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6. Uluslararası Ankiros Döküm Kongresi

Bu bildiri 6. Uluslararası Ankiros Döküm kongresinde sunulmuştur

This paper was presented on 6th Ankiros Foundry Congress

http://kongre.tudoksad.org.tr/

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DI Ferritic Grade with Impact at low Temperature:

Influence of Samples Position, Charge and Casting Compositions.

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Rio Tinto Iron & Titanium

Introduction:

Rio Tinto Sorelmetal Technical Services regularly investigates foundry customers' microstructures and properties. During some of these investigations, variations in mechanical properties, including impact strength at low temperatures, often appeared to be independent of chemistry and matrix microstructure. The most probable cause for these differences was theorized to be the position in the casting or test coupon from which the sample was taken.

A foundry/laboratory research program was developed and conducted in Rio Tinto's R & D lab in Sorel-Tracy, Quebec to confirm or deny this dependence of mechanical properties to casting position. Some results of this work have been presented in other forums.

The latest results of our experimental work will be presented. This work will relate metallic charge and chemical analyses "coupled" with the position of samples. Charpy impact testing was performed at -20C, -40C and -50 C.

Some slides will present variations of chemistry by position and one slide will address variations in tensile and yield strength by position

This paper would not exist without help and strong investments in these researches of Chantal Labrecque & Serge Grenier

Outline:

Background

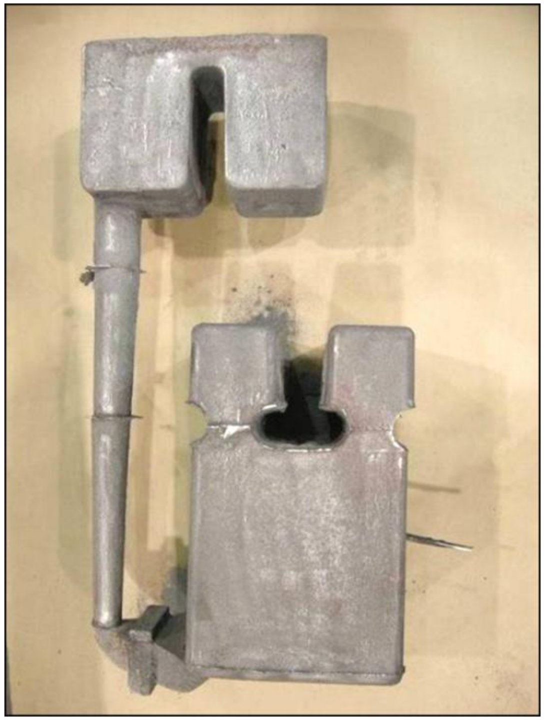
Effect of Position

Effect of Casting Composition

Effect of Charge Composition

Conclusions

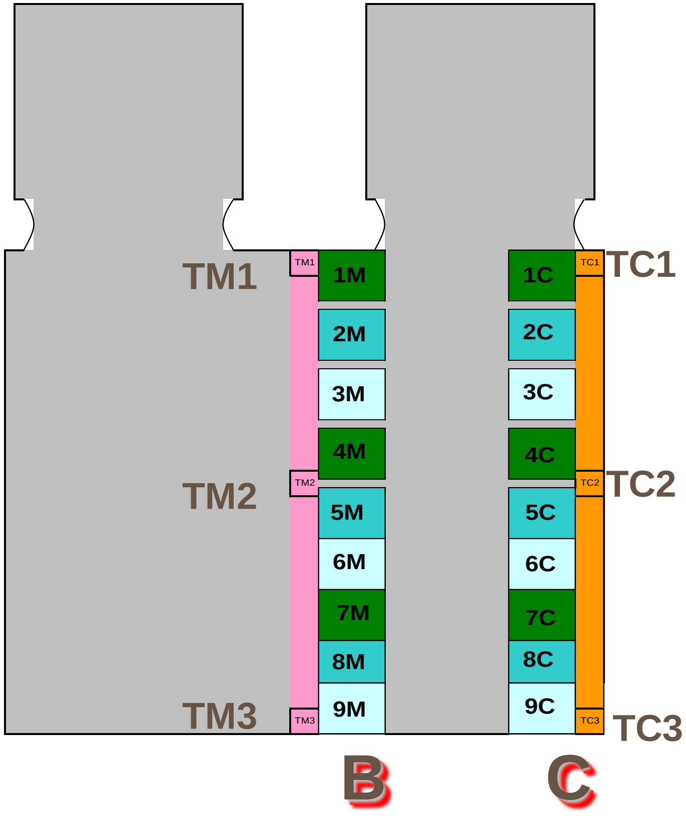
Background: our casting, our samples



Chemical Composition: average of TM1 & TM2

Microstructural Examination (TMx and TCx)

Impact Tests Samples (xM and xC).



Bottom filled rectangular prism:180 x 180 x 190 mm

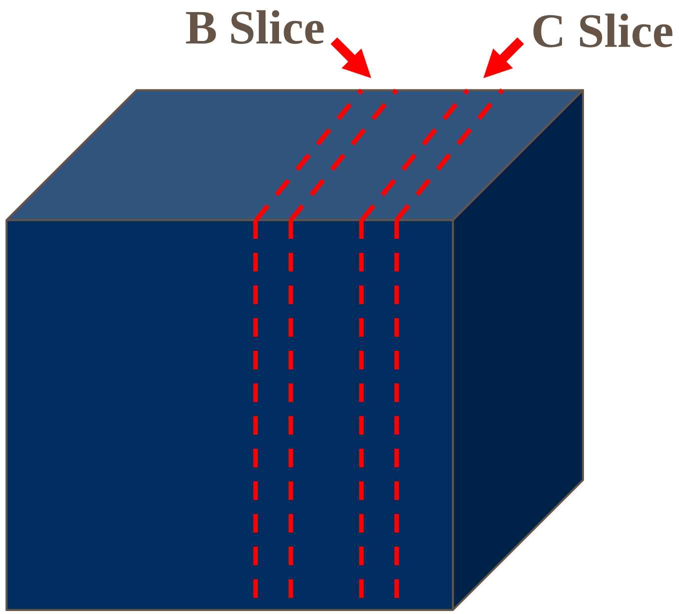
Liquid speed 0,5 m/s at the gate/mould

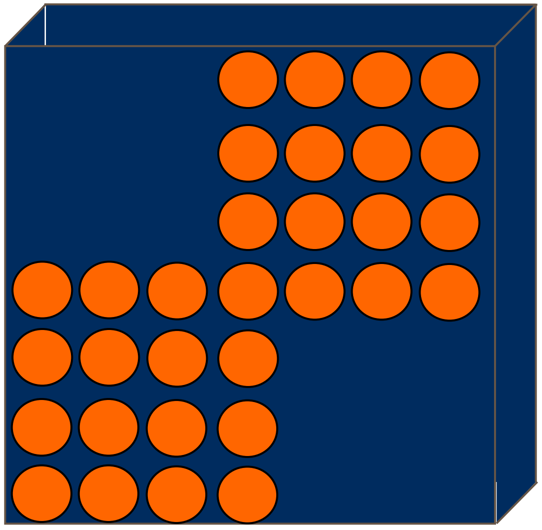
Casting weight 44 kg without top bars - Resin bonded sand mould

Induction furnace + Mg treatment by plunging process + Ladle and mould inoculation

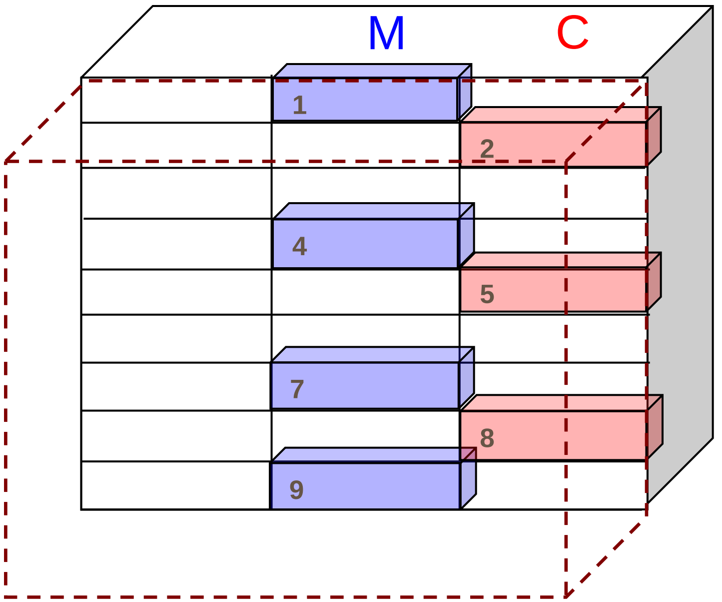
Methods: sampling

Two slices (B & C) and a half/cross section for detailed composition and micrographic analysis (mapping analysis)





