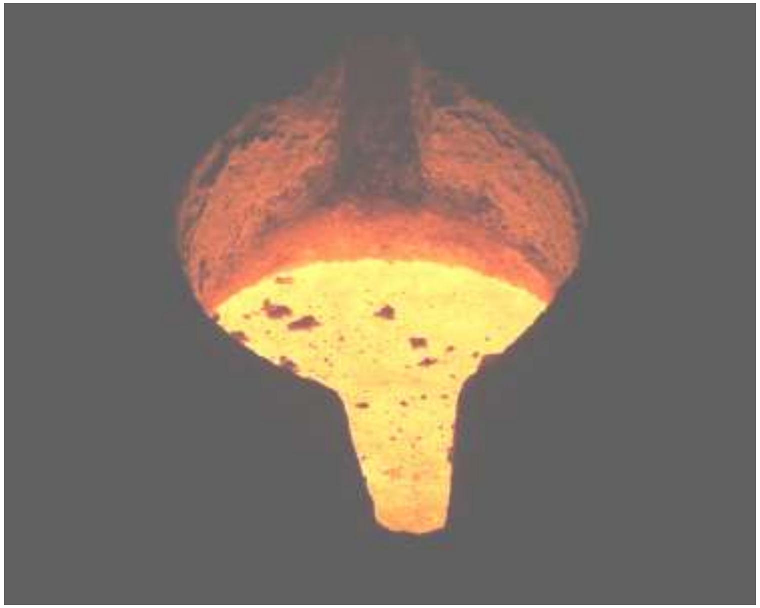
Slag Formation





Addition:

MgFeSi:	1.5wt%
FeTi:	0.25wt%

Addition:

CompactMag™:	0.35wt%
Other:	None

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Comparison of Treatment Cost

Example:

Titanium

1.3 wt% MgFeSi	$	13
0.25 wt% FeTi	$	6
0.3 wt% Inoculant	$	5
Total Cost	$	24

CompactMag™

0.35 wt% CompactMag	**$**	**5**
0.2 wt% Inoculant	**$**	**3**
Total Cost	**$**	**8**

About $ 16 savings per MT iron!!

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Some important considerations….

- ➔ Base iron composition
- ➔ Sulphur content of base iron
- ➔ Preconditioning
- ➔ Sandwich cover
- ➔ Inoculation
- ➔ Final iron composition

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Base Iron Composition

C.E	4.3 – 4.5	%
C	3.7 – 3.9	%
Si	1.5 – 2.0	%
S	0.007 – 0.017	%
P	Max 0.03	%

Note: ***Impurities should be kept low***

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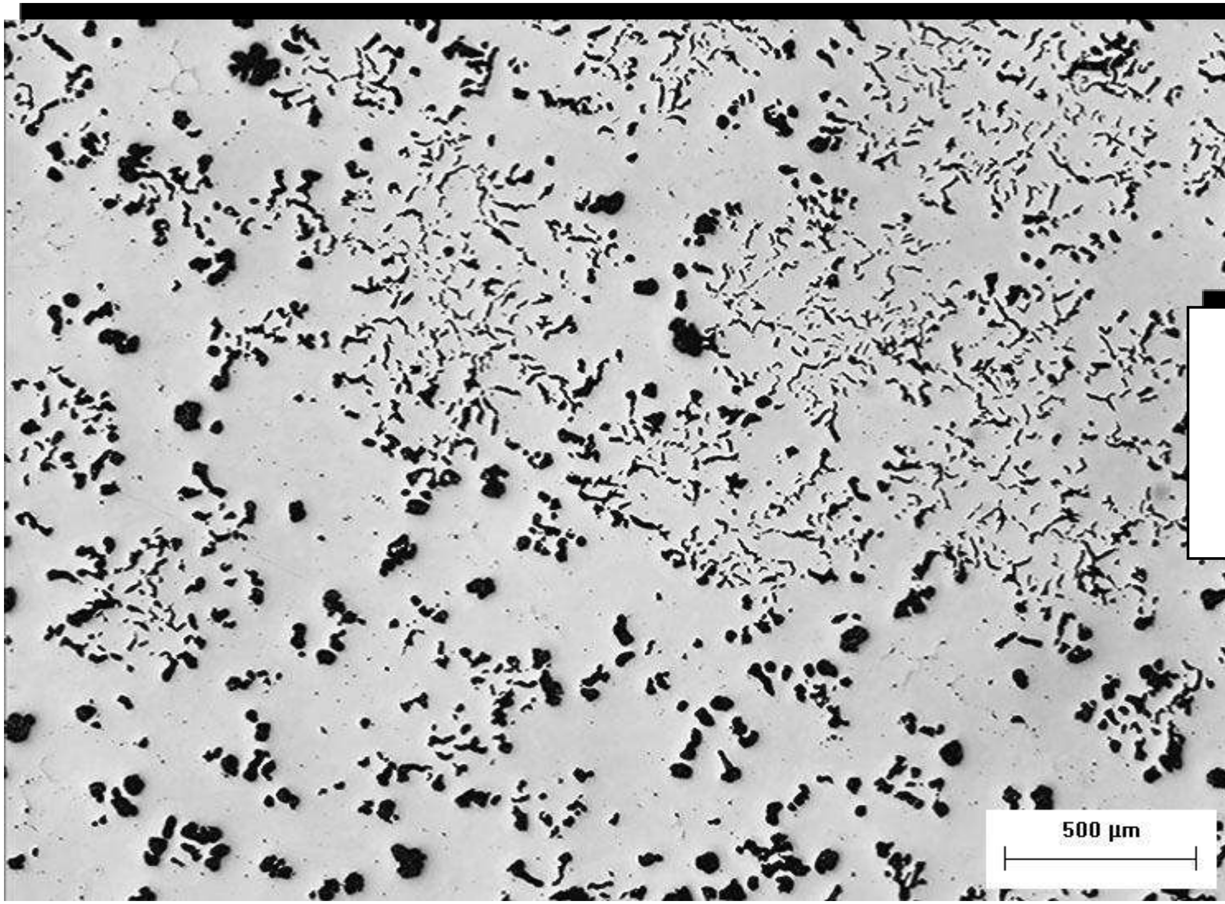
High Sulphur Treated Iron



