Welding Alloys Group

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Corrosion resistant alloy cladding and weld overlay with cored wires

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Summary

Many engineering applications require both high strength and corrosion resistance for long term performance and reliability. Cladding is an ideal way of combining corrosion resistance and mechanical strength. As a result, the use of this technique is widespread in equipment for the process and offshore industries.
Many processes are used for weld overlay, such as electroslag strip cladding, submerged arc welding with wire or strip, gas tungsten arc welding with cold or hot wire and gas metal arc welding, including its controlled short circuit variants.
Cored wire, tailored to the application, is a consumable of choice. Cored wires have become increasingly accepted by the industries for weld cladding because they have proved, in numerous cases, to be versatile, productive and reliable.
Flux or metal cored arc welding processes with or without an external shielding gas are employed in applications where solid wire or strip is commonly used.
This paper describes, through practical examples, the various cored wire processes and how they complement existing solid wires. It compares FCAW to SMAW and GMAW. It highlights the complementarity with strip cladding, describes the effects of the various process parameters and presents current cladding applications where cored wires are being used to produce austenitic and duplex stainless steel, nickel base and cobalt base overlays.

Introduction [1]
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.
Nickel and cobalt base alloys are used to extend the resistance to more aggressive media or when other wear mechanisms occur besides corrosion and heat.
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.

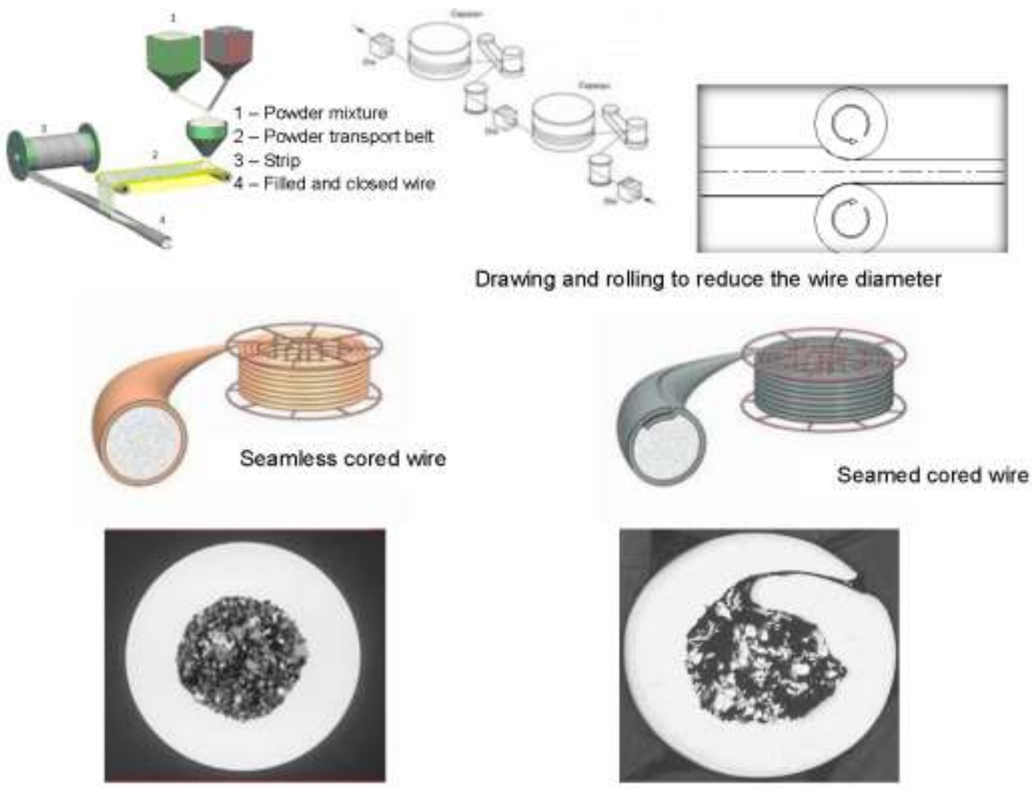


Figure 1: production of corrosion resistant alloy cored wires

Nickel base and cobalt base cored wires are produced similarly. 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 performance of cored wires in terms of productivity, weldability, ease of handling and feeding quality in addition to mechanical properties and resistance to various forms of corrosion - according to the type of stainless steel deposited - depends on a large number of factors, such as, for example:

- The strip: composition, dimensions, surface finish, impurity levels, general condition.
- The flux type (for a flux-cored wire): rutile, rutile-basic, basic. The details of the slag formulation, the consistency of the raw materials used and their purity are of overriding importance. It is well known that cored wires of the same classification from different manufacturers are never quite the same.
- The manufacturing process: rolling sequence, lubrication system, heat treatments etc.

