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Modern Design Criteria for Stainless Steel Welding Consumables

by

Vincent van der Mee & Jan Hilkes

CWA Welding Symposium, October 22, 2002 Toronto

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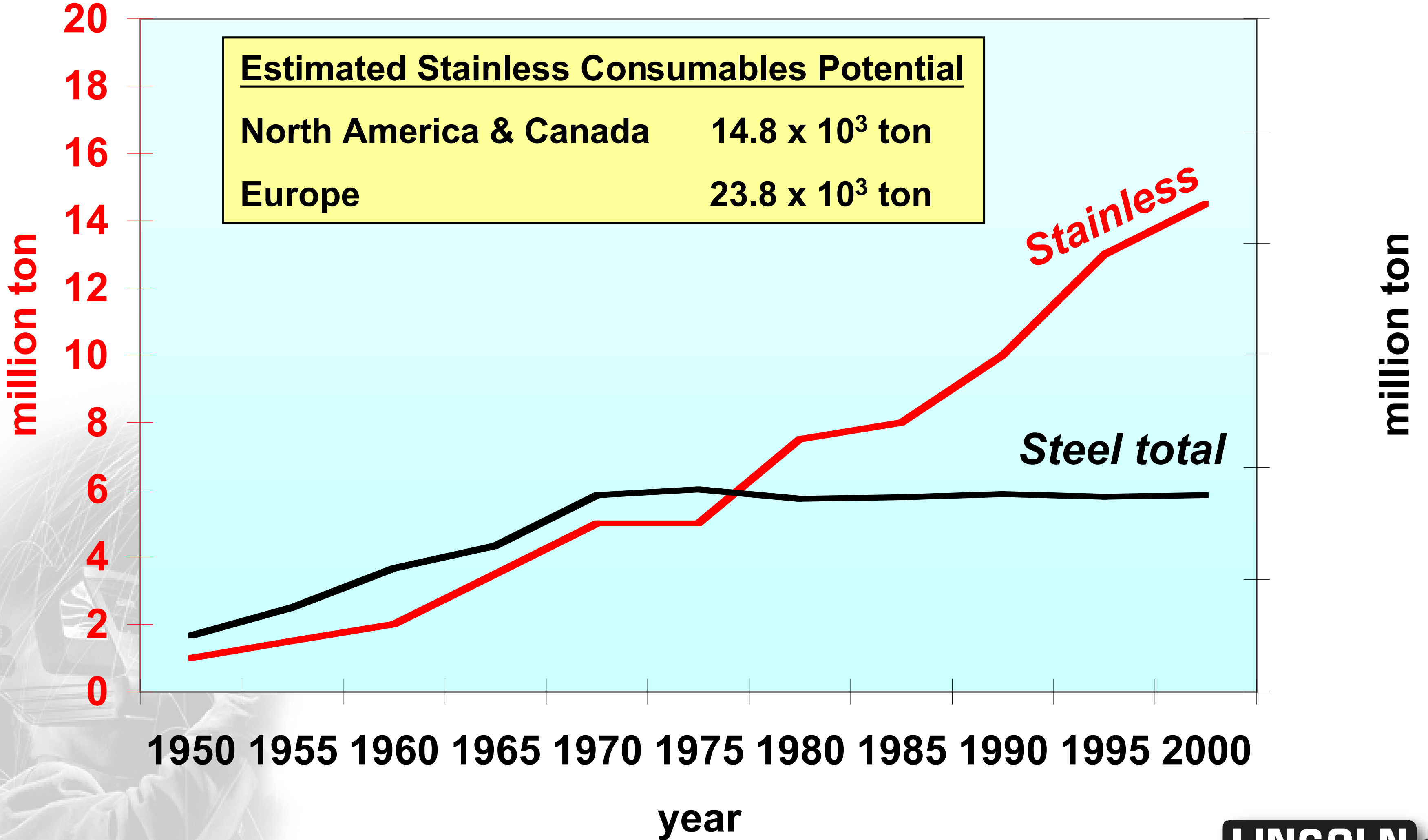
Content

Introduction

Stainless Steel World Production 1950-2000



Introduction
Share of consumables per process

Process	*Total Welding Market*	*Stainless Steel Only*
SMAW	*22 %*	*60 %*
GMAW	*57 %*	*35 %*
FCAW	*15 %*	*5 %*
SAW	*6 %*	*<1 %*

Weld Metal Grades
Stainless Steel Base Materials

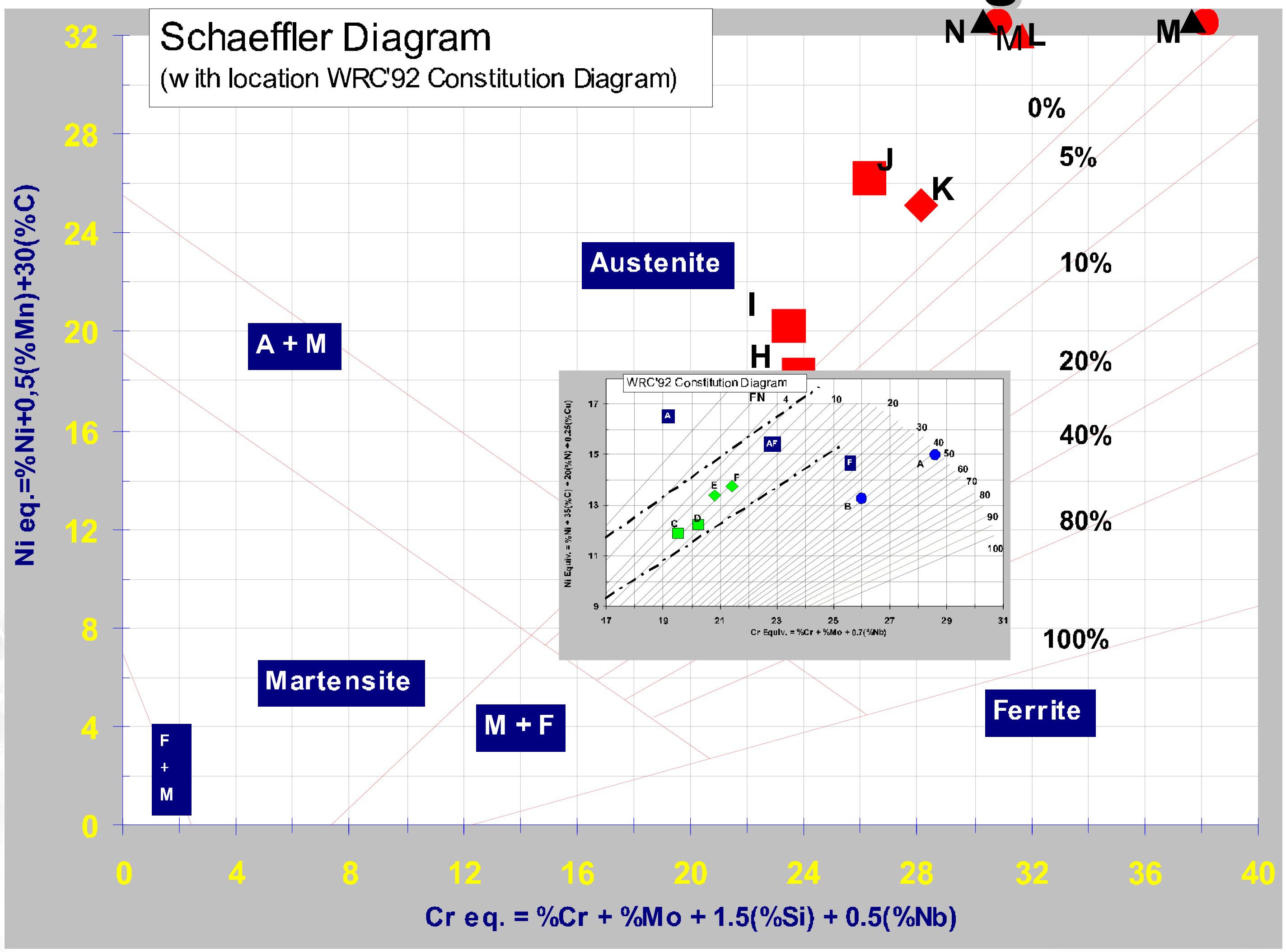
- ***Regular stainless steel***
  - ***Austenitic, with up to 12 FN***
- ***Fully Austenitic***
- ***Duplex & Superduplex***
- ***Supermartensitic***

