Cored welding wires for corrosion resistant applications

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Abstract:

*C*ored wires are increasingly becoming the filler metal products of choice for arc welding applications where corrosion is the principal constraint. Stainless steel, nickel base and cobalt base cored wires are currently used in industry. They are available with or without slag. They can be welded with or without gas or flux shielding, using the many different welding processes now available.

Cored welding wires are composite products comprising a metal strip (folded into tubular form) and a powder filling. For a given analysis, several strip compositions are frequently available to choose from. The final analysis is adjusted through metallic additions to the filling. Allowance must be made for element burn-off and the effects of the shielding media. The shielding gas or flux used, if any, affects the composition of the weld deposit. The details of the design and formulation of the wire also exert a strong influence. Various production techniques for corrosion-resisting cored wires exist.

The amount and nature of compositional adjustment by the filling can have an impact on the corrosion resistance under certain welding conditions. The same is true for the gas shield, the flux and the type of slag, if used.

Chemical analyses and standardised pitting corrosion testing have been carried out on a series of corrosion-resistant weld deposits. Causes of corrosion test failures are described and illustrated.

Examples of industrial applications are given to illustrate the potential of the cored wire solution.

1. Introduction

Most stainless steels are used to provide corrosion resistance. Many different stainless alloys exist, often tailored to particular applications. Their corrosion resistance depends essentially on their composition. As a general rule, the more highly alloyed the steel (particularly in chromium), the better it resists corrosion.

Cored arc welding wires are one category of welding filler materials used to assemble or clad stainless steels. Others are shielded metal arc welding electrodes (SMAW, flux covered electrodes or "stick-electrodes"), gas metal arc welding wires (GMAW, solid wires), strips and powders. Flux cored arc welding wires (FCAW) consist of a seamed tube and a filling of metallic and nonmetallic powders (Figure 1).

For a given alloy, it is possible to design several different types of flux-cored wire to suit specific applications. This is done by adding particular materials to the core. The metallic powders are added to achieve the desired chemical analysis. Nonmetallic powders (usually minerals) form a protective slag over the weld metal and influence the characteristics of the welding arc Each type has advantages and disadvantages: there is no one type that outperforms all the others under all conditions. The Welding Alloys range of stainless steels cored wires consists of four types:

- TUBE S (GMAW or SAW): contains metal powders only in the core, therefore slag-free. This design allows the widest range of compositions, because there are no space-filling minerals in the core. It is usually welded using argon shielding or Ar + 0 – 5% CO_2 gas mixtures. It may also be welded using flux protection, usually with larger wire diameters. The joint penetration is high and the deposit has good mechanical properties. However, the usable welding parameter window is narrow and this type of wire demands a high level of welder skill, particularly when working away from the horizontal position.

- TETRA S (FCAW): contains a mix of minerals, preponderantly rutile and other oxides. It is welded using Ar + 15 – 25% CO_2 mixtures or pure CO_2. This greatly improves the welding properties, allowing the wire to be welded by relatively unskilled personnel. This product gives the best weld bead appearance of all types, and usually needs minimum post-weld finishing (brushing, grinding, machining). However, it is only suitable for use in horizontal and near-horizontal positions, and the mechanical properties of the weld deposit (particularly the toughness) are not as good as those of a metal-cored wire, because the minerals add oxygen to the weld pool. Oxygen acts as a parasite in most steels.

- TETRA V (FCAW): closely related to TETRA S D57L-G, and uses the same gas shielding. It contains a similar mineral mix, but the proportion of rutile is increased in order to raise the freezing point of the slag. This allows the wire to be welded in any position, even overhead. The properties of the weld deposit are practically identical to those of TETRA S D57L-G, but its appearance is not quite so pleasing.

- TETRA SB (FCAW): contains a "basic" flux mix, composed largely of fluoride minerals. It is welded using Ar + 15 – 25% CO_2 mixtures. The fluorides have a purifying action on the weld metal and reduce the oxygen content considerably. As a result, this wire type gives the toughest and most ductile weld metal of all. However, its welding behavior is not as good as the rutile types, the appearance of the weld deposit is less pleasing, and it can only be used in horizontal and near-horizontal positions.