Slice B or C



Slice B sampling

Background: The European Standard, EN-1563

Material Designation Symbol	Relevant Wall Thickness t [mm]	Minimum impact resistance Mean 3 tests [J]	Minimum impact Resistance Individual [J]	Minimum Tensile Strength [MPa]	Minimum 0.2% Proof Stress [MPa]	Elongation %
En-GJS-350-22U-LT Impact at - 40 C	<30	12	9	350	220	22
	30 < t ≤ 60	12	9	330	210	18
	60 <t ≤ 200	**10**	**7**	**320**	**200**	**15**
En-GJS-400-18U-LT Impact at - 20 C	<30	12	9	400	240	18
	30 <t ≤ 60	12	9	390	230	15
	60 <t ≤ 200	**10**	**7**	**370**	**220**	**12**

Methods:

charge compositions

Steel Scraps:

1 = Electrolytic Iron

2 = Good steel scrap

3 = Low quality steel scrap

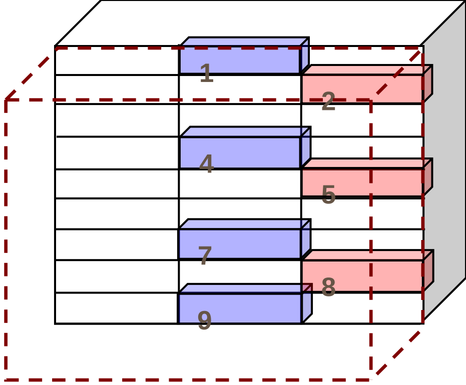
Returns: ferritic returns from an American foundry

Pig Iron: different grades and level of quality

Under investigation

Heat	PI	%PI	Steel	% Steel	% Returns
HS 8	1	67	1	33	0
HS 9	1	67	1	33	0
HS10	1	67	1	33	0
HS13	1	67	3	33	0
HS14	1	67	3	33	0
HS15	1	67	3	33	0
HS16	1	67	3	33	0
HS19	1	67	1	33	0
HS20	2	67	1	33	0
HS22	5	67	1	33	0
HS23	2	67	1	33	0
HS24	4	67	1	33	0
HS25	4	67	1	33	0
HS26	1	67	1	33	0
HS27	1	50	3	20	30
HS28	1	50	3	20	30
HS29	1	30	3	40	30
HS30	1	50	1	20	30
HS31	3	50	2	20	30
HS32	3	30	2	40	30
HS35	1	30	2	40	30
HS36	1	50	2	20	30
HS37	1	30	2	40	30
HS38	2	30	2	40	30
HS39	2	50	2	20	30
HS40	6	30	2	40	30
HS41	1	30	2	40	30
HS42	2	30	2	40	30
HS43	2	30	2	40	30
HS44	1	30	2	40	30
HS45	2	50	2	20	30
HS46	1	50	2	40	30
HS47	2	30	2	40	30
HS48	2	15	2	55	30
HS49	2	15	2	40	45
HS50	2	50	2	20	30
HS51	2	50	2	20	30
HS52	2	50	2	20	30
HS53	2	50	2	35	15
HS54		0	2	50	50
HS55	5	50	2	20	30
HS56	2	50	2	20	30
HS57	5	30	2	40	30
HS58	5	50	2	20	30
HS59	7	50	2	20	30
HS60	7	30	2	40	30

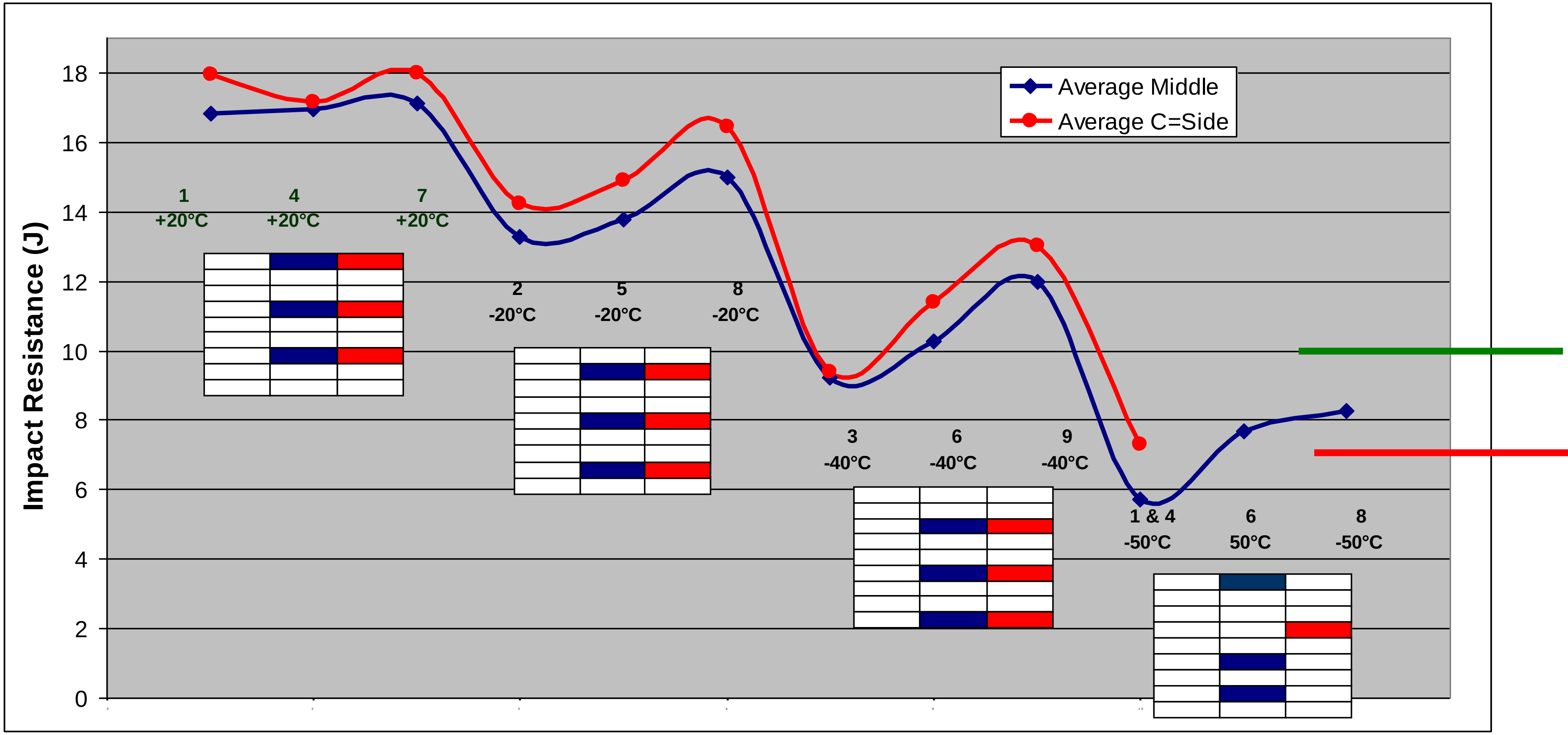
Effect of Position

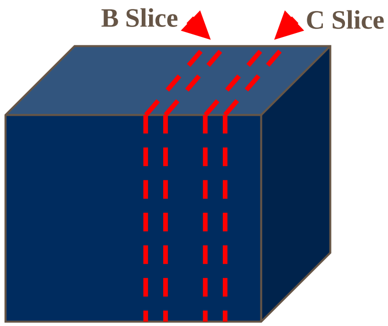


Average of impact tests for each position of the sample:

According to the position, some results at low temperature seem better than tests at higher temperature !!!

→ **side & bottom samples are the best**





Effect of Position

According to the position, some results at low temperature seem better than tests at higher temperature. Why ?

Nodules Count versus position ?

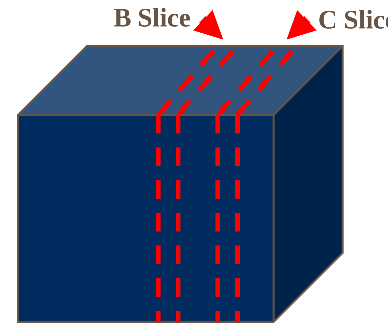
7 trap - HS20 **Slice B**

178	160	189	141	189	160	178
172	231	147	169	147	231	172
169	166	149	192	149	166	169
159	145	204	151	159	159	178
177	121	162	155	162	121	177
203	201	131	162	131	201	203
297	263	196	139	196	263	297

176 Nod/mm²

188 Nod/mm2

100
120
140
160
180
200
Max



Effect of Position

According to the position, some results at low temperature seem better than tests at higher temperature !!! Why?

Nodularity (% Nod) versus position ?

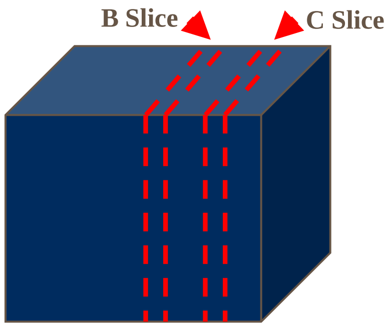
7 trap - HS20 **Slice B**

87	82	90	95	90	82	87
88	89	85	90	85	89	88
82	86	82	89	82	86	82
83	81	91	82	84	88	84
83	95	93	91	93	95	83
87	89	96	87	96	89	87
91	92	90	91	90	92	91

86,5%

90,5%

80-84
85-89
90-94
95-100



Effect of Position

According to the position, some results at low temperature seem better than tests at higher temperature !!! Why?

Nodularity (% Nod) versus position?