We shall distinguish here between corrosion resistant alloy cored wires used with gas or flux protection and those which, like stick-electrodes, are used on their own.
Of those wires used with a gas shield, rutile and rutile-basic types are available for downhand welding and for out-of-position welding. Basic types and metal-cored types also exist. These latter contain no mineral additions, or only in minimal quantities. Metal-cored types are also available for submerged-arc welding

TUBE S (GMAW or SAW) → Stainless steel / STELLOY →Cobalt base / STELLOY → Nickel base

Contain 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 with or without helium (typically 15 to 30 %) addition. TUBE S may also be welded using flux protection, usually with larger wire diameters. The joint penetration is wide and the deposit has good mechanical properties. However, the usable welding parameter window is narrow -though increased when compared to solid wires- and this type of wire demands more welder skill, particularly when working away from the horizontal position.

TETRA S (FCAW) → Stainless steel

Contain 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 unexperienced 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 but it improves welder appeal.

TETRA S is designed for maximum efficiency in downhand welding, but may also be used for positional work. The deposit efficiency is of the order of 90%. The slow-freezing slag and the presence of arc stabilisers gives several advantages:

- Very pleasing arc characteristics
- Absence of spatter
- Self-detaching slag (or close to it), giving important time savings during weld finishing
- Smooth clean bead with fine ripple but with no silicate surface layer, comparable to that of a high efficiency stainless steel stick electrode, but without interruptions for electrode changes
- Wide tolerance of parameter settings. Weld quality is easily maintained even if the operator uses different parameters to those prescribed, for whatever reason.

TETRA V → Stainless steel / GAMMA V → Nickel base (FCAW)

Positional welding of stainless steels or nickel base alloys with solid wires is not easy: lack of penetration, spatter, porosity and poor bead appearance are a frequent consequence of the least deviation from the optimum welding parameters. With TETRA V, the proportion of rutile is increased in order to raise the freezing point of the slag (fast freezing slag) which contains the weld pool well, allowing welding in any position with the same parameter settings. Transfer by spray-arc with an active shielding gas assures excellent penetration, particularly in the vertical-up position where the productivity of this family is greatest. Deposition rates are at least twice those of standard MIG. Excellent results are also obtained in the overhead, horizontal-vertical and vertical-down positions

TETRA SB → Stainless steel / GAMMA → Nickel base (FCAW)

Contain 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.

TRI S → Stainless steel / GAMMA-O → Nickel base (FCAW)

Self-shielding flux-cored Corrosion Resistant Alloy wires do not need an external protective gas. Their filling contains gas-forming elements and other materials which help purify the weld pool. Metal transfer is of the globular type. Weld beads are white in colour with very little spatter. Diameter 1.2 mm and 1.6 mm wires are available for most austenitic stainless steel and some nickel base alloys. TRI S wires are approved for assembly work and their mechanical properties give no cause for complaint compared with gas-shielded wires. Their main use is surfacing. Self-shielded stainless steel wires are of interest for cladding and repair work, and also assembly work, when the use of gas protection is impractical or uneconomic.