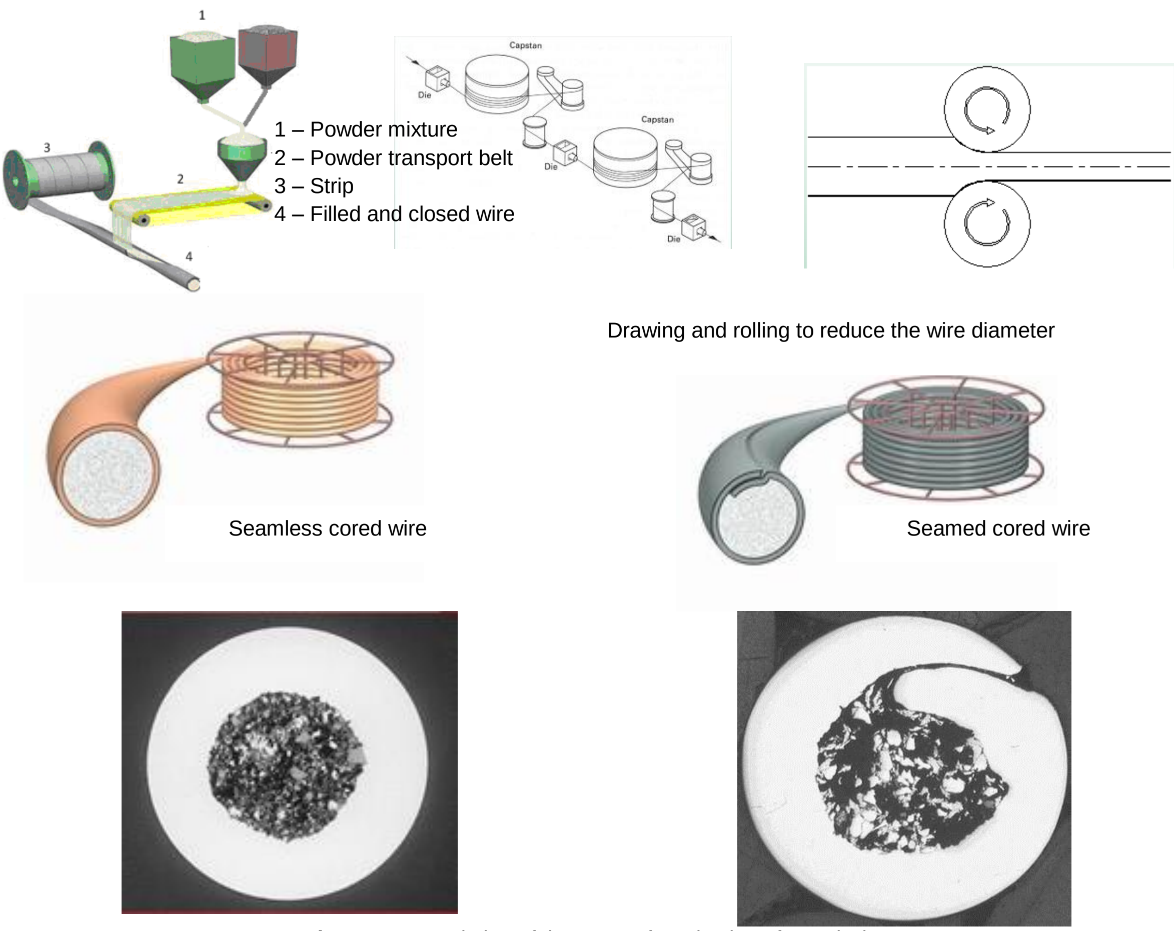


Figure 1 : Description of the steps of production of cored wire

One important family of stainless steels is known as the “duplex stainless steels”. Their name derives from their duplex metallurgical structure, which is a mixture of austenite and ferrite. Their corrosion resistance is far superior to common austenitic grades like 304L and 316L. They perform particularly well in chloride-containing media such as sea-water. They are now well-established in the offshore petroleum industry and in chemical processing industries such as petrochemicals, desalination, pulp and paper, pharmaceuticals and the food and beverage industry.

The corrosion resistance of duplex steels increases with chromium, molybdenum and nitrogen content. A useful index for estimating corrosion resistance is known as the Pitting Resistance Equivalent Number (PREN). It is calculated from the contents of these three elements as follows:

$$PREN = \%Cr + 3.3 \times \%Mo + 16 \times \%N.$$

The PREN value can be used to make rough comparisons between different materials. However, corrosion testing is a more accurate indicator of performance. Duplex stainless steels are most often evaluated using the ASTM G48 test, which involves immersion in a ferric chloride solution. It measures corrosion resistance through weight loss (to evaluate general corrosion) and microscopic examination (to determine the onset of localised corrosion). The test proceeds for a set time (usually 24 or 48 hours) at a set temperature, and is repeated at progressively increasing temperatures until the start of pitting or crevice corrosion. This gives the critical pitting temperature (CPT) or critical crevice corrosion temperature (CCT). An example of corrosion pitting is shown in Figure 2.

Weldments present characteristics of their own in corrosive media. The microstructure of weld metal is very different to that of forged and rolled plates and tubes (see Figures 3A and 3B), and its composition may be different as well. Duplex steel welding products are deliberately over-alloyed in nickel (9% as against 5% for wrought metal) in order to preserve the duplex structure under welding conditions. An arc welded joint contains three different microstructures, as shown in Figure 4: the parent metal, a heat-affected zone in the parent metal adjacent to the weld boundary, and the weld metal itself. This juxtaposition of different structures may create conditions that can accelerate corrosion and promote pitting.