7 trap - HS20 **Slice C**

86	90	90	94	90	90	86
86	91	91	91	91	91	86
93	92	88	91	88	92	93
87	88	91	94	92	89	88
87	90	92	91	92	90	87
95	94	93	95	93	94	95
95	92	87	87	87	92	95

90,0%

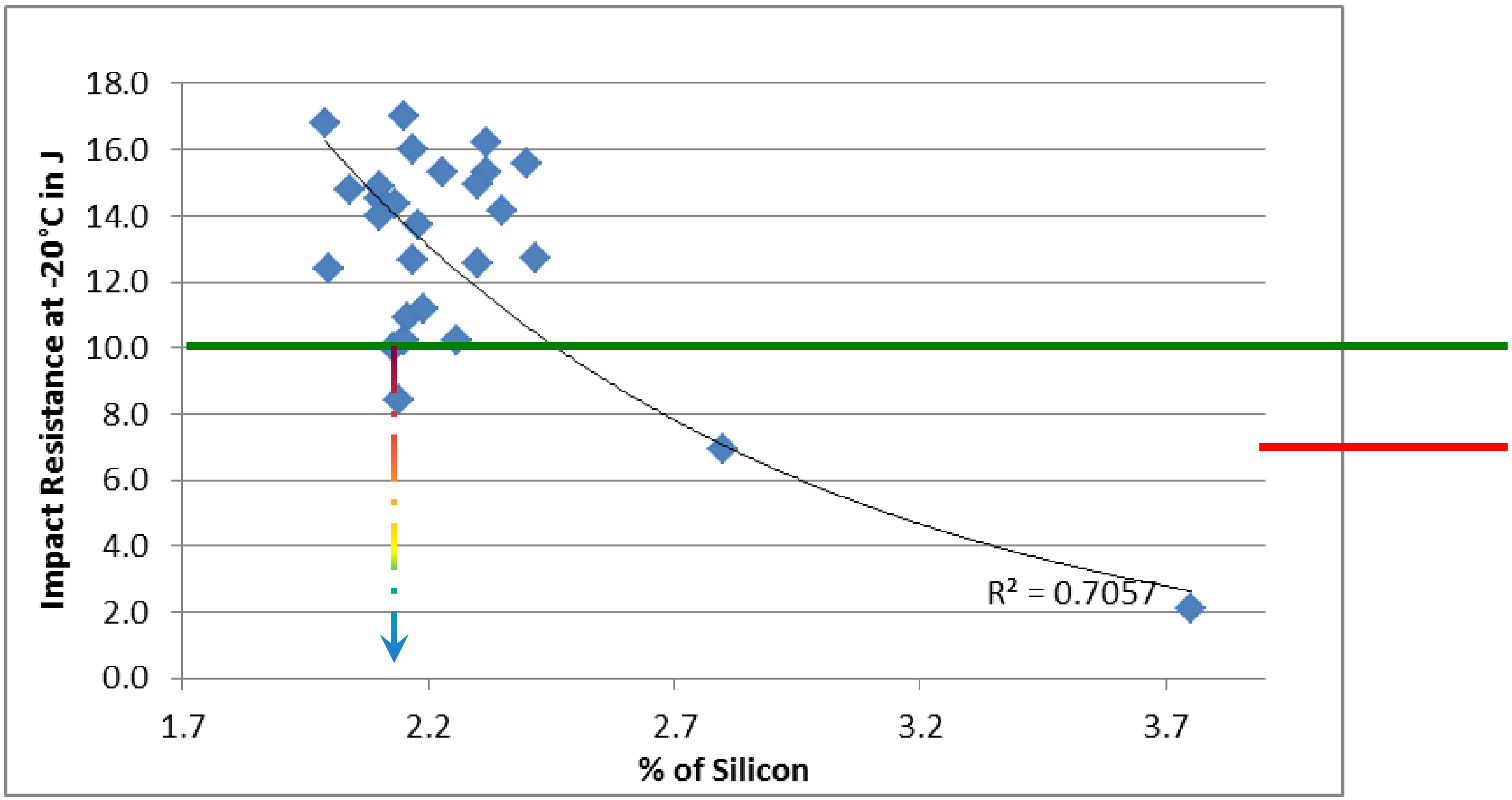
91,4%

80-84
85-89
90-94
95-100

Effect of Composition: Si %

The effects of Silicon on impact value is well known:

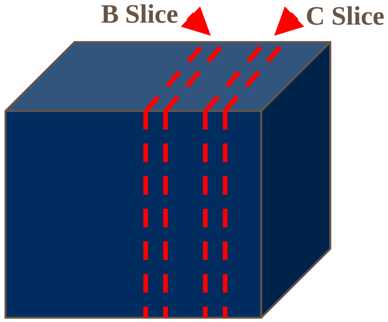
A Si% at 2.2 – 2.5 may only be acceptable under certain conditions. However we recommend to maintain the level lower than 2.2%.



Effect of Composition: Si %

The effect of Silicon on impact values is well known:

But, Si is associated with some “volumetric dispersion”



Si % for Slice B : heat HS20

2,33	2,38	2,33	2,33	2,33	2,38	2,33
2,31	2,38	2,34	2,36	2,38	2,37	2,31
2,34	2,40	2,38	2,43	2,38	2,40	2,34
2,29	2,36	2,32	2,31	2,37	2,30	2,35
2,27	2,28	2,30	2,29	2,30	2,27	2,27
2,31	2,33	2,36	2,33	2,36	2,33	2,31
2,34	2,35	2,31	2,34	2,31	2,35	2,34

2,36%

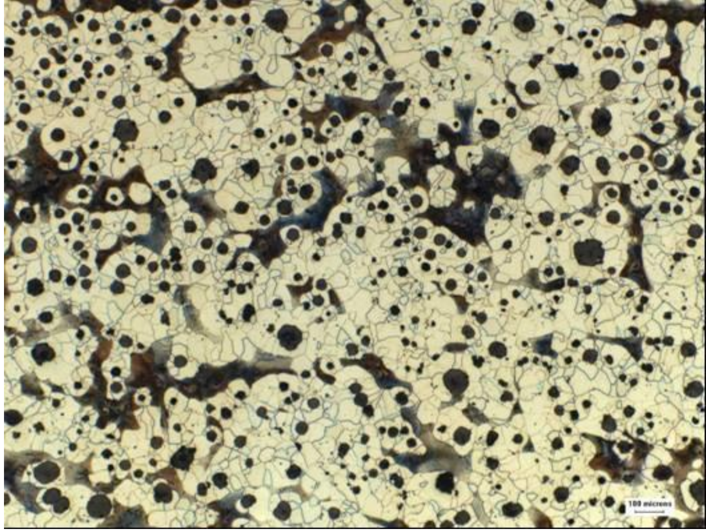
2,32%

≤2,31
2,32-2,34
2,35-2,37
≥2,38

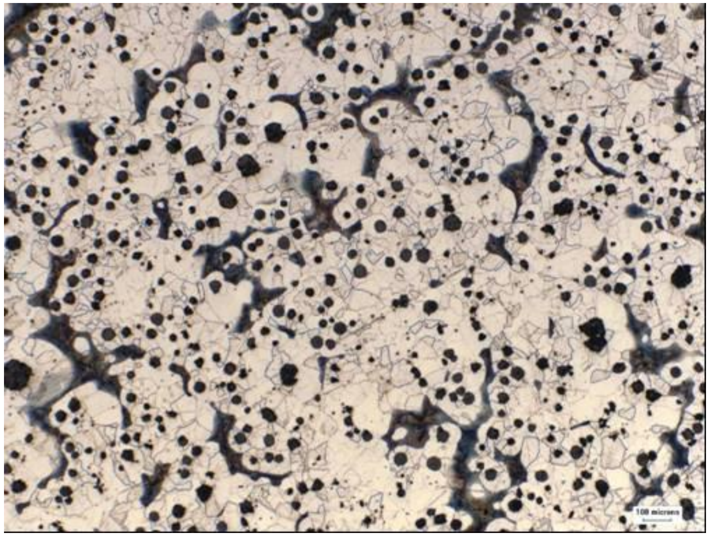
Effect of Composition:

The charge composition of HS29 **(30% PI – 40% bad steel scrap & 30% DI returns)** has a direct effect on pearlite content and structure despite exhibiting similar chemical analyses!