Corrosion Resistant alloy cored wire types					
Description	**Gas or flux shielded**				**Open arc**
Core ingredient	**Slag**			**Metal**	**Slag**
Positions (EN ISO)	PA, PB	All	PA, PB	PA, PB	PA, PB
Positions (ASME)	1G, 1F, 2F	All	1G, 1F, 2F	1G, 1F, 2F	1G, 1F, 2F
Stainless steel	**TETRA**	**TETRA V**	**TETRA S B**	**TUBE S**	**TRI S**
Nickel base		**GAMMA V**	**GAMMA**	**STELLOY Ni**	**GAMMA -O**
Cobalt base				**STELLOY Co**	
Classification	R / T0-1/4	P / T1-1/4	B / T0-4	M / ECXXX	U / T0-3
Slag	Rutile	Rutile	Basic	None	Basic
Slag characteristic	Slow-freezing	Fast-freezing	Slow-freezing	-	Slow freezing
Shielding gas (EN ISO)	M21, M20 CO_2	M21, M20 CO_2	M21, M20	M12, I1, M13	None
Shielding flux (EN ISO)				AB, FB	

Table 1: Corrosion Resistant Alloy cored wires availability

Advantages of Corrosion Resistant Alloy cored wires

Compared with stick-electrodes:

- Reduction in welding time: stick-electrodes have a handicap: low deposit rates. It is rarely possible to deposit more than one kg/hour using stick-electrodes. The use of cored wires at least triples the deposit rate while giving equivalent weld quality.
- Welder motivation: more often than one thinks, stick-electrodes are chosen simply because there are more welders available qualified for this process than there are operators trained on an automatic process. A stick-electrode welder adapts rapidly to the use of cored wire because they behave in a closely similar manner to stick-electrodes of the same composition (slag, position, arc radiation etc
- Superior yield: it is not possible to use the complete length of a stick-electrode. About 15% is lost as a discard. It also contains more slag than a cored wire. These factors must be kept in mind when estimating the actual cost/kg of a consumable. 100 kg of stick-electrodes yields about 65 kg of weld metal whereas 100 kg of TETRA / GAMMA cored wire yields about 90 kg of weld metal.

Compared with solid wire used for MIG welding: [2]

- Lower heat input: for a given current and voltage, the arc generates a certain quantity of heat which is shared between the wire, the base material and external losses. If the proportion of one increases, that of the other decrease. At 200A, a standard current level for 625 MIG welding, deposit speeds are 4.80 kg/hour for 625 basic cored wire (at 28V) and 3.95 kg/hour (at 31V) for solid wire. Assuming external losses to be constant, the heat injected by the arc, calculated per unit weight of metal deposited (V x I / welding speed), drops as the welding speed increases. In other words, the cored wire weld pool is colder than that of solid wire, even though deposit rates are higher.
- Appearance: weld beads resemble those produced by stick-electrodes.
- No lack of fusion (cold laps): radiographic inspection of welds made by MIG using solid wire reveals unmelted zones, necessitating costly repairs. This type of defect remains a common risk, even with pulsed MIG welding using ternary protective gases. Cored wire eliminates this problem thanks to greatly improved wetting, an oxide-free bead surface and different penetration characteristics.
- Better penetration: the penetration profile of a basic flux cored wire is wider and better spread than that of a solid wire.
- No pores: the slag helps to absorb any impurities. Many vessels are coated with stainless steel or nickel base alloys. This is done by submerged-arc or electroslag welding using strip. All constructors use these processes. Certain components of the reaction vessel, made in mild or low-alloy steel, must be surfaced by manual or semi-automatic welding. With solid wire, pores are frequently encountered and grinding between layers is necessary to avoid exacerbating the problem. Cored wire contributes to achieve sound welds, actually with the same quality as with shielded metal arc welding electrodes but with the productivity of gas metal arc welding.

Examples of industrial applications with coroosion resistant alloy cored wires

Welding and surfacing of 1.4539 steel

Material number 1.4539 - UNS N08904 (Uranus B6, 904L) is a low carbon highly alloyed fully austenitic stainless steel. To avoid hot cracking problems, welding consumables with specially low impurity levels together with suitably adapted procedures must be chosen.
Flux cored wires are available for downhand welding (TETRA S 904L-G) as well as for positional welding (TETRA V 904L-G) and are frequently used for cladding. The weldability, bead appearance and weld quality explain the success of 904L FCAW.
For surfacing with 904L, metal-cored wires for GMAW or SAW come into their own. A first layer welded with TUBE S 309LMo and a second layer in an over-alloyed EC385 give excellent results. An alternative is to clad with standard TUBE S 904L.