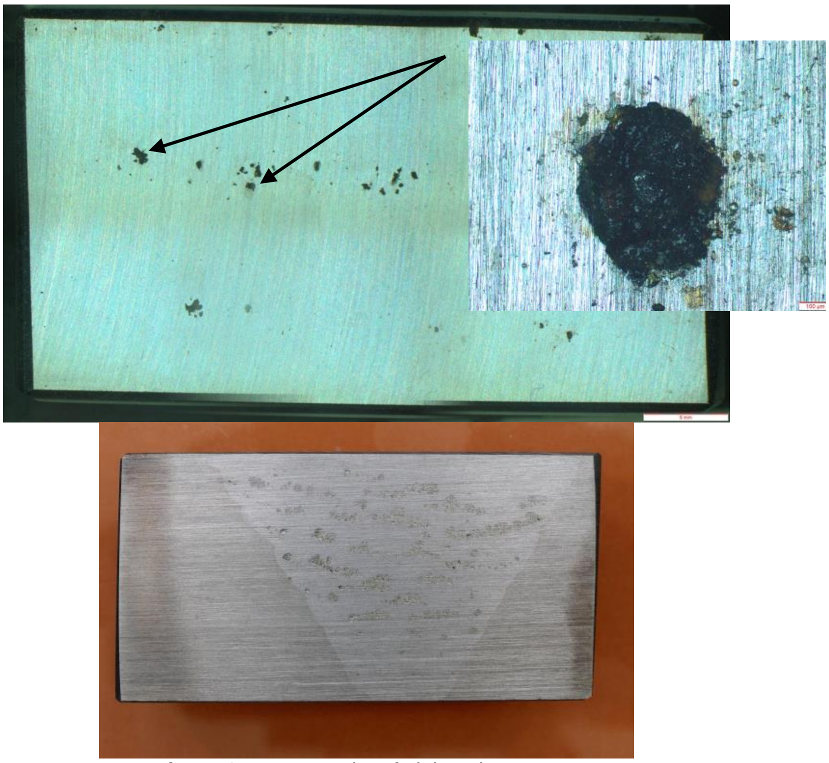


Figure 2: Macrographs of pitting phenomena

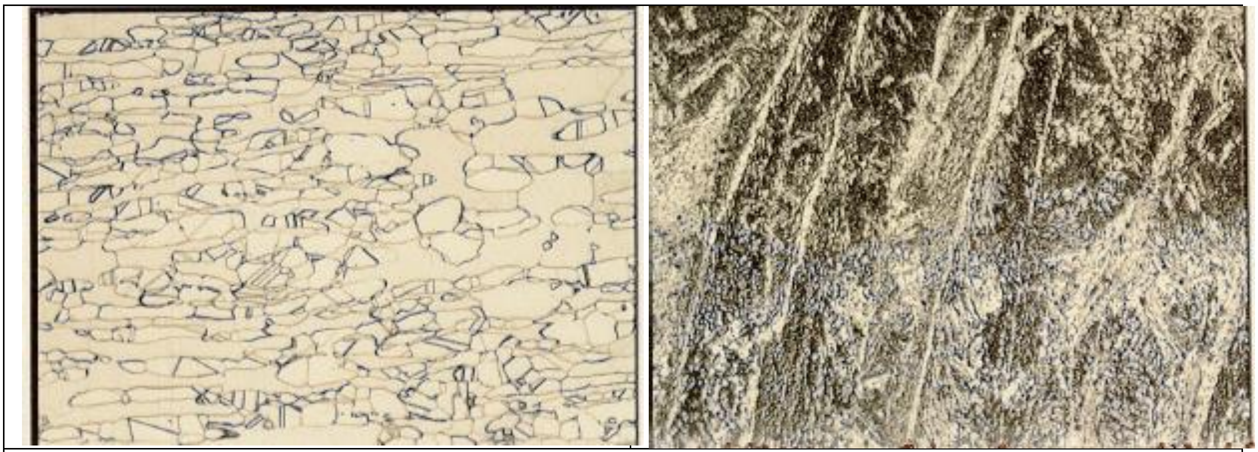


Figure 3: Microstructures of duplex steel (a) rolled plate (b) weld metal

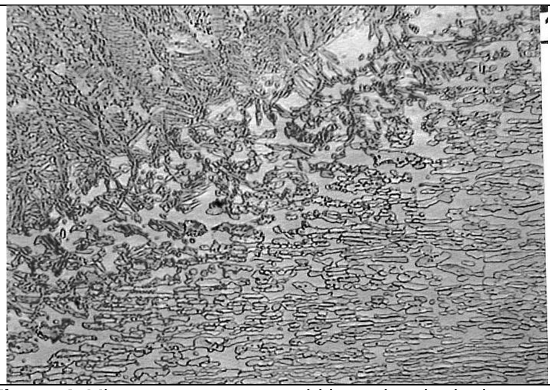


Figure 4. Microstructures at a weld boundary in duplex steel

Literature research:

Typical CPT's and CCT's for a range of stainless steels are shown in Figure 5. The standard compositions of these materials are given in Table 1.

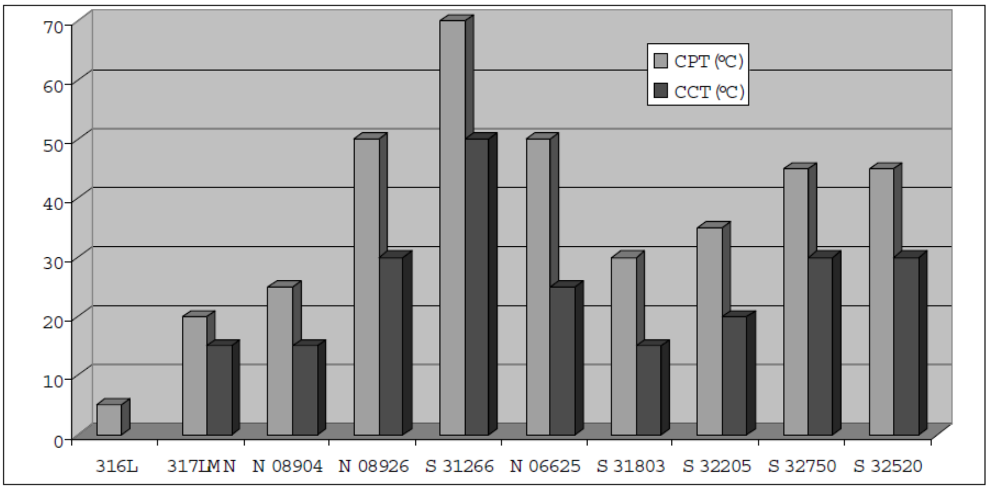


Figure 5: Typical critical pitting and crevice corrosion temperatures obtained in the ASTM G48A test. [1]