Base S 0.07%,
Final S 0.03%,
Final Mg 0.020%

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Preconditioning

- Preconditioning of CGI may be useful to control base oxygen and make reproducible conditions for nucleation and growth of graphite
- Preconditioning needs to introduce some low stability source of oxygen, preferentially to the saturation level of the iron
- Addition of 0.1 - 0.2 wt% of the Ultraseed® inoculant is found to be useful (approx. 10 ppm O)

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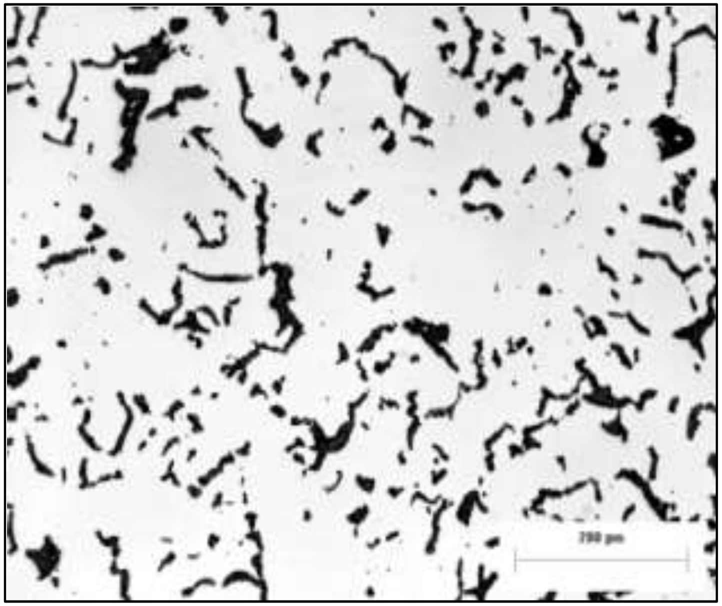
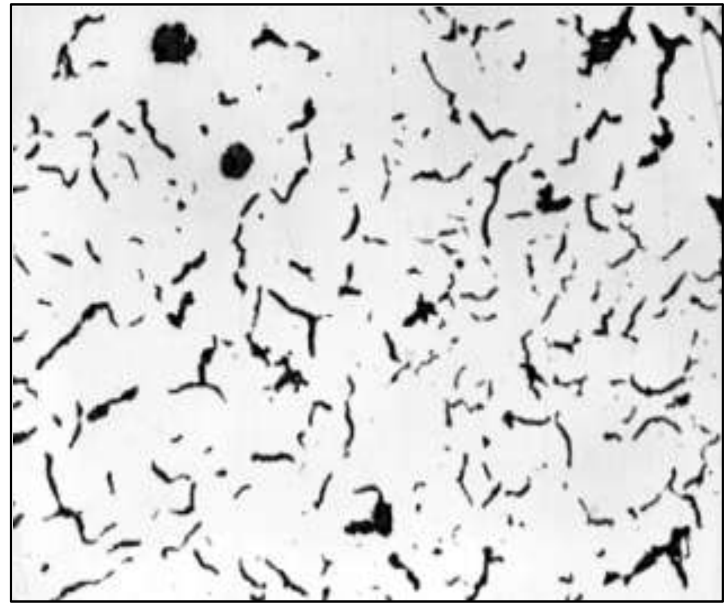
Effect of Sandwich Cover

NO COVER	0.3 wt% Foundrisil® inoculant
	

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Inoculation

- Different inoculants may be used successfully to make CGI, but is not always necessary.

Recommendations for inoculant:

- Barium containing:
  - Foundrisil® inoculant
  - Barinoc® inoculant
- Strontium containing:
  - Superseed ® inoculant

- Time for addition: sandwich cover, ladle or in stream may all be used.

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Final CGI Composition

C.E	4.4 – 4.7	%
C	3.6 – 3.8	%
Si	2.3 – 2.9	%
S	0.007 – 0.010	%
Mg	0.007 – 0.009	%
Ce	0.006 – 0.008	%

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Summary Production Routes for CGI

- Undertreatment with Mg, normally MgFeSi
- Suppression of nodules to compacted form by using Mg + Ti
- The use of CompactMag™ Mg/RE system

Summary CompactMag™

- wider production window and more flexibility
- low reactivity in the ladle, thus reducing the need for subsequent inoculation
- low residual Mg and RE levels, which reduces susceptibility to chill
- can be used over a range of sulphur levels within normal limits for CGI production
- low slag generation
- no contamination of returns with Ti
- used in conjunction with Foundrisil® inoculant cover in the treatment ladle minimises the need for post inoculation

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