Non N-alloyed Base Metal	N-alloyed Base Metal	Weld Metal EN / AWS	Identification
Supermartensitic			
X80-11Cr2Ni		22 9 3 NL / 2209	B
X80-13Cr4.5Ni1.5Mo / X80-13Cr6Ni2.5Mo		25 9 4CuWNL / 2553	A
(Super)Duplex			
	X2CrNiMoN 22-5-3	22 9 3 NL / 2209	B
	X2CrNiMoN 25-7-4	25 9 4CuWNL / 2553	A
	X2CrNiMoCuWN 25-7-4	25 9 4CuWNL / 2553	A
Regular stainless steel			
X2CrNi18-9	X2CrNiN18-9	19 9 L / 308L	C
X6CrNiTi18-10		19 9 Nb / 347	D
X2CrNi17-12-2	X2CrNiMoN17-12-2	19 12 3 L / 316L	E
X6CrNiMoTi17-12-2		19 12 3 Nb / 318	F
X2CrNiMo18-14-3	X2CrNiMoN17-13-5	18 16 5 NL / (4439)	G
		20 16 3 MnNL / (4455)	H
Fully Austenitic			
X1NiCrMoCu25-20-5		20 25 5 CuNL / 385	J
	X1CrNiMoN25-22-2	[illegible] / 310Mo	K
X1N[illegible]		27 31 4 CuL / 383	L
	X1CrNiMoCuN20-18-7	Ni6059 / NiCrMo-13	M
		Ni6625 / NiCrMo-3	N

Increased resistance to stress corrosion

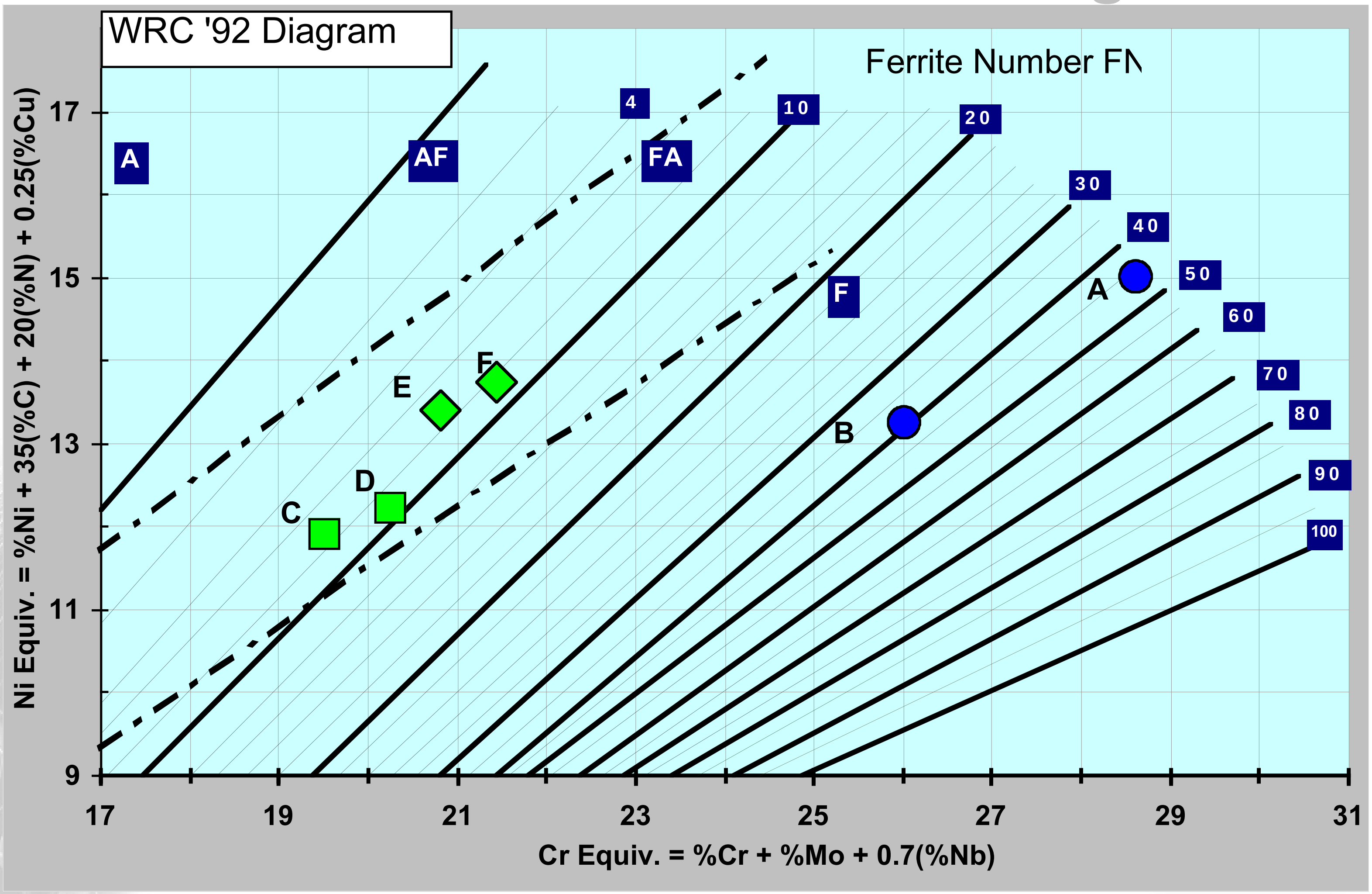
Increased resistance to pitting and general corrosion