	EN	ASTM OR UNS ALLOY	C[%]	Ni[%]	Cr[%]	Mo[%]	Cu[%]	Fe[%]	N[%]	Others[%]	PREN
Stainless steels ‘300’ Series	1.4306	304L	0.02	10	18			Bal			18
	1.4432	316L	0.02	11	17	2.6		Bal			26
	1.4439	317LMN	0.02	14	17	4.1		Bal	0.14		33
Duplex and superduplex stainless steels	1.4462	S32205/2205/ S31803	0.02	5	22	3.1		Bal	0.17		35
	1.4410	S32750/2507	0.02	7	25	4		Bal	0.27		42
	1.4507	S32520/2507Cu	0.02	6	25.5	3.5	1.5	Bal	0.25		41
Special austenitic stainless steels	1.4539	904L	0.01	25	20	4.3	1.5	Bal	0.1		36
	1.4529	N08926	<0.02	25	21	6.5	0.9	Bal	0.2		46
		S31266	0.02	22	24	6	1.5	Bal	0.4	2 W	50
	1.4547	UNS S31254 / SS2378 /254SMO	0.01	18	20	6.1		Bal	0.2		43
	1.4652	UNS S32654 /654SMO	0.01	22	24	7.3	0.5	Bal	0.5		56
Nickel base	2.4856	N06625 /625	0.02	62	22	9		3		3.4 Nb	52

Table 1 = Typical chemical composition of the materials

Figure 5 clearly shows that the CPT and CCT increase as the level of alloying increases. The most heavily alloyed superaustenitic stainless steels rival the performance of nickel alloys such as 625. The duplex and related superduplex stainless steels have CPT’s in the range 30 - 45°C.

The literature on pitting and crevice corrosion of weldments in chloride environments (welded using stick-electrodes) has been reviewed by Gear (2). A summary of this review, together with results from other published work, will now be given.

Austenitic steels: CCT’s measured using standard test solutions range from under 2.5°C (calculated) to 28°C [3, 4-6]. The lower temperatures are measured on cold rolled and welded stainless steels, and on the higher carbon and lower alloy content stainless steels. As might be expected, CPT’s obtained in seawater and standard test solutions tend to be higher than CCT’s by 5 to 35°C. The best performing alloy is 904L, a fully austenitic stainless steel [5].

Superaustenitic steels: CCT’s range from 50°C [6 - 8] to more than 60°C for 654SMO [9]. CPT’s range from 30°C [10] to 110°C for the more highly alloyed Uranus 66 and 654SMO [11,12], with a spectrum of data covering both grades that varies according to the precise environmental conditions under which the data were obtained. The NACE technical committee report on the use of corrosion resistant alloys in oil field environments [13] gives localized corrosion limits for grade 254SMO between 0°C and 40°C; lower temperatures for untreated seawater, and higher temperatures for chlorinated seawater.

Duplex steels: The literature gives CPT’s in the range 20 - 40°C for duplex grades (~22% Cr) in $FeCl_3$ and chloride solutions [13 – 15]. Unpublished results obtained by Welding Alloys give CPT’s of weldments made using duplex flux cored wire of 20 - 35°C depending on the gas shielding, the nature of the flux used, the welding position and the design of the weld (joint or undiluted deposit). Solid wire ER2205 gives a CPT of 30°C.

Nowacki et al [16] measured the effect of welding energy input (expressed in kJ per unit length of weld bead) on the corrosion resistance of duplex joints welded using the submerged arc process (i.e. solid wire welded under a flux blanket). They found CPT’s around 20°C, with no effect of energy input from 3 - 5 kJ/mm. The general weight loss decreased from 1.15 mg/m^2 to 1.05 mg/m^2 as the heat input increased.

Superduplex steels: Values given in the literature vary. Field experiments using 25% Cr super duplex, butt welded tubes [17] in natural, chlorinated seawater identified a localised corrosion resistance limit of 60°C, when crevices were absent. This limit fell to 40°C in the presence of crevices in both chlorinated and unchlorinated seawater and down to 25 - 30°C in the presence of severe crevices, such as threads. Laboratory data on superduplex steels have indicated CCT limits from 10 - 15°C in $FeCl_3$ [18] up to as high as 100°C in chloride solutions [19] depending on alloy content and environment. The adoption of limits between 20°C and 30°C by other workers who have provided CPT and CCT maxima appear to be pitched between the values found in the literature. There are no indications regarding what source data was used to set these limits.

Standard	Method	Solution	Preparation	Duration & temperature	Purpose
ASTM G 48	A	6% wt $FeCl_3$	Machined specimen, last layer brushed, Cut edges ground with grit 180	Incr. 5°C/24h each session. Start temperature is function of the material to be tested Recommended temperature 22 ± 2°C and 50 ± 2°C	Pitting test
	B				Crevice Corrosion test
	C	6% wt $FeCl_3$ + 1% HCl		Incr. 5°C/24h each session. Start temperature is function of the material to be tested Recommended temperature 0 and 85 ± 2°C	Critical Pitting Temperature test for nickel base and bearing alloys
	D				Critical Crevice Temperature test for nickel base and bearing alloys
	E				Critical Pitting Temperature test for stainless steels
	F				Critical Crevice Temperature test for stainless steels

Table 2 = ASTM G 48 description [20]

Kobelco literature [21] mentions that the CPT measured by ASTM G48 method E (Table 2) for superduplex stainless steel is 40°C when welded using stick-electrodes or flux cored wire, and 50°C when welded using the TIG process (solid wire rods welded under argon using a non-consumable tungsten electrode. This process gives particularly pure weld metal.)

Tests at Welding Alloys on superduplex stick electrodes using the ASTM G48 method C (Table 2) test have given CPT's between 30 and 50°C. Corresponding tests on superduplex flux cored wire gave between 30 and 45°C depending on the type gas shielding, the nature of the flux used, the welding position and the design of weldment (joint or undiluted weld metal).