UNS N 08904 → Two layer cladding with TUBE S – GMAW process

Base material analysis

C	Mn	Si	Cr	Ni	Mo	Cu	N	S	P
0.059	0.46	0.14	0.16	0.16	0.02	0.58	0.01	0.046	0.047

Analysis of TUBE S 309MoL-G Ø 1.2 mm filler used for the first layer

C	Mn	Si	Cr	Ni	Mo	Cu	N	S	P
0.016	1.45	0.55	24.59	13.61	2.82	0.08	0.049	0.010	0.017

Analysis of TUBE S 904SPL-G Ø 1.2 mm filler used for the second layer

C	Mn	Si	Cr	Ni	Mo	Cu	N	S	P
0.015	1.75	0.63	23.59	26.94	5.28	1.38	0.076	0.009	0.025

Surfacing parameters

	1st layer	2nd layer
Protective gas:	argon 4.6	argon 4.6
Wire speed:	7.4 m/min	7.1 m/min
Current:	250 A – 25 V – 40 cm/min	240 A – 25 V – 40cm/min
Bead thickness:	4 mm	4 mm
Bead overlap:	50 %	50 %
Interpass temperature:	< 120°C	< 100°C

Surface layer analysis – 1mm

C	Mn	Si	Cr	Ni	Mo	Cu	N	S	P
0.018	1.74	0.60	23.05	24.05	4.56	1.19	0.052	0.009	0.024

Testing

- Dye penetrant testing on 309LMo under-layer → nothing to report
- Dye penetrant testing on 904L layer → nothing to report
- 4 transverse bend tests over mandrel diameter = 4 times thickness → no defects after 180° of bending
- ASTM A 262 Practice E corrosion test after heat treatment 9hr 30 min at 570°C → no attack
- Hardness traverse (HV10)

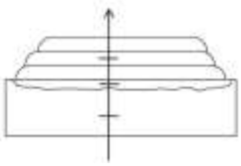
904L:	zone 1 : 193.199.195.193	zone 2 : 193.195.193.199
309LMo:	zone 1 : 221.221.221	zone 2 : 213.221.221.221
Heat-affected zone:	zone 1 : 237.221.187	zone 2 : 212.193.221
Base material:	zone 1 : 162.160.160	zone 2 : 162.170.170

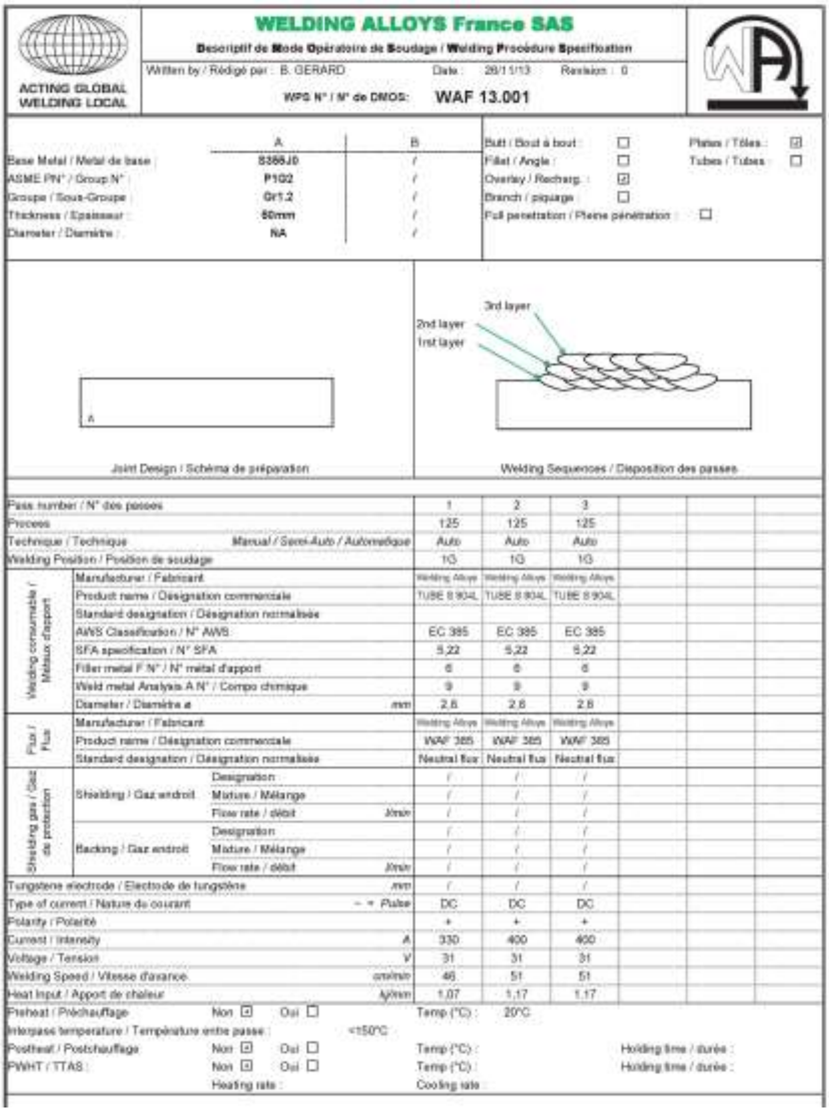
Figure 2: GMAW with TUBE S
Two layer 904L cladding