Weld Metal Grades
Schaeffler Diagram



Weld Metal Grades

WRC '92 diagram



Weld Metal Design Criteria
Controlled Ferrite content

- ***A controlled weldmetal ferrite content requires a balanced chemical composition***
- ***Controlled ferrite for an E(R)316L type implies a ferrite content of 4 - 10 FN***
- ***Too low ferrite increases the risk of hot-cracking***
- ***Too high ferrite increases the risk of embrittlement and/or preferential corrosion attack of the ferrite***

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Weld Metal Design Criteria

External requirements for E316L electrodes

	AWS A5.4	EN 1600	Smitweld Standard
% C	0.04 max.	0.04 max.	0.030 max.
% Si	0.90 max.	1.20 max.	0.4-0.9
% Mn	0.5-2.5	2.0 max.	0.5-1.1
% Cr	17.0-20.0	17.0-20.0	17.0-19.0
% Ni	11.0-14.0	10.0-13.0	11.0-12.5
% Mo	2.0-3.0	2.5-3.0	2.7-3.0
Ferrite (FN)	---	---	4-10

Among investigated European and US suppliers,
6 out of 14 comply for "-17" grades
10 out of 12 comply for "-16" grades

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Weld Metal Design Criteria
Horses for Coarses!

♦ *The type of slag system to be used, depends on the required combination of:*

- *Weldability,*
- *Mechanical Properties,*
- *Corrosion Resistance AND*
- *Specific Application*

Weld Metal Design Criteria

- ***Balanced chemistry***
  - ***Cr, Ni, Mo, Mn, Si, C, S, P, Cu, Nb, W & N, etc.***
- ***Weld metal to match or exceed base metal for CORROSION RESISTANCE.***
  - ***Core-wire alloyed***
- ***Weld metal adapted to match or exceed base metal MECHANICAL properties.***
- ***Free of detrimental phases***
  - ***Carbides, sigma, etc.***
- ***Controlled ferrite content (FN)***

Weld Metal Design Criteria
Flux types & Slag systems

- ***Vertical down***
  - *Fast freezing* — *High rutile*
- ***Downhand fillets***
  - *Wettability* — *Rutile / Silicate*
- ***All position***
  - *Weldability* — *Rutile / Basic*
  - *Mechanical properties* — *Basic*

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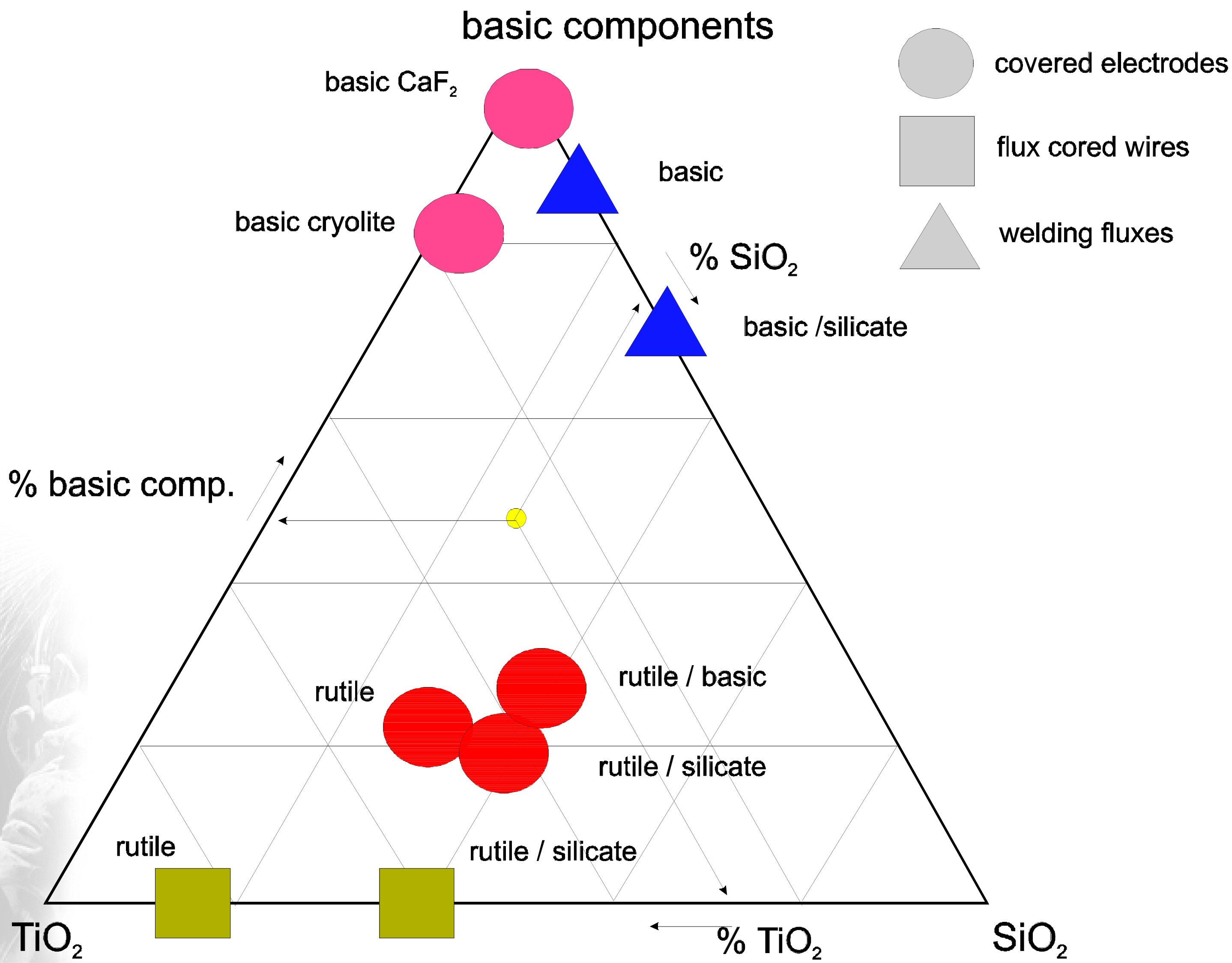
Weld Metal Design Criteria

Coating composition vs Slag system

	TiO_2	SiO_2	$CaCO_3$	CaF_2	Na_3AlF_6
Rutile	55-65	20-25	5-10	5-10	---
Rutile/Silicate	50-55	25-30	5-10	5-10	---
Rutile/Basic	50-55	20-25	10-15	5-10	---
Basic-Fluorspar	5-10	<5	30-40	40-50	5-15
-Cryolite	5-10	<5	30-40	5-15	40-50
-Combined	5-10	<5	25-35	20-25	30-40

