# Welding duplex chemical tankers the ESAB way

## Wide scale application of ESAB welding solutions at Factorías Vulcano S.A., Spain

*By Ben Altemühl, Svetsaren editor, interviewing Factorías Vulcano production management.*

**Factorías Vulcano S.A, Vigo, is a medium size shipyard in the north of Spain producing an extensive range of civil and maritime products, including chemical carriers in both carbon and duplex stainless steel. Currently, the yard is finalising the construction of The Primo, a duplex chemical tanker for the Swedish shipping company Initia. The fabrication, from the indoor panel lines down to the final outdoor block assembly, is characterised by wide scale use of ESAB welding solutions with a key role for ESAB OK Tubrod cored wires. This article reviews the production of chemical tankers at Vulcano. Special attention is focussed on the role of FCAW.**

### Acknowledgement

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### Introduction

The title "Welding duplex chemical tankers the Esab way", is perhaps a bit over-ambitious, but it is rightly chosen in the sense that Factorías Vulcano apply our welding solutions in practically every stage of the fabrication process of chemical tankers. The shipyard has made intelligent use of ESAB's capability to serve as a total supplier for stainless steel fabrication, selecting dependable and productive consumable/equipment combinations for practically all fabrication steps. The yard possesses a high level of practical welding knowledge, providing a solid basis for, sometimes difficult, but often fruitful technical discussions between our companies. Over the years, the cooperation in developing and implementing new techniques has developed such that today we feel we can rightfully claim that Esab's mission statement to be "the preferred partner for welding and cutting" is fully valid for this shipyard.

This article presents a bird-eye-view on the fabrication of chemical tankers in duplex stainless steel at Factorías Vulcano. Avoiding too much technical detail, it will step by step discuss the fabrication process as well as the ESAB welding solutions that have become established. The FCAW with rutile cored wires is emphasised, because it plays a key role in the fabrication and because these products are relatively new for duplex stainless steel welding.

### Factorías Vulcano

Starting out with the repair of railway engines in 1919, Factorías Vulcano widened their capabilities to what they are today; a full scale fabricator of civil and maritime constructions. Today's product range comprises civil engineering products like boilers, marine fresh water generators, refuse incinerators and sewage treatment plants, whereas the shipbuilding segment fabricates container ships, refrigerated vessels and chemical carriers.

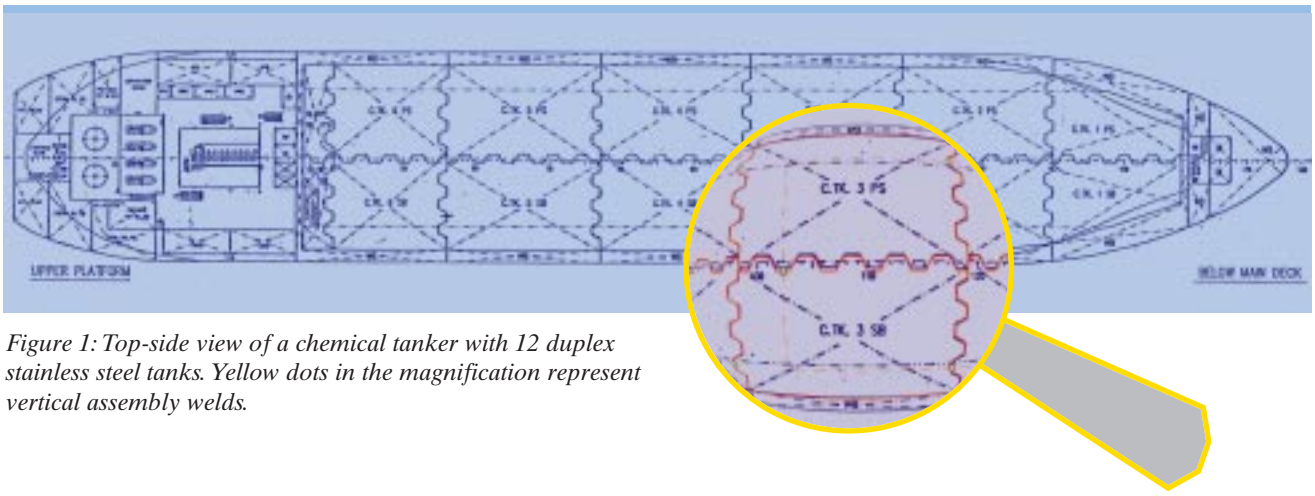



*Figure 1: Top-side view of a chemical tanker with 12 duplex stainless steel tanks. Yellow dots in the magnification represent vertical assembly welds.*

In 1990 the company commenced a three year plan to restructure and modernise the shipyard, involving a 1200M Pesetas investment. What results today is a modern medium-size shipyard with advanced FORAN CAD/CAM design facilities, an ESAB NUMOREX NXB9000 under water plasma cutting installation connected to the CAD/CAM system. Also, a panel fabrication line with two ESAB A6-LAE1250-TAC1000 submerged arc welding machines, mechanised welding stations for stiffener attachment and various systems for mechanised SAW and FCAW applied in sub-assembly and final assembly. The yard lay-out guarantees an efficient flow of work through production. Along with the modernisation, the yard implemented the ISO 9001 quality assurance system. Together with an orderbook of specialised projects that reaches well into the next century, the yard is well positioned to compete in today's demanding market.