Object

A programme of research was undertaken to measure and compare the pitting corrosion behavior of welds made using stainless steel cored wires. The following influences were investigated:

- Corrosion of austenitic, duplex and superduplex stainless steel weld metals as a function of PREN
- The alloy of the strip used to make superduplex cored wire
- The type of filling (mineral and metallic powders) used to make superduplex cored wire
- The type of shielding (gas or flux) used to weld superduplex cored wire

No research reported in the literature has evaluated the influence of these parameters on the corrosion performance of weld metal from flux cored wires.

2. Experimental procedure

Corrosion resistance tests were carried out according to ASTM G48 Method A [20]. The test protocol does not propose pass/fail criteria, so those specified by Det Norske Veritas [22] were used.

Series of weld cladding deposits were prepared for testing. Stringer (not weaved) weld beads were deposited on a mild steel plate, in the horizontal position. After each bead, the assembly was allowed to cool to less than 150°C before starting the next one. Five layers of weld metal were built up so that the final layers would be free of dilution from the base plate. A completed weld deposit is shown in Figure 6. Test specimens were cut from the cladding so as to include only undiluted metal ("all weld metal").

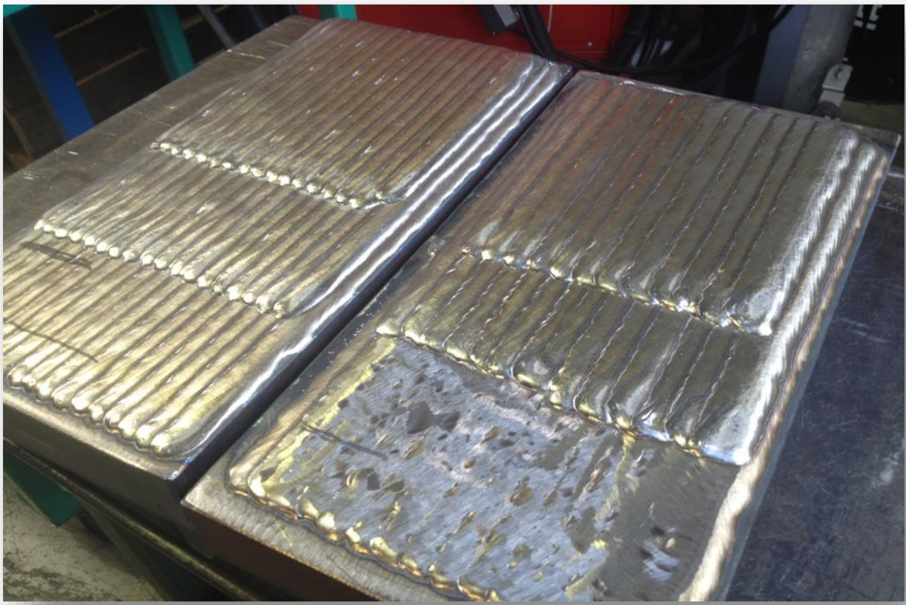


Figure 6: Three layer weld deposit by SAW

The specimens were approximately 44 x 25 x 5 mm in size, as proposed by ASTM G48-A (Table 2). It is not critical to the test that all specimens have exactly the same dimensions. The samples were ground to a 180 grit polish on all the cut faces. All edges were rounded by grinding.

Corrosion testing was carried out by immersion in the prescribed solution: 100g $FeCl_3{\cdot}6H_2O$ in 900 ml water. The test duration was 24 hours at the set temperature. After each test, the specimen was cleaned, dried, weighed and examined under a binocular microscope at 20X magnification to check for pitting and to assess its extent. Weight loss, if any, was measured and converted to weight loss per unit surface area of the specimen. Testing was started at 25°C and repeated at successively higher temperatures until pitting was observed. According to Det Norske Veritas guidelines a weight loss of less than 20 mg (about 4 g/m^2) is acceptable.

3. Results and discussions

a. Influence of the PREN on corrosion resistance of stainless steels

Four stainless steel flux cored arc welding wires types in diameter 1.2 mm were selected to illustrate the effect of the PREN on corrosion resistance. The welding products tested were flux cored wires (TETRA S) containing a rutile-based slag system (see section 1). Their compositions are given in Table 3. PREN's from 29 to 42 are represented.

Welding product	Alloy description	C	Si	Mn	Cr	Mo	Ni	Fe	N	Cu	PREN
316L-G	Austenite + ferrite	0.023	0.81	1.8	18.6	3.0	12.3	63	0.032	0,12	29.0
22 9 3L-G	Duplex	0.029	0.83	1.2	22.2	2.9	8.9	62	0.152	0,12	38.54
904L-G	Austenitic	0.027	0.51	2.8	20.3	4.7	26	44	0.093	1.57	37.1
D57L-G	Superduplex	0.028	0.54	1.1	25.6	3.9	8.9	58	0.217	1.32	41.8

Table 3: Chemical composition of TETRA S weld deposits

The welding parameters used are given in the table below. As far as possible, the same parameters were used for each product.

	Unit	316L-G	22 9 3L-G	904L-G	D57L-G
Wire feeding speed	m/min	9,8	9,7	9,7	9,8
Welding current	A	210	220	215	205
Voltage	V	29,8	29,6	29,2	29,5
Wire extension	mm	20	20	20	20
Welding speed	m/min	0,42	0,41	0,41	0,42
Gas shield		Ar + 18% CO_2			

Table 4: Welding parameters used for TETRA S wires

The weight losses in g/m^2 for each test are given below. The CPT for each product is the temperature at which the weight loss exceeds 4 g/m^2 (shown emboldened).