Weld Metal Design Criteria



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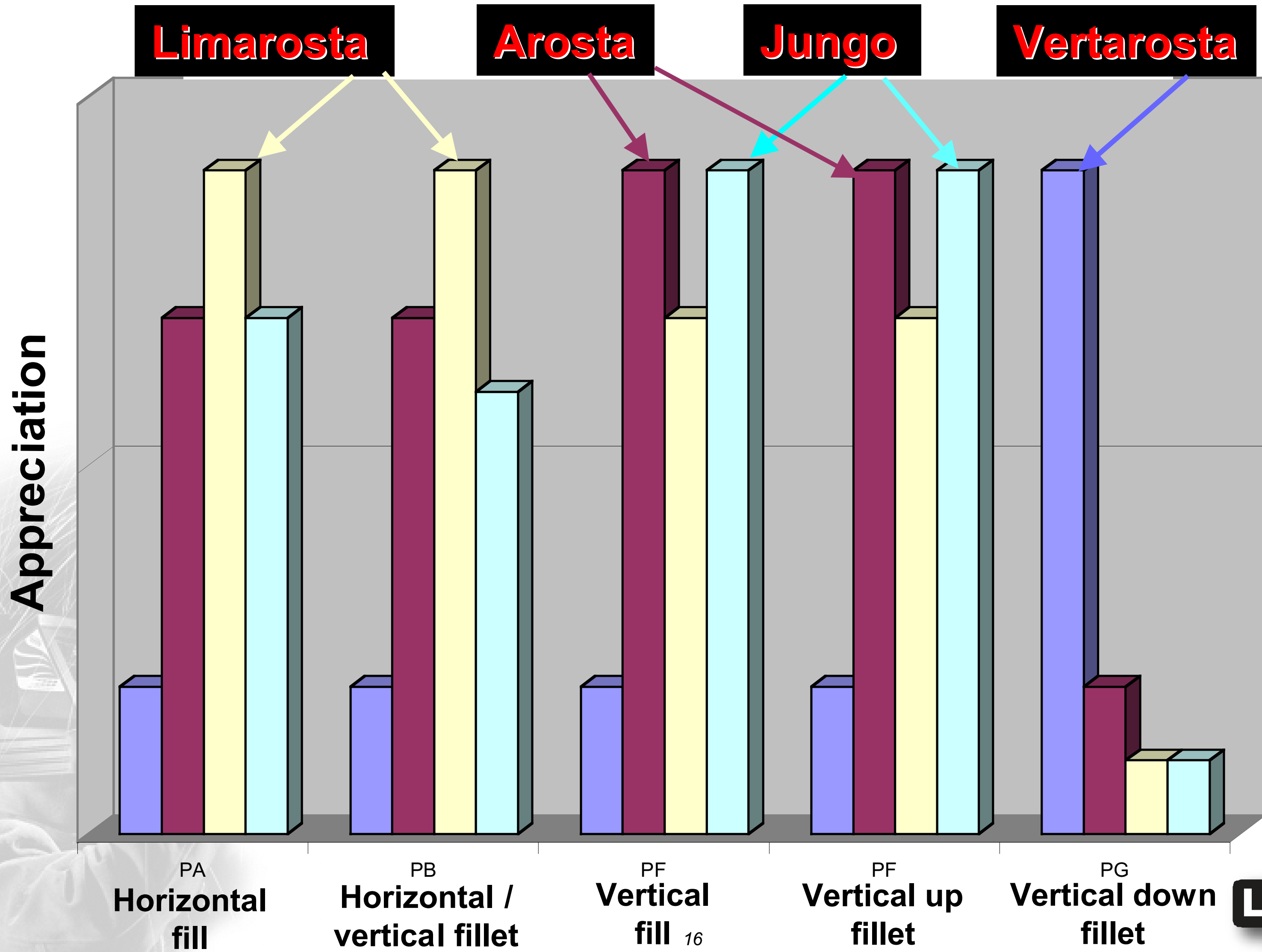
Weld Metal Design Criteria

Suitability of stainless steel electrode types



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Weld Metal Design Criteria

Summary of stainless Steel Alloy Effects

ELEMENT	PROMOTES	EFFECT ON PROPERTIES
Chromium	Ferrite	Improves general corrosion resistance and resistance to oxidizing environments
Nickel	Austenite	Improves general corrosion resistance and resistance to reducing environments
Carbon	Austenite	Increases strength, decreases corrosion resistance
Nitrogen	Austenite	Increases strength, improves pitting resistance
Manganese	Austenite or netural	Improves hot cracking resistance, increases solubility of nitrogen
Molybdenum	Ferrite	Improves pitting a nd crevice corrosion resistance

Continued . . .

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Weld Metal Design Criteria

Summary of stainless Steel Alloy Effects

ELEMENT	*PROMOTES*	*EFFECT ON PROPERTIES*
Niobium	*Ferrite*	*Forms stable carbonitrides to resist sensitization*
Silicon	*Ferrite or neutral*	*Improves wetting and flow, improves high temperature oxidation and carburization resistance*
Titanium	*Ferrite*	*Forms stabl e carbonitrides to resist sensitization*
Aluminum	*Ferrite*	*Improves high temperature oxidation and carburization resistance*
Copper	*Austenite (weak)*	*Improves resistance to reducing environments. Can be used for precipitation hardening*
Sulfur	*Neutral*	*Improves machinability, promotes hot cracking*
Phosphorus	*Ferrite*	*Promotes hot cracking*

Weld Metal Design Criteria

External requirements for E316L electrodes

	AWS A5.4	EN 1600	Smitweld Standard
% C	0.04 max.	0.04 max.	0.030 max.
% Si	0.90 max.	1.20 max.	0.4-0.9
% Mn	0.5-2.5	2.0 max.	0.5-1.1
% Cr	17.0-20.0	17.0-20.0	17.0-19.0
% Ni	11.0-14.0	10.0-13.0	11.0-12.5
% Mo*	2.0-3.0	2.5-3.0	2.7-3.0

*some customer requirements 2.7-3.0 % Mo

Among investigated European and US suppliers,
5 out of 14 comply for "-17" grades
3 out of 12 comply for "-16" grades

Properties
Corrosion Resistance

As an indicator for the corrosion resistance we can use the PITTING RESISTANCE EQUIVALENT, being:

$$PRE_N = \%Cr + 3.3x\%Mo + 16x\%N$$

Corrosion Resistance Properties

Elements	Effect	Reason	Practical limitation
C	negative	Precipitation of carbides, resulting in Cr depletion	Max. 0,03%
Si	positive	Si stabilizes the passive film	Max. 2,0%, dueto its effect on structural stability and on nitrogen solubility
Mn	negative	Mn rich sulphides act as initiation points for pitting. Mn may destabilize the passive film	Max. 2%, as high amounts might increase the risk for precipitation of intermetallics
S	negative	Sulphides (except Cr- and Ti-) tend to initiate pitting	Max. 0,02%
Cr	positive	Cr stabilizes the passive film	Max 25-28%, depending on Mo content. Higher contents increase the risk for precipitation of intermetallics
Ni	negative	With other elements constant, nickel dilutes the austenite with regard to N, which in turn decreases the PRE. When the alloy is very sensitive to precipitation of Cr-nitrides, nickel can have a positive effect.	Nickel is primarely ised to control the austenite content
Mo	positive	Mo stabilizes the passive film.	Max. 4-5%, depending on Cr content. Mo enhances the precipitation of intermetallics
N	positive	N increases the PRE of the austenite significantly.	Max. 0,15% in Mo-free DSS. Max 0,3 in 25Cr high Mo SDSS, and max 0,4% in 25%Cr SDSS with high Mn and Mo
Cu	positive	Slight positive effect	Max 2%, due to undesired hardenability
W	positive	Similar effect as Mo	Increases tendency to precipitation of intermetallics
Ferrite	positive	Increased ferrite increases the N, Cr and Mo content of the austenite	Too high ferrite content may cause precipitation of Cr carbides and nitrides
Intermetallics	negative	Precipitates with accompanying depletion of alloying elements	
Cr-carbides / nitrides	negative	Cr carbides and nitrides cause Cr depleted zones, which are selectively attacked in certain corrosive environments	