UNS N 08904 → Cladding with TUBE S – SAW process

Figure 3: SAW with TUBE S
TUBE S 904L-S + WAF 385

WAF 13.001 [illegible]				
	Hardness test (HV10)			
Base Metal	165	160	156	
Heat Affected Zone	186	190	178	
Weld Metal	185	187	193	198





WELDING ALLOYS France SAS

Descriptif de Mode Opératoire de Soudage / Welding Procédure Spécification

ACTING GLOBAL WELDING LOCAL

Written by / Rédigé par : B. GERARD   Date : 28/11/13   Revision : 0

WPS N° / N° de DMOS: WAF 13.001

	A	B
Base Metal / Metal de base :	S355J0	/
ASME PN° / Group N° :	P1G2	/
Groupe / Sous-Groupe :	Gr1.2	/
Thickness / Epaisseur :	60mm	/
Diameter / Diamètre :	NA	/

Butt / Bout à bout : ☐ Plates / Tôles : ☒
Fillet / Angle : ☐ Tubes / Tubes : ☐
Overlay / Recharg. : ☒
Branch / piquage : ☐
Full penetration / Pleine pénétration : ☐

Joint Design / Schéma de préparation

Welding Sequences / Disposition des passes

3rd layer
2nd layer
1rst layer

		1	2	3
Pass number / N° des passes		1	2	3
Process		125	125	125
Technique / Technique	Manual / Semi-Auto / Automatique	Auto	Auto	Auto
Welding Position / Position de soudage		1G	1G	1G
Welding consumable / Métaux d'apport	Manufacturer / Fabricant	Welding Alloys	Welding Alloys	Welding Alloys
	Product name / Désignation commerciale	TUBE S 904L	TUBE S 904L	TUBE S 904L
	Standard designation / Désignation normalisée			
	AWS Classification / N° AWS	EC 385	EC 385	EC 385
	SFA specification / N° SFA	5,22	5,22	5,22
	Filler metal F N° / N° métal d'apport	6	6	6
	Weld metal Analysis A N° / Compo chimique	9	9	9
	Diameter / Diamètre ø (mm)	2.8	2.8	2.8
Flux / Flux	Manufacturer / Fabricant	Welding Alloys	Welding Alloys	Welding Alloys
	Product name / Désignation commerciale	WAF 385	WAF 385	WAF 385
	Standard designation / Désignation normalisée	Neutral flux	Neutral flux	Neutral flux
Shielding gas / Gaz de protection	Shielding / Gaz endroit — Designation	/	/	/
	Shielding / Gaz endroit — Mixture / Mélange	/	/	/
	Shielding / Gaz endroit — Flow rate / débit (l/min)	/	/	/
	Backing / Gaz endroit — Designation	/	/	/
	Backing / Gaz endroit — Mixture / Mélange	/	/	/
	Backing / Gaz endroit — Flow rate / débit (l/min)	/	/	/
Tungstene electrode / Electrode de tungstène	mm	/	/	/
Type of current / Nature du courant	~ = Pulse	DC	DC	DC
Polarity / Polarité		+	+	+
Current / Intensity	A	330	400	400
Voltage / Tension	V	31	31	31
Welding Speed / Vitesse d'avance	cm/min	46	51	51
Heat Input / Apport de chaleur	kj/mm	1.07	1.17	1.17