Description	PREN	Weight loss (g/m^2)			
		25°C	30°C	35°C	40°C
316L-G	29.0	***8,8***			
22 9 3L-G	38.5	0,9	1,2	***6,9***	
904L-G	37.1	0,49	2,3	***4.8***	
D57L-G	41.8	0,0	0,7	3,2	***5,5***

Table 5: Weight loss and CPT of TETRA S weld deposits during corrosion testing

As expected, the CPT increased as a function of the PREN. The CPT of the 316L austenitic alloy was below 25°C. The duplex and the special austenitic alloys both had CPT's of 35°C. The superduplex alloy had the highest CPT at 40°C. These results agree with those published in the literature. They confirm that the PREN is a reliable indicator of corrosion resistance.

b. Influence of the homogeneity of the raw materials on corrosion resistance

Further tests were conducted on the superduplex alloy cored wire, TETRA S D57L-G 1.2 mm. Three different versions of the same product were made using three different metal strips, 304L, 316L and duplex. These strips formed the wire sheath and provided the basis of its composition. The final composition of each wire was adjusted by adding the appropriate metal powders to the core; however, the more alloyed the strip, the less adjustment was needed.

Chemical analyses of the three wires are given in Table 6 below, along with the analysis of the strips used to make them. The PREN of each wire was identical within ± 0.4.

Description	C	Si	Mn	Cr	Mo	Ni	Fe	N	Cu	PREN
D57L-G 1.2 (304L strip)	0,0283	0,538	1,13	25,57	3,88	8,88	58,09	0,217	1,32	41,8
304L strip	<0.015	0.35	1.4	19	-	9.5	70	-	-	-
D57L-G 1.2 (316L strip)	0,025	0,571	1,03	25,99	3,88	8,9	58	0,211	1,03	41,9
316L strip	<0.015	0.5	1.2	17.5	2.5	10	68	-	-	
D57L-G 1,2 (Duplex strip)	0,026	0,551	1,04	25,36	3,79	9,09	58,74	0,219	0,825	41,4
Duplex strip	<0.015	0.4	1.2	22	3	5	67	0.15	-	

Table 6: Chemical composition of the TETRA S D57-G weld deposits and of the strips used to make these wires

The welding parameters used are given below in Table 7.

	Unit	D57L- 304L strip	D57L- 316L strip	D57L- duplex strip
Wire feeding speed	m/min	9,8	9,8	9,8
Welding current	A	205	200	210
Voltage	V	29,5	29,7	29,7
Wire extension	mm	20	20	20
Welding speed	m/min	0,42	0,42	0,42
Gas shield	Ar + 18% CO_2			

Table 7: Welding parameters used for TETRA S D57L-G wires

The wire made using duplex strip gave a higher CPT than that using 316L strip, which in turn gave a higher CPT than the wire made using 304L strip. This shows that the CPT increases with the homogeneity of the design of the welding product, that is to say, as the composition of the strip approaches that of the final product. These values of CPT agree with those in the literature using the FCAW and other processes: SMAW, GTAW and GMAW.

This increase of CPT with the homogeneity of the product can be explained as follows. Elements not present in sufficient quantity in the strip must be added to the powder filling. This applies particularly to refractory elements like molybdenum, which melt more slowly in the welding arc than the other metals in the mix. If care is not taken, inclusions of unmolten metal may remain in the weld metal after cooling (Figure 7). The use of 304L or 316L strip increases this risk.

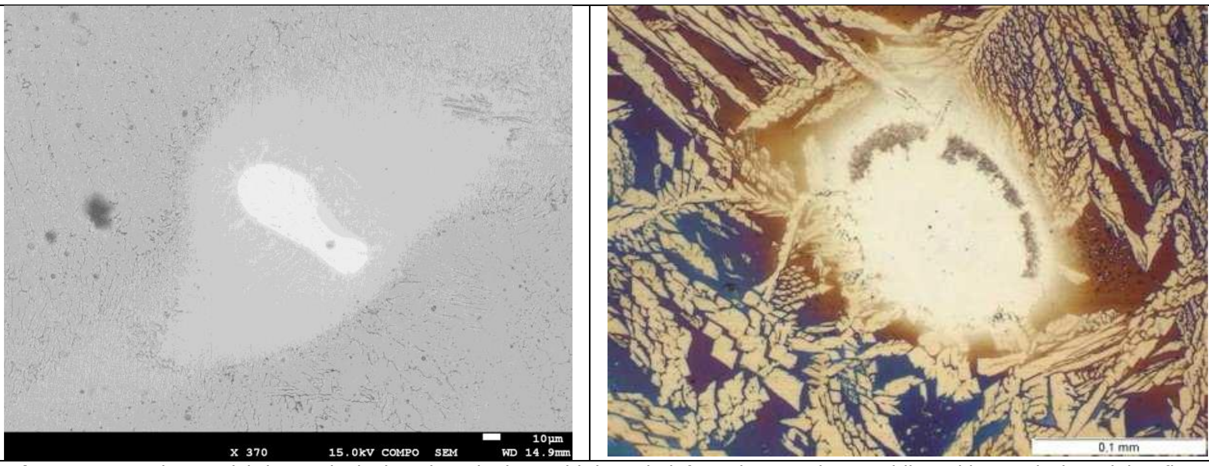


Figure 7: Unmolten molybdenum inclusions in a duplex weld deposit: left - submerged arc welding with cored wire; right - flux cored arc welding under a gas shield. Pitting corrosion temperature below 22°C

	Weight loss (g/m^2)					
Description	**25°C**	**30°C**	**35°C**	**40°C**	**45°C**	**50°C**
D57L-G 1.2 (304L strip)	0,0	0,7	3,2	***5,5***		
D57L-G 1.2 (316L-G strip)	0,0	0,01	1,17	3,2	***5,2***	
D57L-G 1,2 (Duplex strip)	0,11	0,11	0,07	1,95	2,97	***5,8***

Table 8: Weight loss and CPT for superduplex weld deposits with different types of strip

These test results clearly show the influence of the design of the cored wire on the corrosion resistance of the superduplex cored welding wire.

c. Influence of the type of wire filling on corrosion resistance

Weld deposits in superduplex stainless steel were prepared using all four cored wire types described in Section 1, and corrosion tested as described previously. Their compositions are given in Table 9. The PREN's of these products are similar.