Figures for Slice B (HS29):

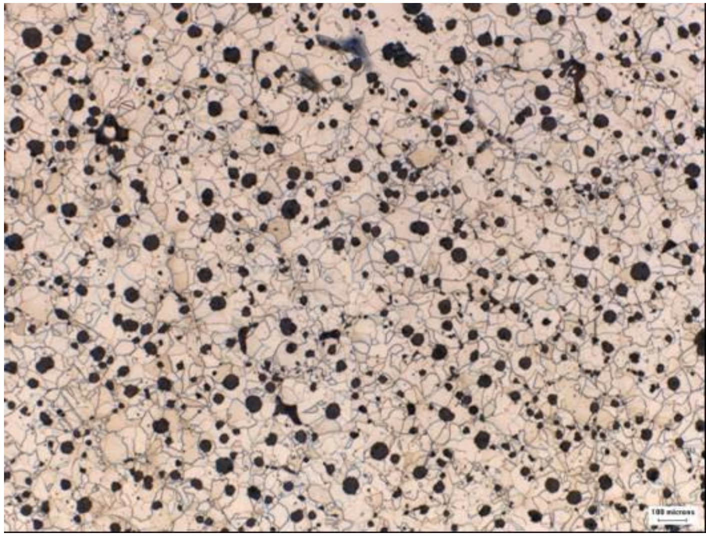


TM1 = Middle slice – top position



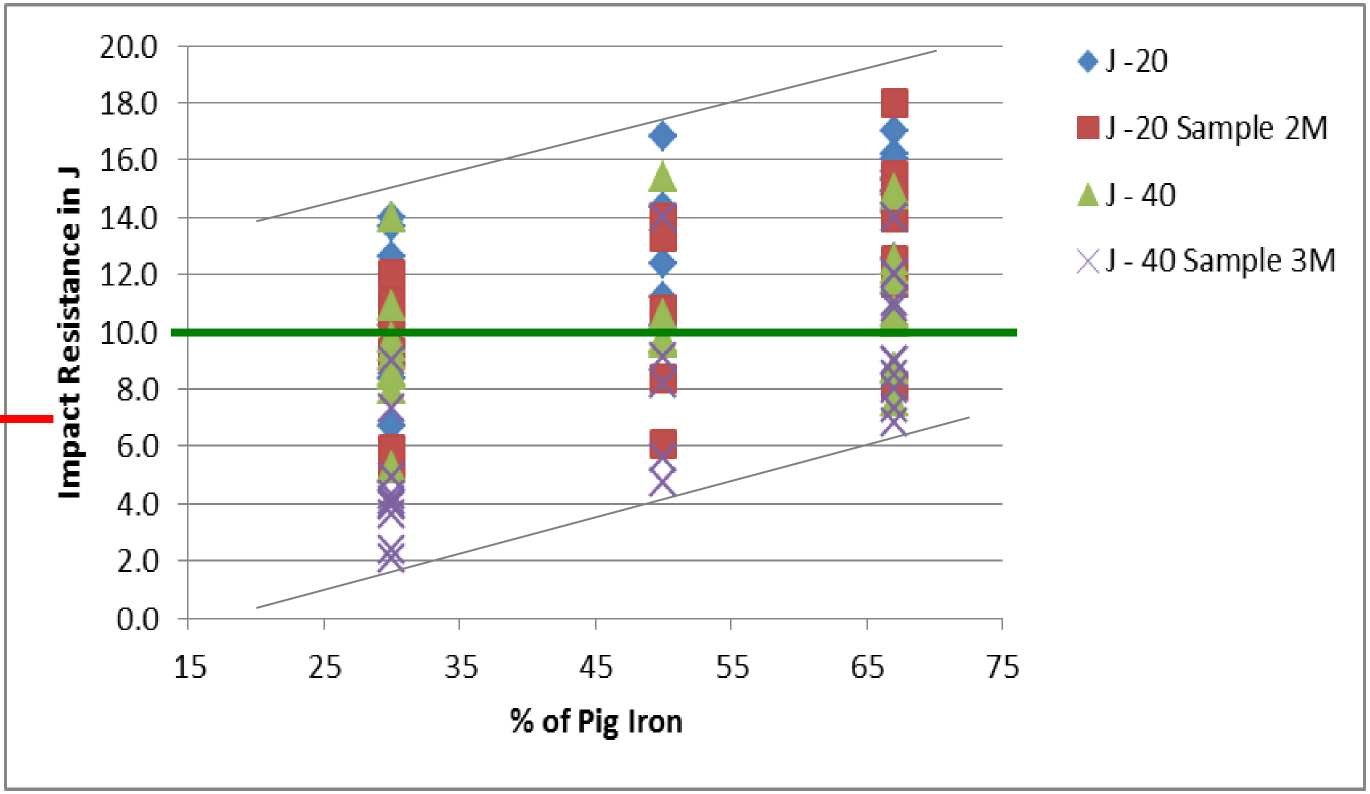
TM2 = Middle slice – middle position

TM3 = Middle slice – bottom position



Effect of Charge Composition:
Pig Iron ratio

A ratio close to 50% looks a "minimum"



	PI code	%PI	Steel code	%Steel	%Returns
HS22	5	67	1	33	0
HS25	4	67	1	33	0
HS26	1	67	1	33	0
HS19	1	67	1	33	0
HS 8	1	67	1	33	0
HS 9	1	67	1	33	0
HS10	1	67	1	33	0
HS24	4	67	1	33	0
HS39	2	50	2	20	30
HS36	1	50	2	20	30
HS16	1	67	3	33	0
HS28	1	50	3	20	30
HS31	3	50	2	20	30
HS13	1	67	3	33	0
HS15	1	67	3	33	0
HS38	2	30	2	40	30
HS35	1	30	2	40	30
HS40	6	30	2	40	30
HS29	1	30	3	40	30
HS32	3	30	2	40	30
HS43	2	30	2	40	30
HS41	1	30	2	40	30
HS45	2	50	2	20	30
HS37	1	30	2	40	30
HS44	1	30	2	40	30
HS42	2	30	2	40	30

26 heats

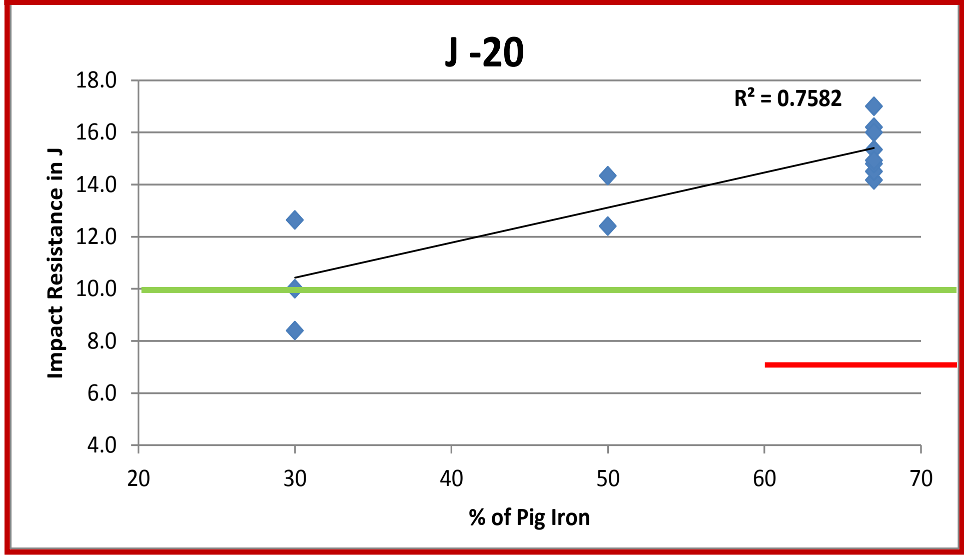
Ceq < 4.28% -- Si< 2.40% -- P< 0.035%

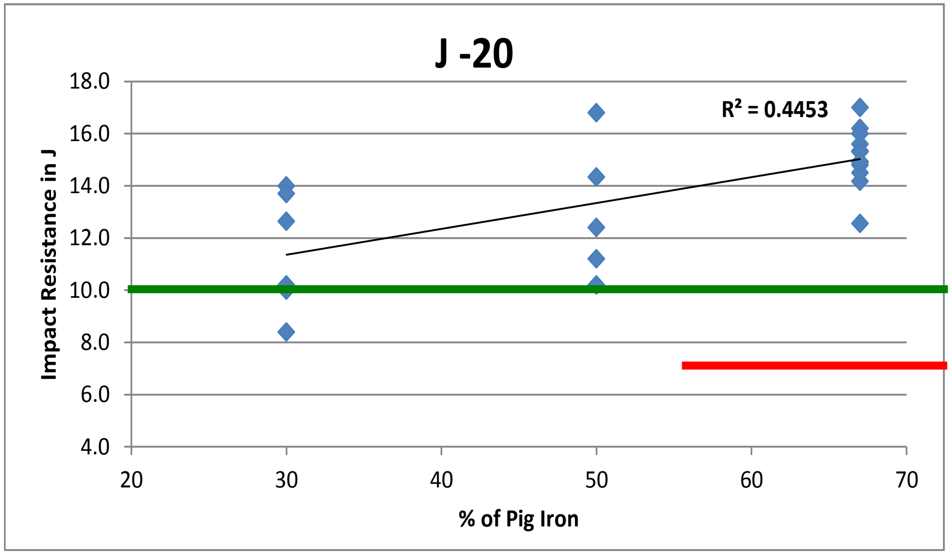
Effect of Charge Composition: Pig Iron Ratio

Effect on fluctuation for average impact at -20°C (in J)

only one Pig Iron grade (TF10):
less fluctuations & better correlation!