Preheat / Préchauffage Non ☒ Oui ☐ Temp (°C) : 20°C
Interpass temperature / Température entre passe : <150°C
Postheat / Postchauffage Non ☒ Oui ☐ Temp (°C) : Holding time / durée :
PWHT / TTAS : Non ☒ Oui ☐ Temp (°C) : Holding time / durée :
Heating rate : Cooling rate :

Figure 4: TUBE S 904L-S, slag release

Figure 5: TUBE S 904L-S, weld appearance

Advantages of cored wires: limitation of the number of layers, welder appeal, standard shielding gas / flux, control of dilution, quality (mechanical properties and corrosion resistance) as with SMAW.

Stainless steel clad contructions undergoing post weld heat treatment

Many engineering applications require both strength and corrosion resistance. Low alloy steels have the strength but do not possess the required corrosion resistance. Hence, cladding makes it possible to combine both characteristics at a reasonable cost.
A post-weld heat treatment is frequently applied on constructions clad with compositions such as 309(L), 309(L)Mo, 309LNb, 347, 316(L), 318, 308(L) or 317(L). A matter of concern in this case is bismuth, a low melting oxide that is often added to corrosion resistant alloy cored wires in order to improve slag release and produce clean welds. [3]
For stainless steel weldments being designed for high temperature application or intended to be given a PWHT, cored wires producing less than 20 ppm (0.002%) bismuth in the deposit should be selected. For more than a decade, Welding Alloys produces an exhautive range of bismuth free corrosion resistant alloy cored wires, including a full range of TETRA S and TETRA V qualities that find widespread use in the industry.
Some advantages of 3XX Bi-free TETRA wires: tailored compositions within AWS / EN ISO specifications or different when required, welder appeal, suitable for mixed gas and for carbon dioxide shielding, track record.

Cladding type 347

Consumables	TETRA V 309L-G 1.2 mm batch 146665 TETRA V 347L-G 1.2 mm batch 146666
Base metal	13CrMo45
Welding position	Flat position PA
Shielding gas	EN ISO 14175 – M21 – ArC – 18
Current type/polarity/pulse	DC+ not pulsed
Interpass temperature	≤ 150°C

First layer TETRA V 309L-G 1.2 mm BATCH 146665

Gun angle	trailing 6°
Wire feed speed	10 m/min
Amperage	210 A
Voltage	30 V
Travel speed	47 cm/min
Electrical stick out	15 mm
Stepover distance	5 mm
Weld bead thickness	3 mm

Dye penetrant testing : no defect

First layer analysis and delta

C	Mn	Si	Cr	Ni	Mo	Cu	Nb	N	FN FERITSCOPE	FN WRC 92
0.054	1.26	0.581	18.30	9.83	0.192	0.078	0.0190	0.0374	3.4	4

Second layer TETRA V 347L-G 1.2 mm BATCH 146666

Gun angle	trailing 6°
Wire feed speed	10m/min
Amperage	215 A
Voltage	30 V
Travel speed	47 cm/min
Electrical stick out	15 mm
Stepover distance	6 mm
Weld bead thickness	3 mm

Dye penetrant testing : no defect

Second layer analysis and delta ferrite

C	Mn	Si	Cr	Ni	Mo	Cu	Nb	N	FN FERITSCOPE	FN WRC 92
0.036	1.51	0.635	19.78	11.24	0.131	0.103	0.292	0.039	6.2	4.9

Third layer TETRA V 347L-G 1.2 mm BATCH 146666

Gun angle	trailing 6°
Wire feed speed	10m/min
Amperage	215 A
Voltage	30 V
Travel speed	47 cm/min
Electrical stick out	15 mm
Stepover distance	6 mm
Weld bead thickness	3 mm

Dye penetrant testing : no defect

Third layer analysis and delta ferrite

C	Mn	Si	Cr	Ni	Mo	Cu	Nb	N	FN FERISSCOPE	FN WRC 92
0.036	1.56	0.645	19.58	11.18	0.120	0.108	0.372	0.041	5.8	4.3

Figure 6:
Cladding with Bi-Free cored wires
Layer 1: TETRA V 309LNb-G
Layer 2: TETRA V 347L-G

WPR - 3 layer cladding
TETRA V 309L-G
TETRA V 347L-G

Cladding NiCu – Alloy 400 [4]

ALLOY 400 is a Nickel-Copper alloy with good mechanical properties and excellent resistance to many corrosive environments. Marine and chemical processing are the two main fields where ALLOY 400 is used.