Description	C	Si	Mn	Cr	Mo	Ni	Fe	N	Cu	O	PREN
TUBE S D57L-G 1.2	0,022	0,55	1,93	25,3	4,1	9,6	56,5	0,20	1,46	0.08	42,1
TETRA S D57L-G 1.2	0,028	0,54	1,13	25,6	3,9	8,9	58,1	0,22	1,32	0.093	41,8
TETRA V D57L-G 1.2	0,028	0,45	1,01	25,0	4,2	9,1	58,6	0,20	1,11	0.100	41,9
TETRA S BD57 L-G 1.2	0,024	0,35	1,04	25,5	4,0	9,7	58,1	0,23	0,87	0,073	42,2

Table 6: Chemical composition of the D57-G wires (with different types of filling) weld deposit and strips used

The wires were welded using the same welding parameters as far as possible, in order to reduce the influence of the energy input. However, some variation between the wire types was unavoidable.

	Unit	TUBE S D57L-G	TETRA S D57L-G	TETRA V D57L-G	TETRA S B D57L-G
Wire feeding speed	m/min	9,1	9,8	9,8	10,5
Welding current	A	260	205	215	220
Voltage	V	27,5	29,5	28,5	30,4
Wire extension	mm	20	20	20	20
Welding speed	m/min	0,41	0,42	0,41	0,37
Gas shield		Ar + 2.5%CO_2	Ar + 18% CO_2	Ar + 18% CO_2	Ar + 18% CO_2
Energy input	kJ/mm	1.05	0.86	0.90	1.08

Table 7: Welding parameters used for superduplex (D57L-G) wires with different core mixtures

The corrosion test results are given in Table 8. They enable the products to be ranked in decreasing order of weight loss as follows: TUBE S < TETRA V < TETRA S < TETRA SB. The TUBE S and TETRA V weld metal had a CPT of 35°C, whereas TETRA S and TETRA SB had a CPT of 40°C.

		Weight loss (g/m^2)				
Description	**O (%)**	**25°C**	**30°C**	**35°C**	**40°C**	**45°C**
TUBE S D57L-G 1.2	0.08	0,02	1	***4,3***		
TETRA S D57L-G 1.2	0.093	0,0	0,7	3,2	***5,5***	
TETRA V D57L-G 1.2	0.100	0,0	0,8	3.8	***7.2***	
TETRA S BD57 L-G 1.2	0,073	0,0	0,02	2,1	3.2	***4.1***

Table 8: Weight loss and CPT for superduplex (D57L-G) weld deposits with different core mixtures

The nature of the core mixture influences the CPT in the range 35 - 45°C. There is a correlation with oxygen content, for the three flux cored wires (Figure 8). The exception is the metal cored wire (TUBE S), for which the CPT is lower than would be expected. Higher oxygen content normally gives rise to a higher density of oxide inclusions, which are potential sites of corrosive attack. Therefore, we conclude that other influences are at work in the case of TUBE S, linked to the absence of a protective slag. The weld pool cools more quickly as a result, which may alter the final grain structure and ferrite content. This anomaly is still under investigation.

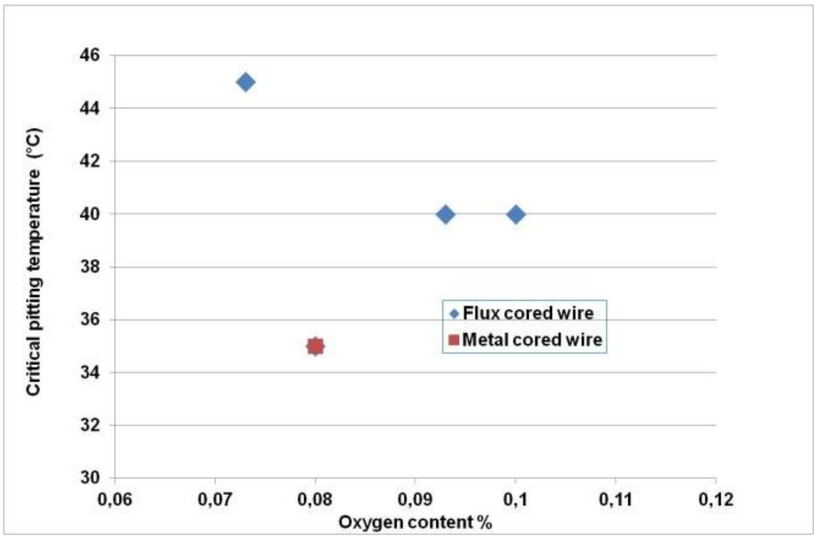


Figure 8. Relation between CPT and oxygen content

- ## Influence of the welding process on corrosion resistance

As already mentioned, the super-duplex metal cored wire TUBE S D57L-G can be welded using either gas shielding or flux shielding (submerged-arc). It was decided to compare the two processes for their effect on corrosion resistance. Weld deposits were prepared as described in Section 2, using 2.4 mm wire. The chemical analyses, ferrite content and PREN obtained are given in Table 9 below. They were closely similar, but not identical. Some differences were expected as different reactions occur during welding in the two cases.