Ceq < 4.28%
Si< 2.40%
P< 0.035%





Effect of Charge and Castings Composition: Quality Index

Most of lower impact values are also associated with a bad quality index: a tool for the future

	Sum of all element than the Five	Sum of pearlitic elements	Sum of carbitic elements	Cu equi	Mn equi<0.35	Mn equi	Px factor	Ferrite	Purity	Segregation	J - RT	J -20	J -20 Sample 2M	J - 40	J - 40 Sample 3M	J - 50
HS22	0.063	0.107	0.076	0.06	0.09	0.17	0.27	86.7	0.08	0.62	17.0	15.3	8.1	12.2	10.9	8.1
HS23	0.086	0.092	0.063	0.07	0.09	0.18	0.28	89.6	0.04	0.58	14.4	10.9		9.1		4.4
HS25	0.108	0.082	0.091	0.04	0.12	0.29	0.37	89.1	0.07	0.84	20.0	12.6	11.7	7.6	6.8	5.5
HS26	0.159	0.091	0.073	0.07	0.14	0.28	0.40	86.9	0.05	0.62	18.9	14.9	14.9	10.6	9.0	6.9
HS20	0.098	0.078	0.072	0.05	0.11	0.22	0.40	89.5	0.06	0.66	17.4	15.6	15.5	12.5	8.5	8.5
HS19	0.162	0.093	0.086	0.07	0.16	0.34	0.52	86.8	0.07	0.82	17.9	17.0	15.0	15.0	12.0	10.4
HS 8	0.164	0.077	0.091	0.04	0.18	0.37	0.53	85.3	0.05	0.76	17.0	15.3	15.0	10.3	9.0	
HS 9	0.163	0.077	0.086	0.10	0.25	0.33	0.74	75.3	0.08	0.68	16.7	14.2	14.0	8.7	8.0	
HS10	0.169	0.092	0.087	0.13	0.26	0.33	0.82	75.1	0.09	0.73	17.5	16.2	15.0	11.8	11.0	
HS30	0.326	0.199	0.156	0.14	0.36	0.58	1.08	73.7	0.05	1.40	3.2	2.1		1.8		1.7
HS24	0.105	0.308	0.312	0.07	0.35	0.50	1.12	67.7	0.08	1.25	21.2	14.9	12.5	8.7	7.3	6.7
HS39	0.262	0.189	0.153	0.12	0.35	0.55	1.20	77.5	0.07	1.18	17.0	16.8	14.0	15.4	14.0	12.0
HS36	0.294	0.187	0.160	0.12	0.39	0.59	1.28	75.4	0.06	1.16	15.8	12.4	8.4	10.6	4.7	6.0
HS16	0.220	0.263	0.223	0.12	0.42	0.54	1.32	70.1	0.07	1.26	16.5	14.8	18.0	11.8	14.0	
HS28	0.331	0.225	0.208	0.10	0.44	0.73	1.36	75.5	0.07	1.56	18.1	14.3	13.3	9.7	9.1	7.6
HS31	0.269	0.264	0.167	0.18	0.44	0.50	1.37	68.6	0.05	1.44	14.6	11.2	10.8	9.8	8.2	6.3
HS13	0.242	0.261	0.220	0.14	0.46	0.57	1.51	69.4	0.08	1.34	16.7	14.5	14.0	10.7	9.0	
HS15	0.237	0.294	0.257	0.14	0.48	0.60	1.56	67.2	0.07	1.33	17.2	16.0	14.0	14.8	12.0	
HS14	0.248	0.271	0.223	0.15	0.48	0.56	1.61	67.1	0.09	1.28	16.0	12.7	9.0	9.3	7.0	
HS27	0.387	0.335	0.244	0.23	0.58	0.62	1.66	56.6	0.08	2.05	15.8	7.0	6.1	4.6	4.1	3.7
HS38	0.289	0.247	0.188	0.16	0.48	0.60	1.67	70.7	0.08	1.38	22.0	14.0	11.0	14.0	9.0	8.5
HS35	0.301	0.239	0.186	0.15	0.49	0.60	1.68	69.6	0.08	1.28	11.4	6.7	5.4	8.5	4.1	3.9
HS40	0.291	0.289	0.240	0.17	0.52	0.67	1.84	67.2	0.12	1.66	15.7	13.7	12.0	9.2	7.3	8.0
HS29	0.334	0.355	0.300	0.14	0.60	0.79	1.86	59.9	0.07	1.58	17.0	12.6	9.3	10.9	4.9	6.9
HS32	0.356	0.370	0.227	0.27	0.68	0.58	2.14	53.4	0.06	2.01	14.7	10.2	10.6	9.5	3.9	5.0
HS43	0.265	0.441	0.365	0.20	0.76	0.76	2.48	51.4	0.08	1.92				8.0	3.6	3.5
HS41	0.237	0.431	0.360	0.20	0.77	0.70	2.56	51.3	0.09	1.92	13.8	10.0	5.4	9.8	4.3	4.1
HS45	0.472	0.451	0.260	0.38	0.86	0.66	2.60	40.7	0.07	2.77	12.1	10.2	6.1	9.6	5.6	5.7
HS37	0.518	0.384	0.284	0.25	0.81	1.01	2.62	57.5	0.08	2.56	12.2	8.4	5.9	8.6	4.0	3.7
HS44	0.541	0.532	0.319	0.43	1.02	0.77	3.10	30.5	0.12	3.20				5.3	2.1	2.0
HS42	0.528	0.545	0.323	0.44	1.04	0.76	3.15	29.5	0.08	3.17				5.2	2.4	2.5

Effect of Charge and Castings Composition:
Quality Index

Most of lower impact values are also associated with a bad quality index: a tool for the future

	Sum of all element than the Five	Sum of pearlitic elements	Sum of carbitic elements	Cu equi	Mn equi<0.35	Mn equi	Px factor	Ferrite	Purity	Segregation	J - RT	J -20	J -20 Sample 2M	J - 40	J - 40 Sample 3M	J - 50
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HS25	0.108	0.082	0.091	0.04	0.12	0.29	0.37	89.1	0.07	0.84	20.0	12.6	11.7	7.6	6.8	5.5
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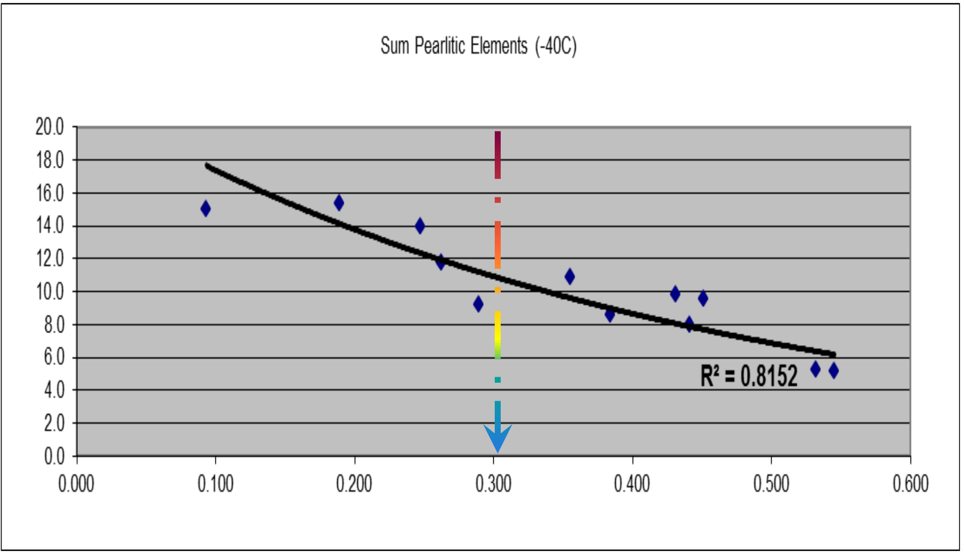
HS20	0.098	0.078	0.072	0.05	0.11	0.22	0.40	89.5	0.06	0.66	17.4	15.6	15.5	12.5	8.5	8.5
HS19	0.162	0.093	0.086	0.07	0.16	0.34	0.52	86.8	0.07	[illegible]	[illegible]	[illegible]	[illegible]	15.0	12.0	10.4
HS 8	0.164	0.077	0.091	0.04	0.18	0.37	0.53	85.3	0.05	[illegible]	[illegible]	[illegible]	[illegible]	10.3	9.0	
HS 9	0.163	0.077	0.086	0.10	0.25	0.33	0.74	75.3	0.08	0.68	16.7	14.2	14.0	8.7	8.0	
HS10	0.169	0.092	0.087	0.13	0.26	0.33	0.82	75.1	0.09	0.73	17.5	16.2	15.0	11.8	11.0	
HS30	0.326	0.199	0.156	0.14	0.36	0.58	1.08	73.7	0.05	1.40	3.2	2.1		1.8		1.7
HS24	0.105	0.308	0.312	0.07	0.35	0.50	1.12	67.7	0.08	1.25	21.2	14.9	12.5	8.7	7.3	6.7
HS39	0.262	0.189	0.153	0.12	0.35	0.55	1.20	77.5	0.07	1.18	17.0	16.8	14.0	15.4	14.0	12.0
HS36	0.294	0.187	0.160	0.12	0.39	0.59	1.28	75.4	0.06	1.16	15.8	12.4	8.4	10.6	4.7	6.0
HS16	0.220	0.263	0.223	0.12	0.42	0.54	1.32	70.1	0.07	1.26	16.5	14.8	18.0	11.8	14.0	
HS28	0.331	0.225	0.208	0.10	0.44	0.73	1.36	75.5	0.07	1.56	18.1	14.3	13.3	9.7	9.1	7.6
HS31	0.269	0.264	0.167	0.18	0.44	0.50	1.37	68.6	0.05	1.44	14.6	11.2	10.8	9.8	8.2	6.3
HS13	0.242	0.261	0.220	0.14	0.46	0.57	1.51	69.4	0.08	1.34	16.7	14.5	14.0	10.7	9.0	
HS15	0.237	0.294	0.257	0.14	0.48	0.60	1.56	67.2	0.07	1.33	17.2	16.0	14.0	14.8	12.0	
HS14	0.248	0.271	0.223	0.15	0.48	0.56	1.61	67.1	0.09	1.28	16.0	12.7	9.0	9.3	7.0	
HS27	0.387	0.335	0.244	0.23	0.58	0.62	1.66	56.6	0.08	2.05	15.8	7.0	6.1	4.6	4.1	3.7
HS38	0.289	0.247	0.188	0.16	0.48	0.60	1.67	70.7	0.08	1.38	22.0	14.0	11.0	14.0	9.0	8.5
HS35	0.301	0.239	0.186	0.15	0.49	0.60	1.68	69.6	0.08	1.28	11.4	6.7	5.4	8.5	4.1	3.9
HS40	0.291	0.289	0.240	0.17	0.52	0.67	1.84	67.2	0.12	1.66	15.7	13.7	12.0	9.2	7.3	8.0
HS29	0.334	0.355	0.300	0.14	0.60	0.79	1.86	59.9	0.07	1.58	17.0	12.6	9.3	10.9	4.9	6.9
HS32	0.356	0.370	0.227	0.27	0.68	0.58	2.14	53.4	0.06	2.01	14.7	10.2	10.6	9.5	3.9	5.0
HS43	0.265	0.441	0.365	0.20	0.76	0.76	2.48	51.4	0.08	1.92				8.0	3.6	3.5
HS41	0.237	0.431	0.360	0.20	0.77	0.70	2.56	51.3	0.09	1.92	13.8	10.0	5.4	9.8	4.3	4.1
HS45	0.472	0.451	0.260	0.38	0.86	0.66	2.60	40.7	0.07	2.77	12.1	10.2	6.1	9.6	5.6	5.7
HS37	0.518	0.384	0.284	0.25	0.81	1.01	2.62	57.5	0.08	2.56	12.2	8.4	5.9	8.6	4.0	3.7
HS44	0.541	0.532	0.319	0.43	1.02	0.77	3.10	30.5	0.12	3.20				5.3	2.1	2.0
HS42	0.528	0.545	0.323	0.44	1.04	0.76	3.15	29.5	0.08	3.17				5.2	2.4	2.5