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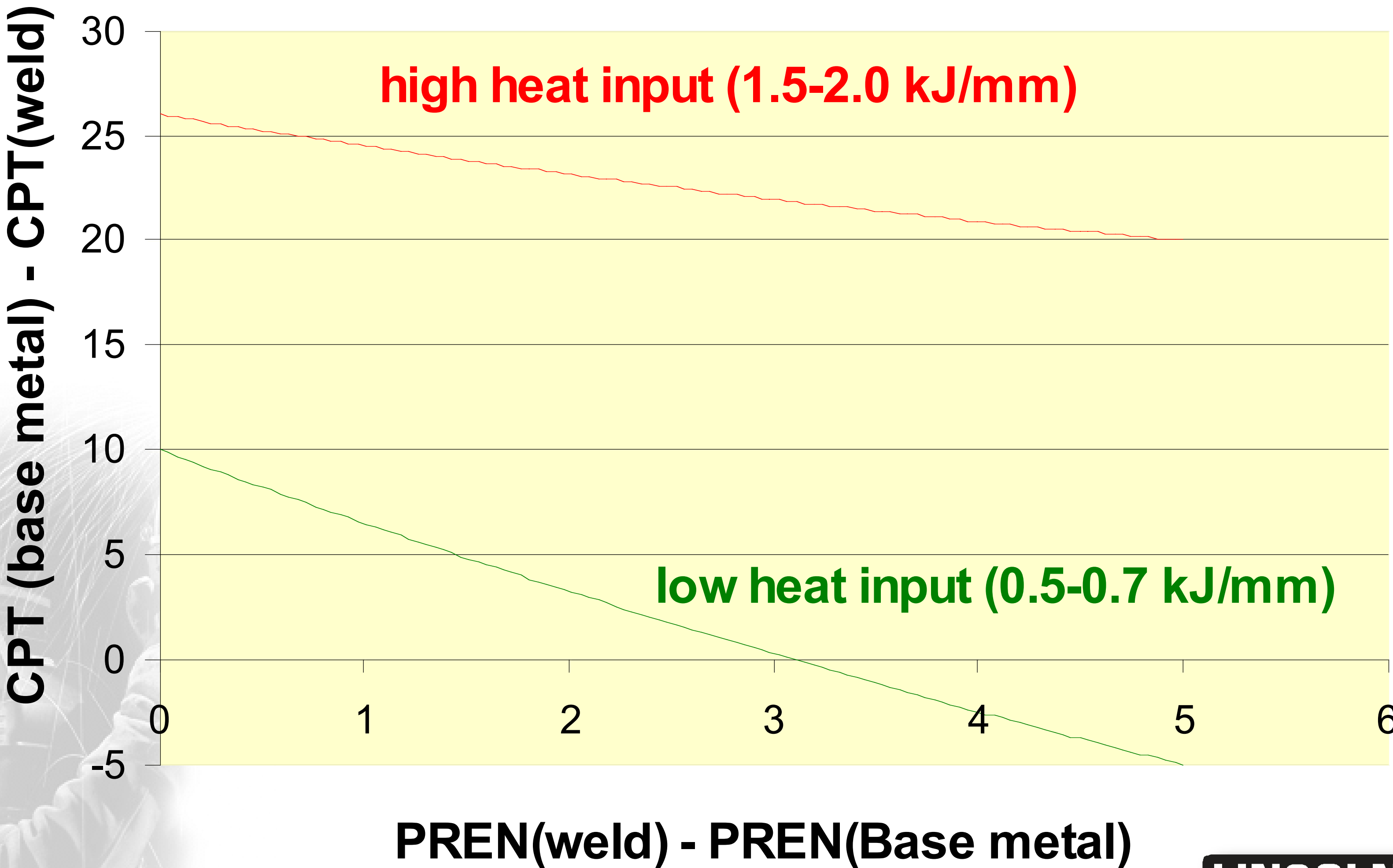
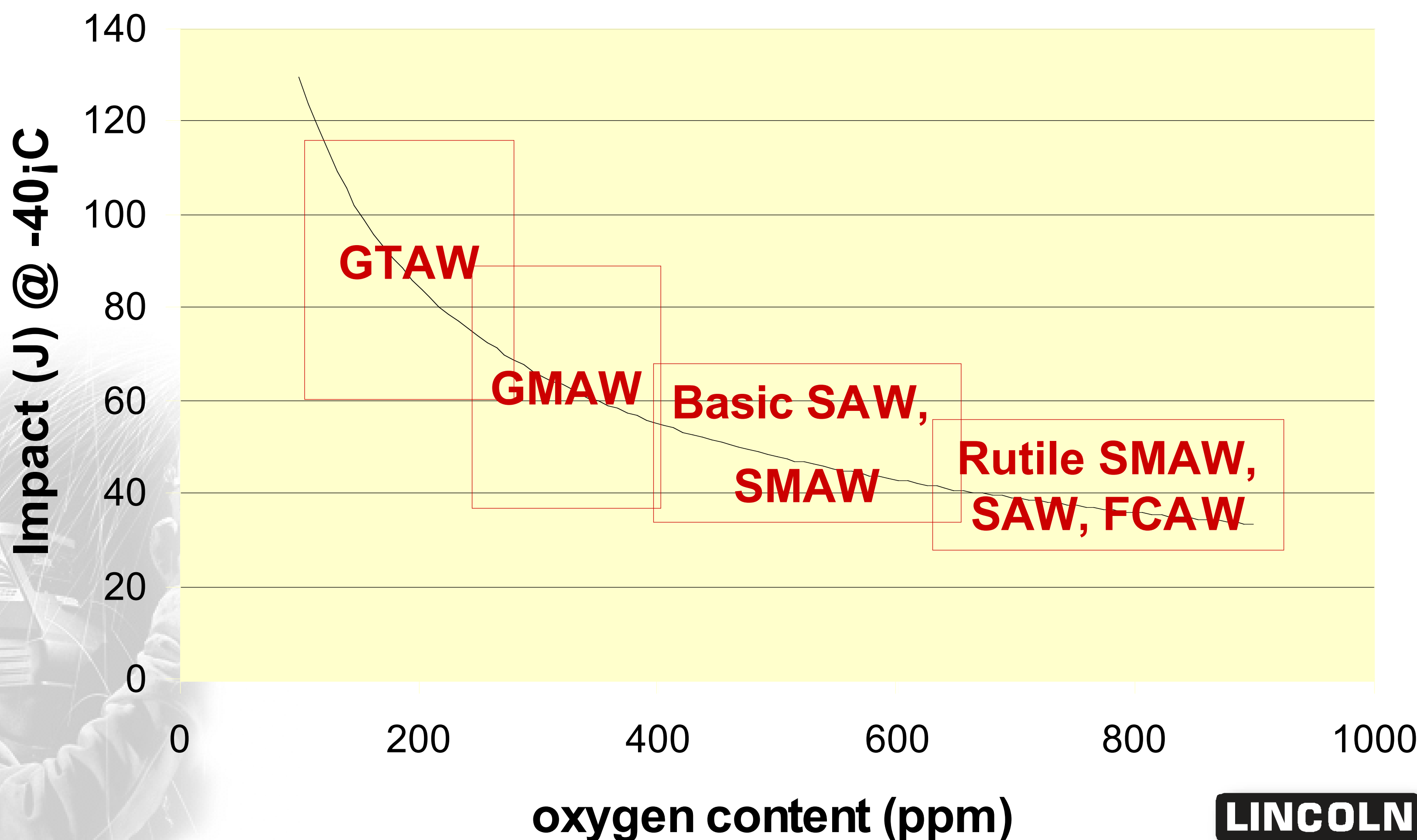
Effect of heat-input on pitting corrosion SDSS