	Nickel	Carbon	Manganese	Iron	Sulfur	Silicon	Copper
ALLOY 400 UNS N04400	63.0 min.	0.3 max.	2.0 max	2.5 max.	0.024 max.	0.5 max.	28.0 – 34.0

Well developed welding processes for joining and cladding applications on Alloy 400 were GTAW, SMAW and GMAW. The MIG process with solid wire was the only one to have a high productivity in either the semi-automatic or automatic mode. However, the best compromise between quality and productivity was the shielded metal arc welding process, due to the oxidation protection thanks to the slag and an accurate and controlled dilution. The selection of any one technique is dependent upon access; welding position; dilution; productivity.
WELDING ALLOYS Group has developed a new basic flux cored wire for welding and cladding Alloy 400. GAMMA 400 meets the NiCu-7 chemical analysis. This cored wire combines the characteristics and benefits of solid wire for GMAW and SMAW electrodes i.e. combines productivity and high quality deposit. The shielding gas is a mix of argon + 15 – 25 % carbon dioxide.
A significant advantage of flux cored wires over solid equivalents is the deposition rate. With the same wire diameters at the same operating parameters (215A-25V-29cm/min), flux cored wire typically runs at wire

feed speeds that are at least 30% higher than solid wires. That means approximately 4.6kg/h for the FCAW process compared to 4kg/h for the solid wire.
Quality is also significantly improved by using cored wires. Using equivalent operating parameters, a cored wire will have a lowest dilution and a better weld pool protection thanks to the slag protection; no trailing shield needed. Using the same cladding parameters on carbon steel base metal, Ni-Cu solid wire (ERNiCu7) will have high risk of hot cracking due to the high dilution rate in 1G/PA position (~23% compared to 13% for GAMMA 400). This translates into iron contents of 15% Fe for the solid wire as opposed to the 9% Fe for the cored wire process.

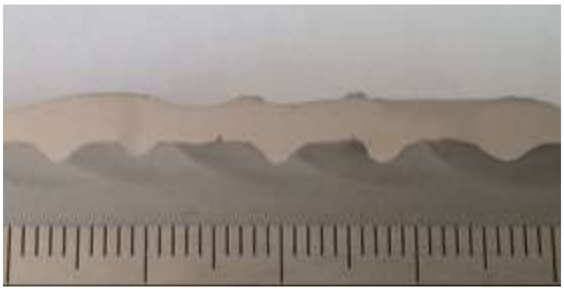


Figure 7
Solid wire – ERNiCu7
Pulsed→ 215A -26V - 29cm/min
1G/PA Position - Dilution 23%
%Fe (1rst layer) = 15%

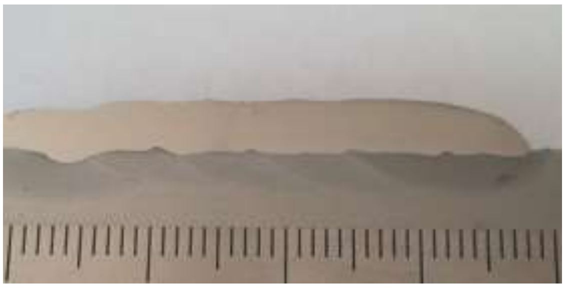


Figure 8
GAMMA 400
DC+→ 215A - 25V - 29cm/min
1G/PA Position - Dilution 13%
%Fe (1rst layer) = 9%

NiCrMo (625) Weld overlay

Flux cored arc welding is one of the most suitable processes for cladding application. It is commonly used on pressure vessel for parts such as shells, dished ends, tube-sheets and nozzles. The process selection is governed by the access, welding position, dilution, productivity and required quality.
GAMMA V 625 is matching nickel base 625 alloy with a typical composition of %Ni - 22%Cr - 9%Mo - 3.5%Nb. For cladding operation, the alloy 625 analysis can easily be achieved in two layers GAMMA V 625.