Si = 3.75

Effect of Charge and Castings Composition:

Quality Index

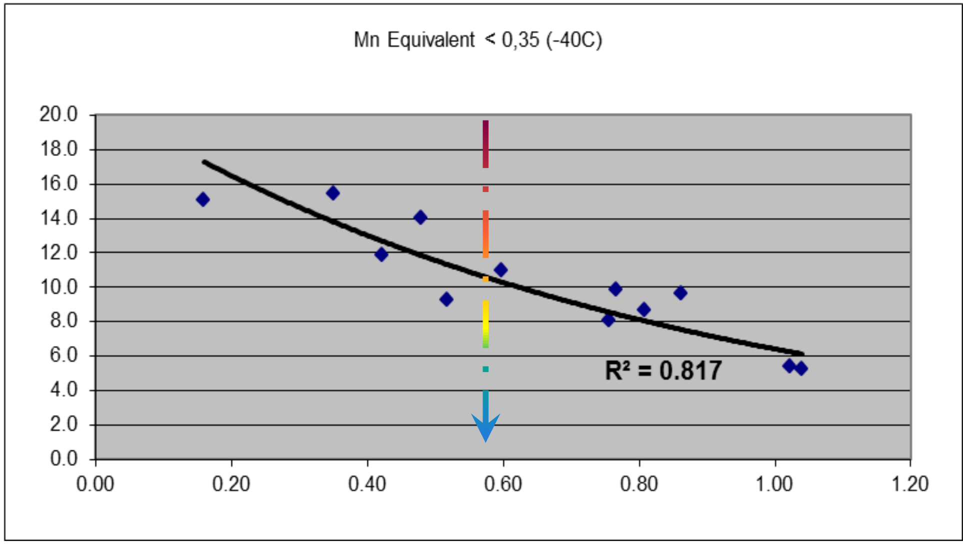
Impact at -40°C in J



C=3,20-3,45%, Si=2,00-2,25%,

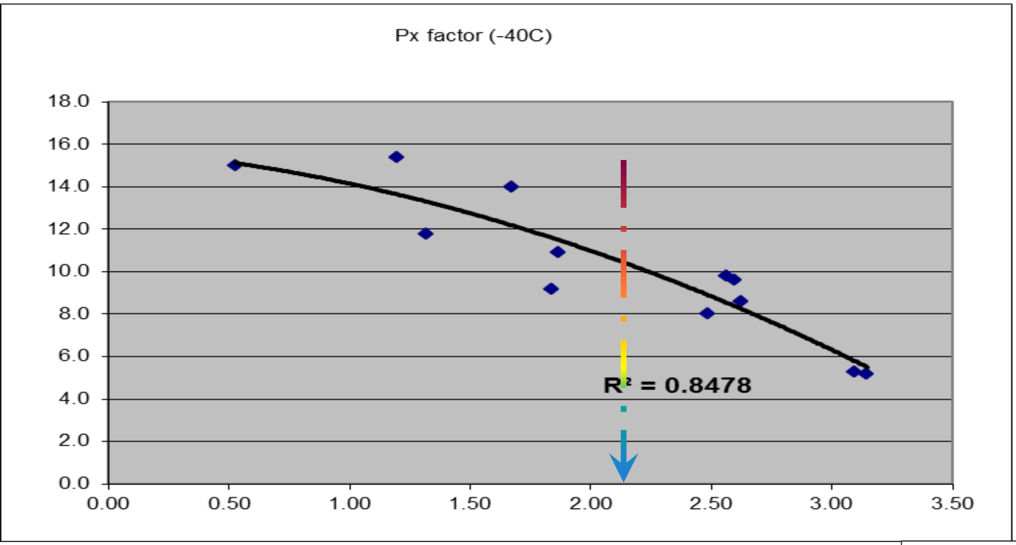
Mg=0,035-0,050%, P < 0.030%

Equivalent Mn (PSA-France) =
Mn + 3 Cu + 3 Cr + 12 Sn + 24 Sb



Effect of Charge and Castings Composition: Quality Index

Impact at -40°C in J



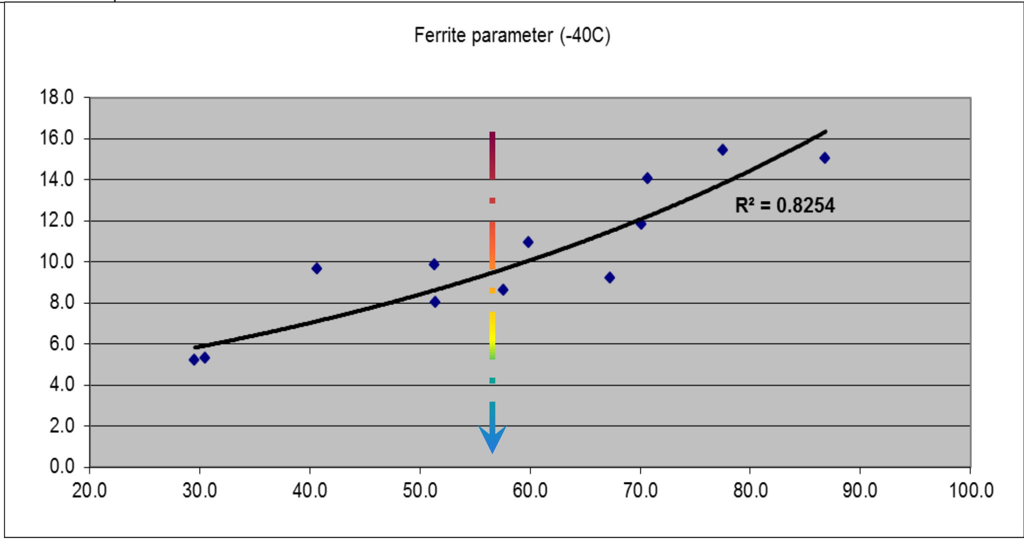
C=3,20-3,45%, Si=2,00-2,25%,

Mg=0,035-0,050%, P < 0.030%

Px Factor (Thielmann) =

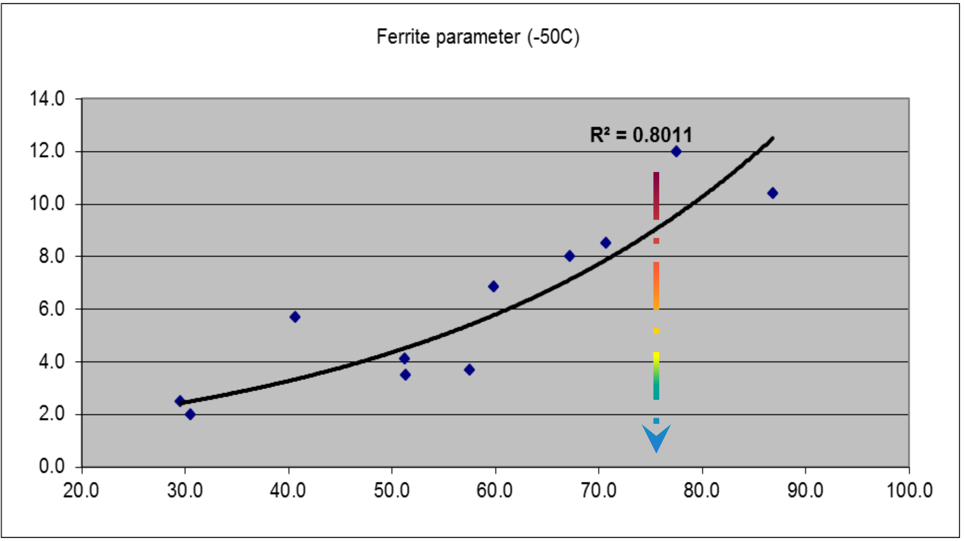
3 Mn + 357 Pb + 7,75 Cu + 20,1 As +
9,6 Cr + 333 Bi + 71,7 Sb + 90 Sn