Properties

Effect of Oxygen level on impact toughness



Stick Electrodes

General Corrosion Resistance

- **304L, 308L and 347 range**
  - Arosta, Limarosta, Jungo, Vertarosta

Increased Pitting and General Corrosion Resistance

- **316L and 318 range**
  - Arosta, Limarosta, Jungo, Vertarosta

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Stick Electrodes

Dissimilar Joints, Buffer Layers and Difficult Weldable Metals

- **308MoL, 309L, 309Nb, 309MoL, 329 and 312 range**
  - *Arosta, Limarosta, Jungo, Vertarosta*

Dissimilar Steel Grades, Armour Plates

- **E307 range**
  - *Arosta, Jungo*

Stick Electrodes

High Temperature Applications, Highly Oxidation Resistant

- ***308H, 309H, 310 range***
  - ***Arosta, Intherma***

Highly Stress Corrosion Resistant in 22%Cr and 25%Cr (super) Duplex Stainless Steels and Supermartensitic Steels

- ***2209, 2553 range***
  - ***Arosta, Jungo, Zeron100***

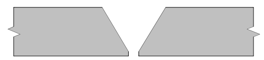
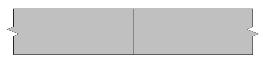
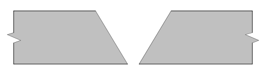
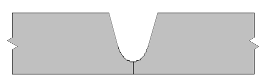
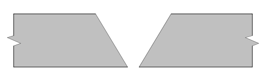
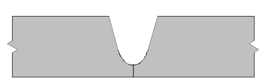
Stick Electrodes

Special Corrosion Resistant Steels, with Increased Pitting Resistance in Oxidizing and Reducing Media

- Pitting-, Intergranular-, Stress Corrosion , Chemical Tankers — Arosta / Jungo 4439
- Cryogenic, Non-magnetic — Jungo 4455
- Urea, Nitric Acid,Strong Oxidizing and Slightly Reducing — Jungo 4465
- Phosphoric, Sulphuric Acids, Paper Mill Plants — Jungo 4500

Applications / Procedures

Full penetration root runs in pipe

Process	Type of joint	Filler material	Comments
SMAW		Coated electrodes Ø 2,0 - 2,5 mm	〈 Only when acceptable to have slag on inside
GTAW	  	Rod Ø 1,6 - 2,4 mm	〈 Purging or welding on Cu or ceramic backing 〈 Good weld pool control 〈 Manual or mechanized 〈 Risk of overheating when manual 〈 In closed joints, addition of filler metal is required
GMAW-STT		Wire Ø 1,0 - 1,2 mm	〈 5G : mechanized 〈 1G: Manual or mechanized 〈 low HI, improved corrosion resistance
PAW		No filler	〈 Only mechanized 〈 Requires solution annealing

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Applications / Procedures

Chemical process installations

Applications / Procedures
Chemical process installations

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Applications / Procedures

Chemical process installations

Base material 22Cr DSS (UNS 31803), consumables SMAW E2209-15, Jungo 4462

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Applications / Procedures
Pipelines

Applications / Procedures

Flow lines

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Applications / Procedures
Chemical tankers

Welding procedures

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Lincoln Smitweld

Welding Procedure Approval Record

WPAR	**STT.008**
Rev.:	2
Ref. WPQ:	95.048

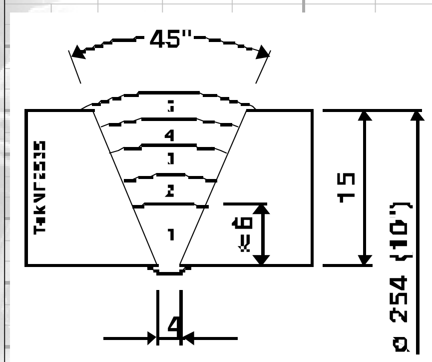
Procedure Specification

Base material	Duplex SS Grade 1.4462		
Welding processes	A: **GMAW - STT**	B: **SAW**	
Manual or machine	Manual and machine		
Welding position	5G down and 1G (PG / PA)		
Filler metal *(trade)*	1: **LNM 4462**	2: **LNS 4462**	
Flux	**P2000** EN760: AAF 2 63 DC		
Filler metal classific.	1: EN12072: G 22 9 3 NL		
	2: EN12072: S 22 9 3 NL		
Shielding gas [l/min]	98Ar + 2% CO_2	Flow	15
Backing (gas) [l/min]	STT: Ar 99.99%	Flow	12 - 15
Purging gas SAW	N^2 dry		
Current / polarity	DC +		
Preheat temp. [¡C]	RT		
Interpass temp. [¡C]	max. 140		
Postheat treatment	NA.		
Welder's name	D. Ritsema and J. Tersteeg		
Laboratory Test No.	DM 32		
Remarks:	Specification-code:		
	Stoomwezen T220/T210; EN288-3		
	NAM NSS-60C-7-02		

Welding Procedure

Pass No.	Consumable index	¯ [mm]	Welding Current Ampere	Volts	Speed [mm/min]	H.I. [kJ/mm]
1	A1	1.2	BC: 95 PC: 260	N.D.	90 - 150	0.5 - 1.0
2	B2	2.4	350	27.0	650	0.9
3	B2	2.4	390	28.5	600	1.1
4	B2	2.4	390	30.0	600	1.2
5	B2	2.4	400	31.6	600	1.3