Protection	C	Si	Mn	Cr	Mo	Ni	Fe	N	Cu	O	PREN
FLUX WAF 385	0,023	0,61	1,5	25,3	4,1	9,1	58	0,188	1,24	0,081	41,7
ARGON + 2,5% CO2	0,023	0,53	1,8	25,5	4.0	9,6	57	0,261	1,32	0,091	42,8

Table 9 . Metal-cored weld deposits (TUBE S D57L-G) under flux and gas shielding

It was not possible to use the same welding parameters for the two processes, but the conditions were adjusted to give similar energy inputs.

	Unit	TUBE S D57L-G	TUBE S D57L-S
Wire feed speed	m/min	4	4
Welding current	A	350	350
Voltage	V	30	28
Wire extension	mm	20	30
Welding speed	m/min	0,40	0,40
Protection		Ar + 2.5 CO_2	WAF 385 flux
Energy input	kJ/mm	1.58	1.47

Table 10: Welding parameters used for metal cored superduplex wires with different welding processes

The measured CPT was 35°C for both processes, although a slightly greater weight loss was observed for the submerged-arc process. These results indicate that the different welding conditions have not significantly influenced the corrosion resistance of superduplex flux cored wire deposits. Further investigations are in progress to resolve this question.

	Weight loss (g/m^2)				
Protection	25°C	30°C	35°C	40°C	45°C
FLUX WAF 385 *	0,002	3,9	***5.5***		
ARGON + 2,5% CO2	0,003	2,8	***5.3***		

Table 11: Weight loss and CPT for superduplex (D57L-G) weld deposits with different systems of protection

*WAF 385 is a aluminate basic agglomerated flux with neutral metallurgical behaviour, that is to say, it does not affect the composition of the weld deposit.

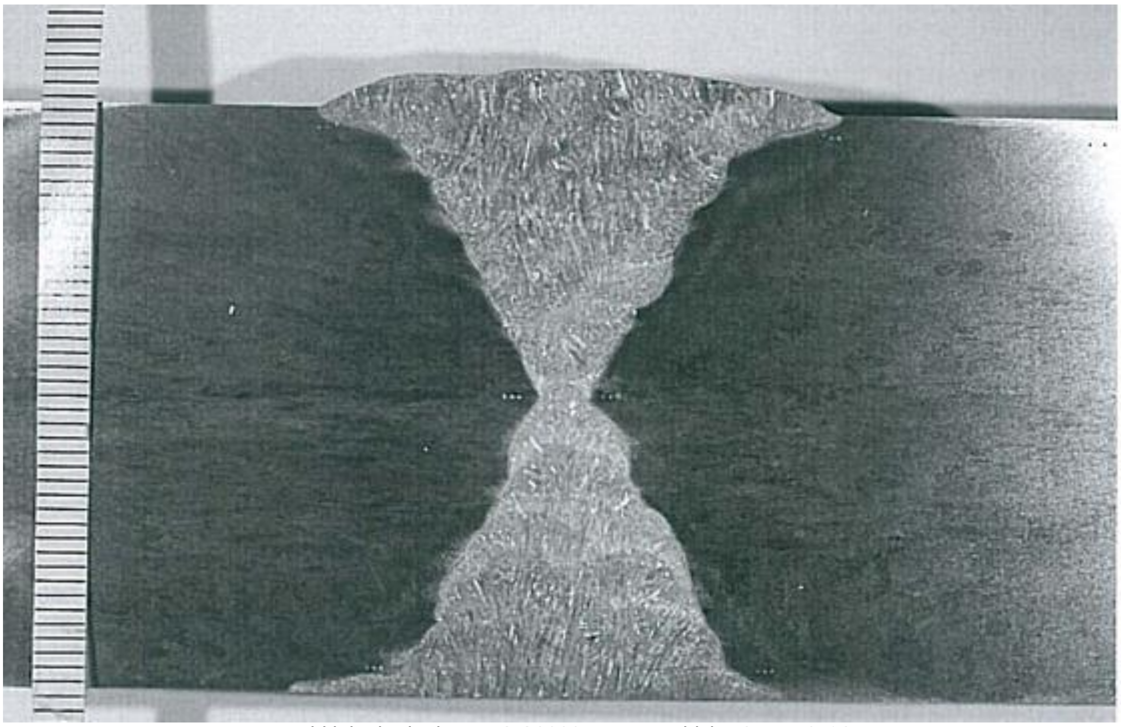
SiO2	CaO + CaF2	Al2O3	Na2O
9,5%	54,5%	33,7%	2,5%

Table 12: Composition of WAF 385 welding flux

4. Applications

Submerged arc welding of Duplex UNS S32205
Welded with cored wire TUBE S 22 9 3L-S + WAF 385 flux

Superduplex UNS S 32520 – welded with TETRA S B D57L-G;   CPT ≥ 40°C



Weld joint in duplex UNS S32205, 45 mm thick. CPT = 25°C

5. Conclusions

- Pitting Resistance Equivalent Number (PREN) is a useful tool for predicting corrosion resistance in stainless steels.
- Corrosion resistance is enhanced by using strip whose composition approaches that of the desired weld chemistry as closely as possible. This is believed to be related to the presence of unmolten metallic inclusions.
- The nature of the core mixture affects the corrosion resistance of the weld deposit. A reduction in oxygen content, achievable by using a “basic” slag mixture, has the effect of raising the CPT.
- Slag-free metal cored wires do not follow the above relation. For a given oxygen content, their corrosion resistance is less good than that of flux cored types.
- No significant difference in corrosion resistance was noted between metal-cored wire deposits welded under flux and under gas.

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