Ferrite parameter (Mortz) =
92,3 – 96,2 Mn – 211 Cu – 14270 Pb – 2815 Sb

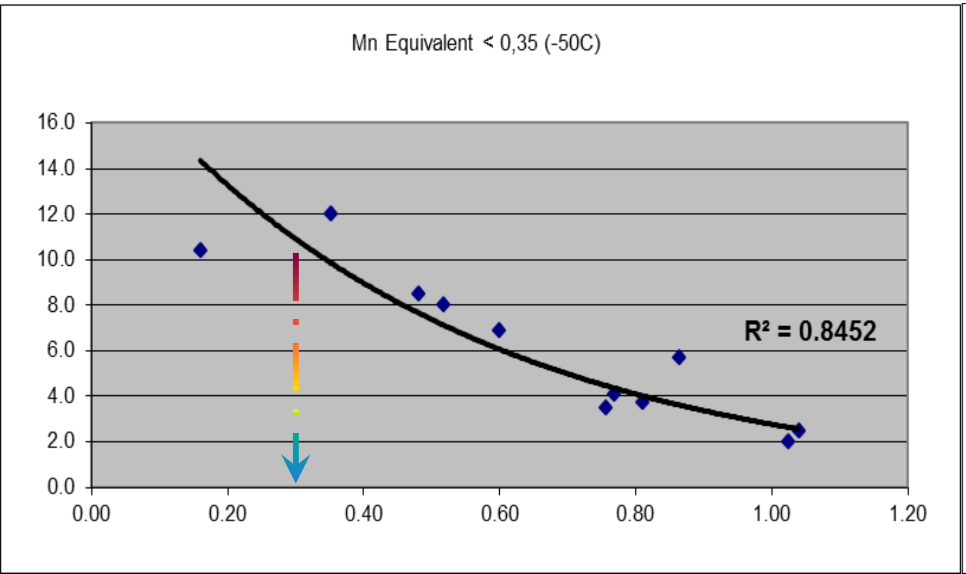


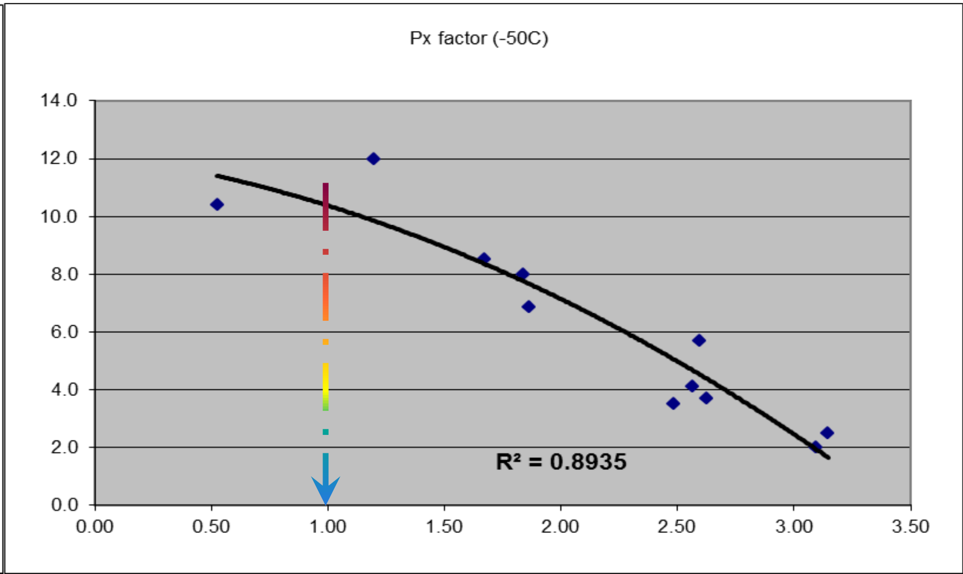
Effect of Charge and Castings Composition: Quality Index

Impact at -50°C in J



C=3,20-3,45%, Si=2,00-2,25%, Mg=0,035-0,050%, P < 0.030%





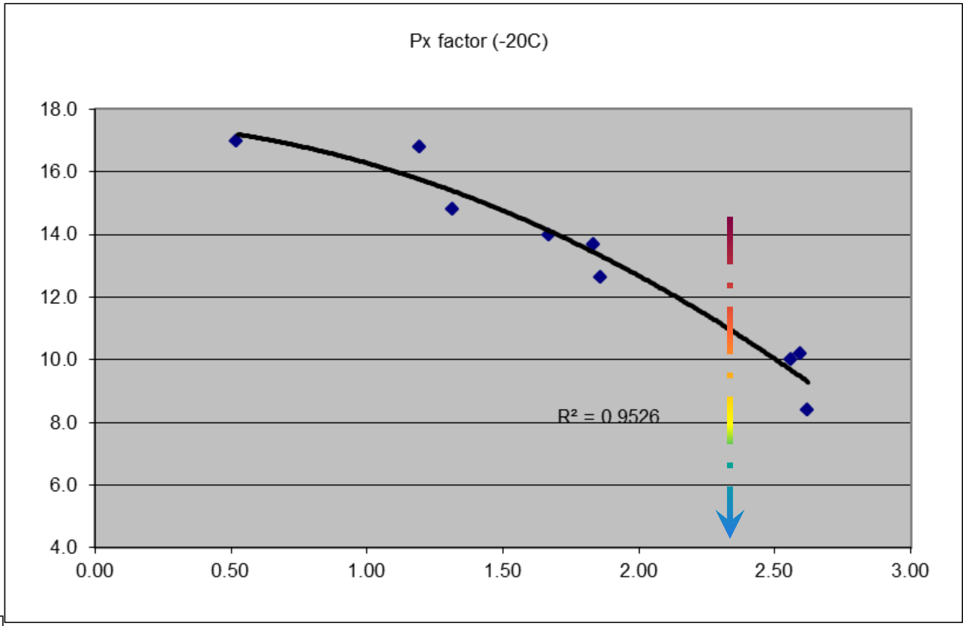
Effect of Charge and Castings Composition:

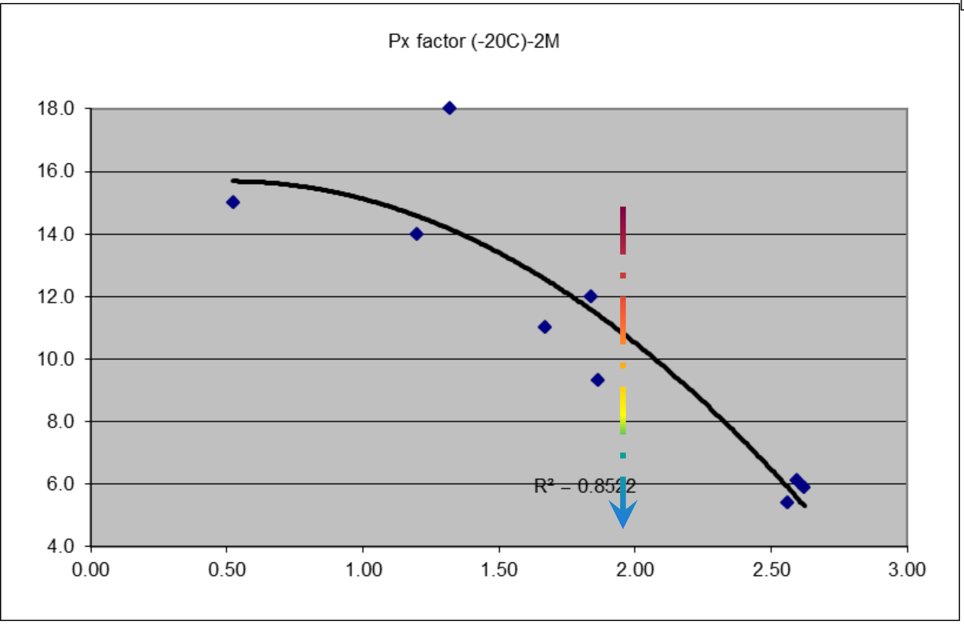
Quality Index

Impact at -20°C in J
Average & position "2"