Joint Detail



Test Results

Radiographic Examination:	Acceptable
Visual Examination:	Good

Reduced-section tension test

Tensile strength [MPa]		Fracture location
17.7 x 11.5 mm	779 MPa	Base material

All-weld-metal tension test

Yield point [MPa]:	
Tensile strength [MPa]:	
Elongation, A5 [%]:	
Reduction, Z [%]:	

Bend tests

		Former diameter:	3 xt + 3.8 xt
Root	20 x 15	180¡	No remarks
Face	20 x 15	180¡	No remarks
Side	10 x 15	180¡	No remarks

Impact tests ISO - V [Joule] Test temp. [¡C]: see below

Size of specimen: 10 x 10 x 55mm — Required 40 Joule

	Clw			av.		av.
- 20¡C	80	73	72	75		

CTOD testing

Notch location	Temp. [¡C]	CTOD value [mm]	Fracture mode

Ferrite Content (FN) Magne Gage method Req. 30 - 99

	BM	HAZ	WM
Face	73 - 74	91 - 91 - 89 - 99	65 - 62 - 66
Centre	---	99 - 79 - 99 - 82	56 - 56 - 56
Root	73 - 78	93 - 98 - 99 - 98	70 - 71

Hardness

Test type: Vickers Load: 20 kg Req. < 325

	BM	HAZ	WM
Face	257 - 243	256 - 257 - 268 - 269	245 - 261 - 258
Centre	---	255 - 266 - 263 - 274	252 - 249 - 254
Root	248 - 236	277 - 288 - 264 - 274	278 - 260

Corrosion tests

Modified ASTM G48a
24 hours
CPT > 30¡C

We the undersigned, certify that the statements in this record are correct.

Manufacturer or Contractor	Lincoln Smitweld bv Nijmegen
Authorized by	L.van Nassau
Issued by	Fred Neessen
Date	23 September 1995

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Welding procedures

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Lincoln Smitweld

Welding Procedure Approval Record

	Page 1 / 1
WPAR:	LNM 4462.01
Rev.:	0
Ref. WPQ:	WDRSTT-17

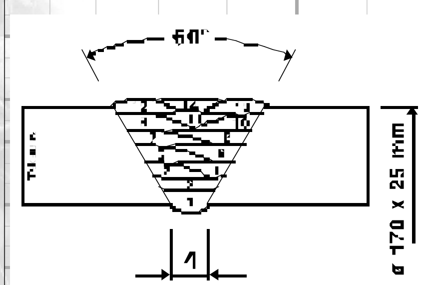
Procedure Specification

Base material	2205 duplex (1.4462)		
Welding processes	A: GMAW-STT	B: GMAW-Pulse	
Manual or machine	Manual		
Welding position	PA (1G)		
Filler metal *(trade)*	1: LNM Zeron 100X	2: LNM 4462	
Flux	NA		
Filler metal classific.	1: EN12072: G 25 9 4 NL		
	2: EN12072: G 22 9 3 NL		
Shielding gas [l/min]	98Ar + 2% CO_2	Flow	15
Backing (gas) [l/min]	Argon 4.0	Flow	15
Gouge method	NA		
Current / polarity	DC +		
Preheat temp. [¡C]	RT		
Interpass temp. [¡C]	max 100		
Postheat treatment	NA		
Welder's name	Arie van der Sluis & Dirk Ritsema		
Laboratory Test No.	BR96 B		
Welding equipment:	STT - II		
	Powerwave 450		

Welding Procedure

Pass No.	Consumable index	¯ [mm]	Welding Current Ampere	Volts	Speed [mm/min]	H.I. [kJ/mm]
1	A1	1,0	BC: 75	14 - 16	120	(0,6-0,8)
			PC: 275			
2	B2	1,0	145	24 - 26	139	1,6
3 + 4	B2	1,0	145	24 - 26	236	0,9
5 + 6	B2	1,0	145	24 - 26	231	1,0
7 - 11	B2	1,0	145	24 - 26	227	1,0
12-14	B2	1,0	150	24 - 26	260	0,9

Joint Detail



Test Results

Radiographic Examination:	Acceptable		

Cross Tensile Test (reduced section) at + 20¡C

Tensile strength [MPa]		Fracture location
Full cross section:	30 x25 mm	
	784 MPa	base material

All weld metal Tension test

Yield point [MPa]:	
Tensile strength [MPa]:	
Elongation, A5 [%]:	
Reduction, Z [%]:	

Guided Bend Tests Former diameter: **3 x t**

Root	satisfactory, no defects
Face	satisfactory, no defects
Side	--

Impact Tests ISO-V [Joule] Test temp. [¡C]: **- 40**

Size of specimen: 10 x10 x 55 mm

	Cap			av.	Root	av.
Clw	**121**	**121**	**116**	**119**		0
Fl				0		0
Fl + 2				0		0
Fl + 5				0		0

CTOD testing

Notch location	Temp. [¡C]	CTOD value [mm]	Fracture mode

Ferrite Content (FN) see sketch

	BM	HAZ	WM	HAZ	BM
Face 1	45		36		46
Mid					
Root	45		32		45
Face 2					

Hardness Survey

Test type: Vickers Load: 10 kg

	BM	HAZ	WM	HAZ	BM
Face	256	250	285	251	260
Root	259	262	279	269	255

Sketch

We certify that the data in this report are actual test results.

Project	Clarification test welding equipment
Manufacturer or Contractor	Lincoln Smitweld bv
Authorized by	Mr. Ir. Leo van Nassau
Issued by	Fred Neessen
Date	27 July 1999

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Welding procedures

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Lincoln Smitweld

Welding Procedure Approval Record

Page 1 /2

WPAR:	**P2000.01**
Rev.:	1
Ref. WPQ:	95.023

Procedure Specification

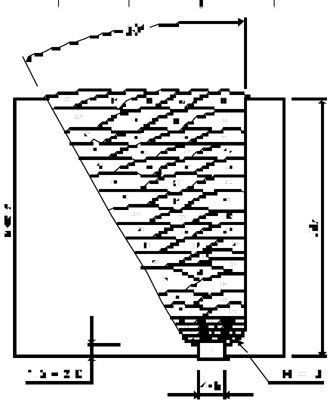
Base material	1.4462		
Welding processes	A: GTAW	B: SAW	
Manual or machine	Manual and machine		
Welding position	1G (PA)		
Filler metal	1: **LNT 4462**	2: **LNS 4462**	
Flux	**P 2000** , EN 760: AAF 2 63 DC		
Filler metal classific.	1: EN 12072: W 22 9 3 NL		
	2: EN 12072: S 22 9 3 NL		
Shielding gas [l/min]	Argon 4.0	Flow	10
Backing (gas) [l/min]	Argon	Flow	10
Gouge method	NA.		
Current/ polarity	GTAW = DC - ; SAW = DC +		
Preheattemp. [¡C]	min. 100		
Interpasstemp. [¡C]	max. 150		
Postheattreatment	NA.		
Welder's name	Tiny Boumans		