## Construction of chemical tankers at Factorías Vulcano

Although fabricated out of two completely different base materials, carbon steel and duplex stainless steel, the construction of chemical tankers at Factorías Vulcano takes place according to established, modern shipbuilding practices involving panel fabrication, the construction of sub-sections, the assembly of block sections, and the final connecting of block sections in the dock. We shall focus on the role of duplex stainless steel cored wires. Since these are applied primarily in the dock assembly, we describe the fabrication of The Primo in reversed order.

*Figure 3: Root pass in deck joint with OK Tubrod 14.37 seen from above.*

Figure 1 gives a schematic view of a 16000DWT chemical carrier frequently built by Vulcano, and very much resembling the Primo. The vessel has 12 tanks in duplex stainless steel and two small tanks serving for storage of cleaning waste. Parts in duplex stainless steel are highlighted in red. Vertical assembly welds are indicated with yellow dots.

Figure 2 shows the Primo somewhere half way during the assembly of the chemical cargo tanks. Prefabricated sections are highlighted with individual colours and all assembly welds are visualised by yellow lines, numbered 1 to 9, and described in the margin.

For a good understanding of the construction, we recommend to first have a look at Figure 4. It shows the next block section to be assembled, comprising a deck section and tank assembly, the corrugated bulkheads. As such, it will be turned and placed in the construction. The yellow lines in Figure 2 may, therefore, indicate ready welds or welds to be made when the next block section has been positioned.

The first step in the duplex stainless steel assembly work involves the joints numbered 1, connecting the prefabricated deck plates to construct the tank floor. Here Factorías Vulcano apply a combination of manual FCAW on ceramic backing strip for single sided root passes and SAW for the filling layers. ESAB OK Tubrod 14.37 has been selected as the FCAW consumable, because of its capabilities for downhand work. With it's slow freezing, fluid slag, it is designed to weld at high travel speed giving high productivity (Figure 3). It gives good penetration and, after slag removal, the back side of the root requires no grinding or brushing. The ceramic backing strips to be used with this product require a rectangular groove to accommodate the slag and to promote a good bead appearance. OK 14.37 is welded in 85%Ar/15%$CO_2$ gas protection, a mixture applied at Factorías Vulcano for all FCAW (stainless and carbon steel). Here, and for all other FCAW, the yard uses simplistic rectifiers without the need for pulsing.

SAW filling is done with the ESAB wire/flux combination OK 16.86/OK Flux 10.93, a combination widely applied in duplex stainless steel fabrication, and with an excellent reputation. The flux is a low-hydrogen, non-alloying, basic agglomerated type (AWS: SA AF 2 DC). OK Autrod 16.86 is of the 23Cr-9Ni-3Mo type alloyed with 0.15%N to obtain a weld metal with sufficiently overmatching mechanical properties, a good austenite/ferrite balance, and excellent corrosion resistance when welding standard UNS

*Figure 4: Fabrication of a block section consisting of a tank cover with vertical corrugated walls in duplex stainless steel.*

S31803 types of duplex stainless steel. Vulcano use ESAB A2 Multitrac SAW machines, guided by rails attached parallel to the joints. The same machine-consumable solution is used all over the yard, providing a dependable welding method in many production steps (see later).

The same method as described for the tank floors is used for the connection of the tank floor to the carbon steel hull of the bottom (2), be it with 309L type welding consumables. The flux-cored wire for welding the root pass on ceramic strip is OK Tubrod 14.22, also a rutile type for all positional use, whereas the wire/flux combination applied for filling is OK Autrod 16.53/OK Flux 10.93.

The next assembly step involves the placement of the two side wall sections to the bottom of the vessel where first the carbon steel parts are connected, followed by weld type number 3 between subsequent block sections. Basically, this is the same type of joint as between the corrugated bulkheads (6), but welded with a slight angle. It is a V-joint welded vertically-up, manually or mechanised with rail-track equipment, with OK Tubrod 14.27. This rutile cored wire with fast freezing slag system is by far the most productive solution for making these kinds of assembly welds, with deposition rates that reach up to 3kg/h. Single-sided root passes are again made on ceramic backing strips with a rectangular groove

Assembly welds type 4 and 5 connect the tank walls to the tank floor. Both types are treated as semi-positional welds, primarily performed with FCAW. Root passes are welded on rectangular ceramic strips in the case of weld 4 and on cylindric ceramics in the case of weld 5. The back side of weld 5 has poor accessibility due to the geometry of the construction. SMAW with ESAB OK 67.50, an established acid- rutile electrode for standard duplex grades, was found to provide the most practical and secure solution for sealing the root.

The next fabrication step concerns the placement of the third prefabricated block section comprising a deck section and a cross of longitudinal and transverse tank walls; the corrugated bulkheads. This section can be seen isolated, and upside down, in Figure 4. The prefabrication of this component will be described later.