Figure 9
Weld appearance
Cladding GAMMA V 625

Figure 10
Longitudinal clad restoration
GAMMA V 625

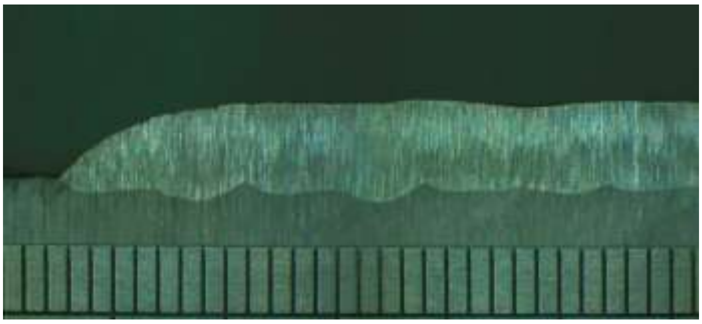


Figure 11: One layer thickness (3.3 - 3.5 mm)

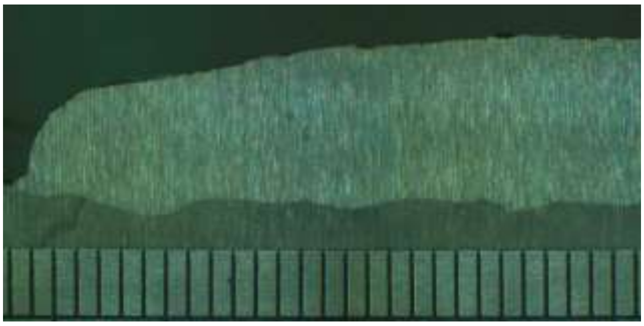


Figure 12: Two layers thickness (6.5 - 6.9 mm)

	%C	%Mn	%Si	%Cr	%Mo	%Nb	%Fe	%Bi	%Ni
N06625	0.1	0.5	0.5	20.0 23.0	8.0 10.0	3.15 4.15	5.0	-	58.0 mini
As welded surface	0.0411	0.0428	0.403	21.13	9.02	3.46	3.53	<0.0001	62.02
-3mm of the top surface	0.0403	0.051	0.386	21.02	8.91	3.45	4.25	<0.0001	61.55

GAMMA V 625 weld overlays have been tested and approved in the as welded condition, PWHT 635°C/ 3h as well as normalized at 910°C-25min.

Cobalt base cladding

COBALT alloys are selected for applications requiring high strength in corrosive aqueous environments or in high-temperature environments. The hardness of common CoCr alloys ranges from 200 HB to more than 50 HRc. Dedicated cladding procedures are implemented with a strict control of preheat and interpass temperature, depending on Co-base grade, base metal and cladding configuration.

	C	Mn	Si	Cr	W	Fe	Ni	Mo	Hardness
STELLOY 1	2.30	1.00	1.00	28.5	12	4.00			53 HRc
STELLOY 6 BC	0.90	1.00	1.00	28.5	4.50	4.00			38 HRc
STELLOY 6	1.05	1.00	1.00	28.5	4.50	4.00			42 HRc
STELLOY 6 HC	1.20	1.00	1.00	28.5	4.50	4.00			44 HRc
STELLOY 12	2.30	1.00	1.00	30.0	7.50	4.00			45 HRc
STELLOY 21	0.25	1.00	1.00	28.5			3.00	5.50	33 HRc
STELLOY 25	0.15	1.50	1.00	20.0	14.0	4.00	10.0		210 HB

Figure 13
Internal cladding of grit traps with STELLOY 6-G

Figure 14
GMAW cladding with STELLOY 21-G

Conclusion

Today, corrosion resistant alloy cored wires provide many options to the welding fabricator when it goes about cladding. Quality welds, high productivity, reduced welding cost, flexibility in composition and attractive weldability are major assets. To optimise their intrinsic benefits, it is very important to be aware of the strengths and limitations of the metal-cored, flux cored and open-arc cored wires.
The attractive properties of corrosion resistant alloy cored wires are currently exploited in a context where quality, productivity, innovation and competitiveness are the keys to success.

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