Remarks: P 2000, batch F3053
LNT 4462, batch 51469429
LNS 4462, batch 51467032
Welded under fully restraint conditions

Welding Procedure

Pass No.	Consumable index	Consumable ¯ [mm]	Welding Current Ampere	Welding Current Volts	Speed [mm/min]	H.I. [kJ/mm]
1	A1	2.0	85 - 90	12	35	1.8
2 - 4	A1	2.0	106	12	35	2.18
5 - 7	A1	2.0	115	12	43	1.93
8 - 13	A1	2.0	120	12	43	2.0
14-21	B2	3.2	350	32	50 - 52	1.32
22-23	B2	3.2	450	32	60	1.44
24-54	B2	3.2	450	32	55	1.57
55-59	B2	3.2	450	34	55	1.67

Joint Detail



Test Results

Radiographic-ultrasonic Examination: acceptable

Reduced-section tension test

Tensile strength [MPa]	Fracture location
Cap :	
Root:	

All-weld-metal tension test

	St 1	St 2	St 3
Yield point [MPa]:	601	626	676
Tensile strength [MPa] :	775	773	805
Elongation, A5 [%] :	30	26	30
Reduction, Z [%] :	51	51	47

Side-bend tests Former diameter:

Root
Face

Impact tests ISO - V [J] Test temp. [¡C] RT
Size of specimen: 10 x 10 x55mm

Level	Clw			Fl + 0-0.5			Fl + 2-5		
1	100	104	102	294	298	293	173	182	148
2	92	100	90	136	120	121	98	96	90
3	106	108	106	131	87	136	98	135	101
4	138	132	134	256	224	243	154	119	122

Impact tests ISO - V [J] Test temp. [¡C] - 40
Size of specimen: 10 x 10 x55mm

Level	Clw			Fl + 0-0.5			Fl + 2-5		
1	79	86	91	91	93	86	76	83	80
2	73	73	72	113	81	83	295	295	295
3	111	99	100	90	90	90	92	91	98
4	77	79	72	109	140	106	220	260	272

Ferrite Content (FN) see sketch

	BM	HAZ	WM	HAZ	BM
Face 1					
Mid					
Root					
Face 2					

Hardness see sketch
Testtype : Vickers Load : 10 kg

	WM	HAZ	BM
Face 1	242-258-258-251-254	270-264-270-264-258	236-236-236
Mid	264-258-268-274-264	258-264-258-262-268-264	228-232-232
Root	274-274-274-274	285-285-279-279-274	236-233-232

Sketch

We the undersigned, certify that the statements in this record are correct

Manufacturer or Contractor	Lincoln Smitweld and MPS/DSM
Authorized by	Bert Colaris from MPS/DSM
Issued by	Fred Neessen
Date	4 June 1995

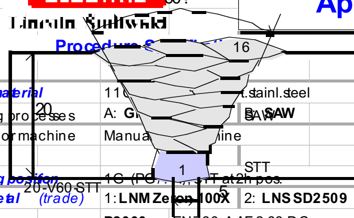
LINCOLN® ELECTRIC

Welding procedures

LINCOLN ELECTRIC
Lincoln Smitweld

Welding Procedure Approval Record

WPAR	13Cr-018b
Rev.:	0
Ref WPQ:	



Procedure S...

Base material	11C...	...t.stainl.steel	
Welding processes	A: GT...	B: SAW	
Manual or machine	Manua...	...hine	
Welding position	1G (PG...) ...STT at 2h pos.		
Filler metal *(trade)*	1: **LNM Zeron 100X**	2: **LNS SD2509**	
Flux	**P2000**	EN760: AAF 2 63 DC	
Filler metal classific.	1: EN12072: G 25 9 4 NL		
	2: EN12072: S 25 9 4 NL		
Shielding gas [l/min]	98Ar + 2% CO_2	Flow	15
Backing (gas) [l/min]	STT: Ar 99.99%	Flow	12 - 15
Purging gas SAW	N^2 dry		
Current/polarity	DC +		
Preheat temp. [¡C]	RT		
Interpass temp. [¡C]	max 140		
Postheattreatment	NA		
Welder's name	D. Ritsema and T.Bouwmans		
Laboratory Test No.			
Remarks:	Specification-code:		
	BIL 13Cr project		

Welding Procedure

Pass No.	Consumable index	¯ [mm]	Welding Current Ampere	Volts	Speed [mm/min]	H.I. [kJ/mm]
1	A1	1.2	BC: 95 PC: 260	N.D.	90 - 150	0.5 - 1.0
2+3	B2	2.4	200	30	650	0,6
4+5	B2	2.4	300	30	600	0,9
6-13	B2	2.4	350	30	600	1,1
14-16	B2	2.4	300	30	600	0,9

Joint Detail

Test Results

Radiographic Examination:	**No defects, Acceptable**
Visual Examination:	**Good, smooth surfaces**

Cross Tensile Test (reduced section)

	Tensile strength [Mpa]	Fracture location
20,1 x 19,0 mm	**689**	**base metal**
20,0 x 19,3 mm	**694**	**base metal**

All-weld-metal tension test

Yield point Rp0,2 [MPa]:	**680**	**678**
Tensile strength [MPa]:	**871**	**869**
Elongation, A5 [%]:	**27**	**29**
Reduction, Z [%]:	**54**	**49**

Bend tests — Former diameter:

Root
Face
Side

Impact tests ISO - V [Joule] Test temp. [¡C]: see below

Size of specimen: 10 x 10 x 55mm Required 40 Joule

n.loc./T		WCL			avg.	FL			avg.
-20	**face**	**61**	**65**	**65**	**64**	**51**	**61**	**50**	**54**
	root	**57**	**51**	**52**	**53**	**51**	**54**	**40**	**48**

CTOD testing

Notch location	Temp. [¡C]	CTOD value [mm]			Fracture mode
WCL	**-20**	**0,26**	**0,24**	**0,24**	**m**

Ferrite Content (FN) Magne Gage method

	WCL
Face	**40**
Centre	**42**
Root	**49**

Hardness

Test type: Vickers Load: 20 kg Req. < 325

	BM	HAZ	WM
Face	254-234	296-313	254-293
Centre	249-234	254-334	260-303
Root	232-244	254-293	296-299

Chem.comp. All weld metal

sample	C	Mn	Si	Cr	Ni	Mo	Cu	V	N
LE-A1	0,030	1,02	0,6	21,20	8,70	2,90	0,20	0,0	0,22

We the undersigned, certify that the statements in this record are correct

Manufacturer or Contractor	Lincoln Smitweld bv Nijmegen
Authorized by	L.van Nassau
Issued by	
Date	'21-03-2000

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SUMMARY

- ***SMAW is still a popular welding process***
- ***Depending on the application, various slag systems can be applied, such as rutile, rutile-silicate, rutile-basic or true basic***
- ***Weldmetal chemical composition must be related to the required corrosion and in some applications, mechanical properties***
- ***Mo is vital for corrosion resistance and should have a decent minimum value***
- ***Ferrite content must be controlled***