C=3,20-3,45%, Si=2,00-2,25%,

Mg=0,035-0,050%, P < 0.030%



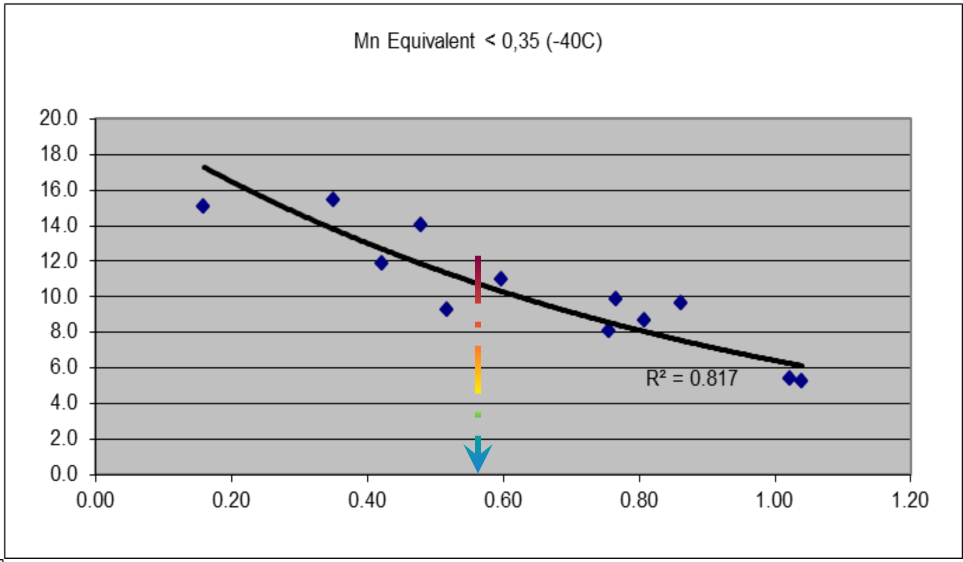


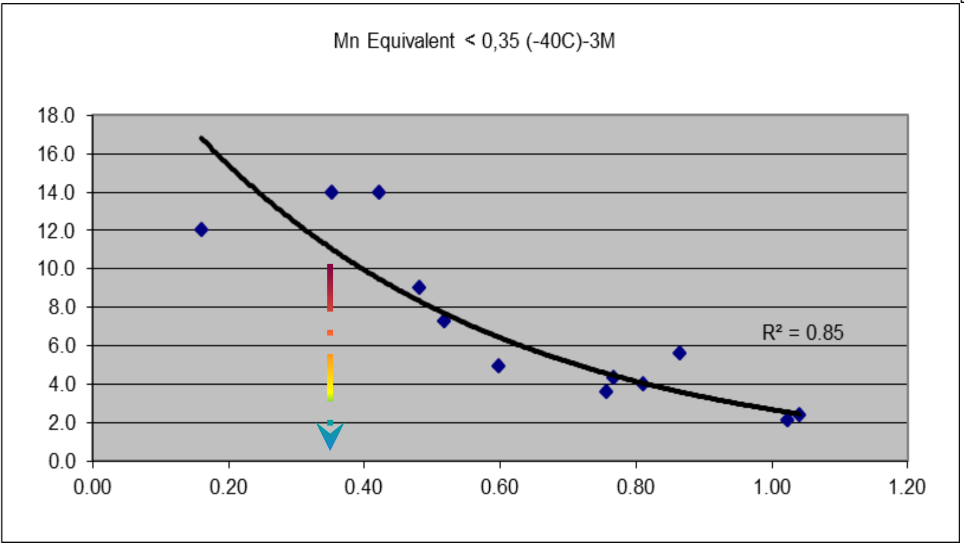
Effect of Charge and Castings Composition:
Quality Index

Impact at -40°C in J
Average & position "3"

C=3,20-3,45%, Si=2,00-2,25%,

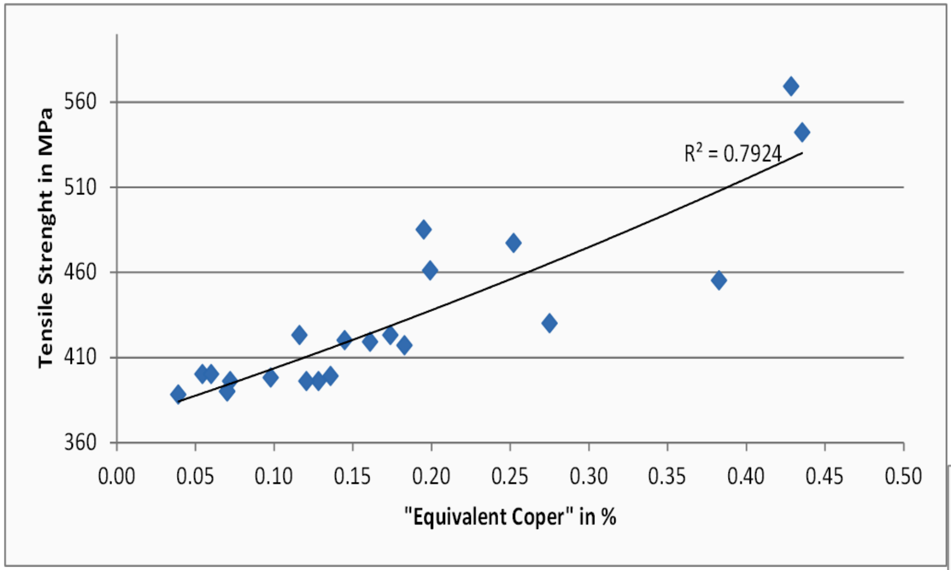
Mg=0,035-0,050%, P < 0.030%





Effect of Charge and Castings Composition: Mechanical Characteristics

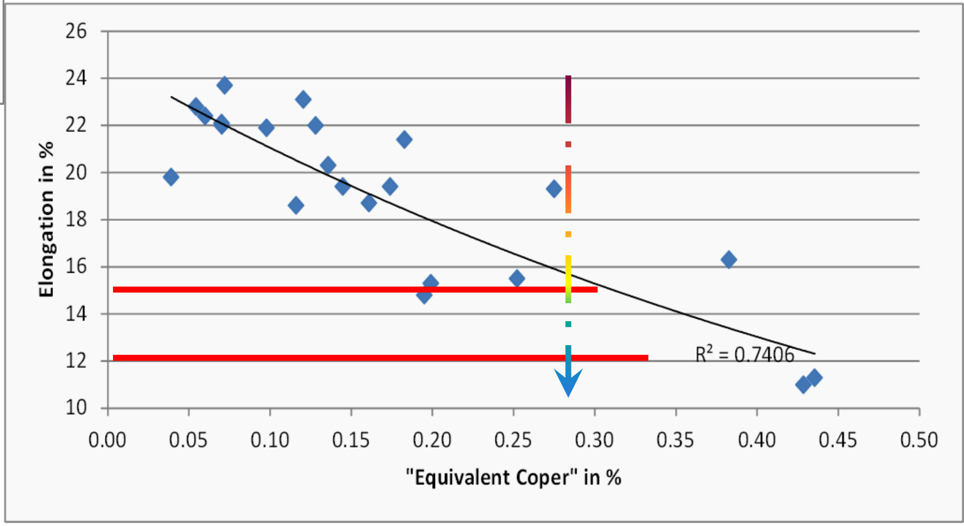
Equivalent Copper =
(0,44Mn+5,6P+4,9Cu+0,37Ni+0,37Cr+7,9Mo+4,4Ti+39Sn+80Sb)/4,9



3.04 < C < 3.55 %,

1.99 < Si < 2.40%,

P < 0.034%



Summary:

According to the preceding slides, we can confirm that the following parameters must be closely controlled in order to meet the specifications minimum values in the as cast state:

	Impact -20°C	Impact -40°C	Impact -50°C	Elongation
Position	Botom and side			
Silicon %	< 2.2%			
Pig Iron %	> 30	> 50		
Sum of Pearlitic Elements		< 0.32		
Equivalent Mn		< 0.063	< 0.037	
Px Factor	< 2.50	< 2.25	< 1.10	
Ferrite Parameter		> 80	> 80	
Equivalent Copper				< 0.30

ATTENTION: erreur sur Mn equi: 0.63 et non 0.063

Conclusions:

•The production of thick castings in ferritic DI with impact test at -20°C, -40°C and -50°C is possible under certain conditions:

Sample position is fundamental:

Different cooling sequences & concentrations/segregations of elements are effective: nodularity, nodule count & ferrite/pearlite ratio differences are a reality

Casting composition must be kept under tight control:

A low Silicon % has been confirmed as well as the cumulative effect of other elements by the Quality Index.

The charge composition and its quality are a reality:

The effect of High Purity Pig Iron in the metallic charge has been shown to promote higher mechanical properties. A higher purity charge also may accommodate a higher final silicon level, without negatively affecting impact strength or transition temperature. Higher silicon levels strengthen the matrix and produce higher tensile and yield strengths.

The use of a “quality index” may be very useful in the successful production of heavy section ductile iron castings.

Alexandre Cabanne

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