After turning and positioning this section between the side walls of the ship, a number of assembly welds remain to be made.

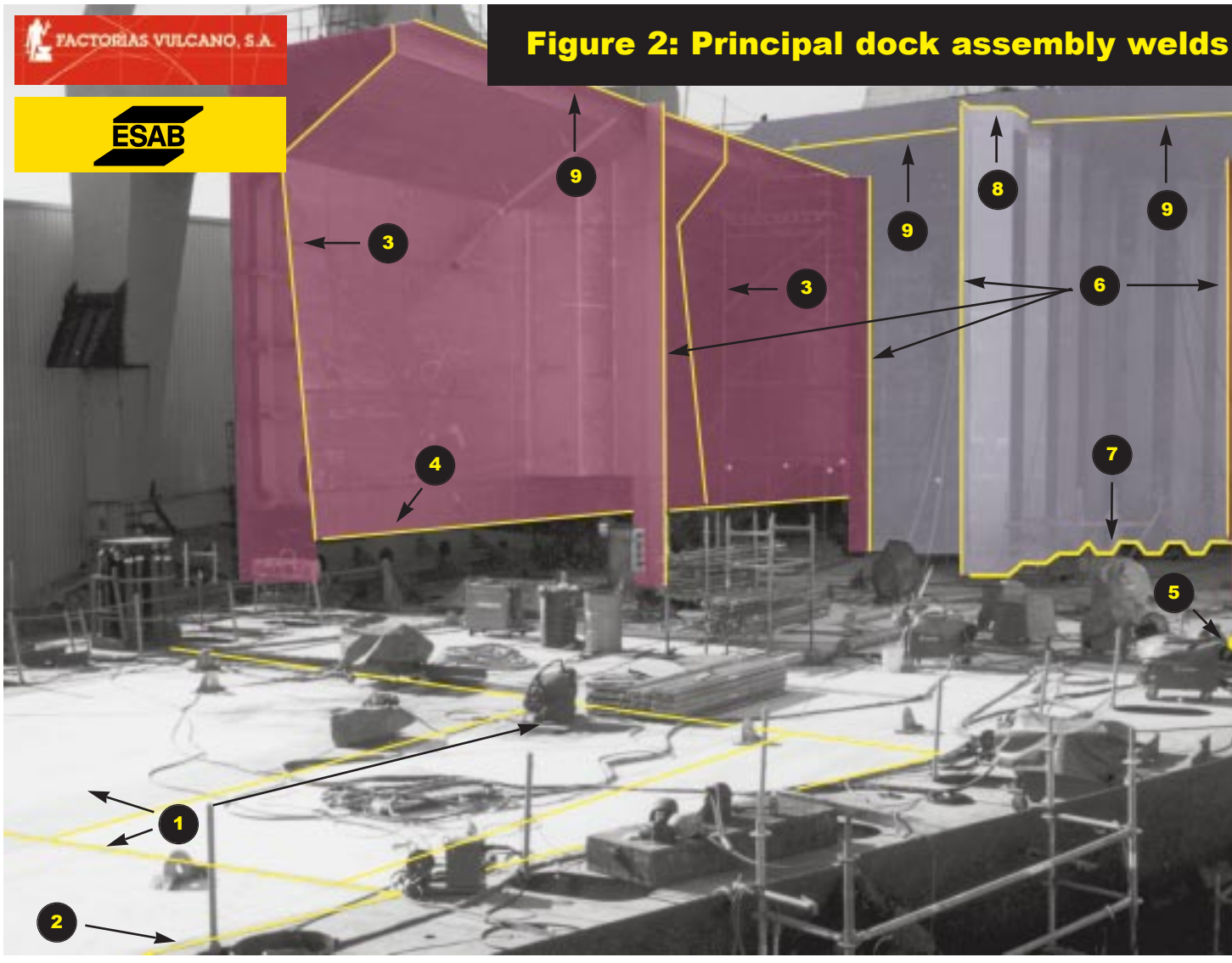
Assembly welds type number 6 are the ones indicated with yellow dots in figure 1. They connect the corrugated longitudinal bulkhead with the previous tank section, and the transverse bulkheads with the corrugated parts attached perpendicular to the side walls. The welding method and consumable used are exactly the same as described for weld type number 3 (OK Tubrod 14.27), but the welding position is truly vertical-up.

To obtain optimal welding economy, Factorias Vulcano apply mechanised welding with rail track systems for the filler layers. Figure 5 shows a typical example of a vertical assembly weld made in this way. Deposition rates amount to 3kg/h when calculated at 100% duty cycle, which is highly productive for this kind of unavoidable assembly welds.

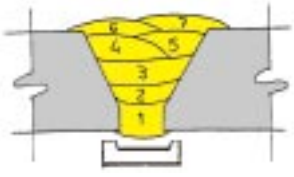
Assembly weld 7, between corrugated bulkheads and the tank floor, is carried out manually, because the geometry of the joint is too complicated to allow mechanisation (Figure 6). Moreover, the root gap may show misalignments, requiring the welder to manually build-up the root with a varying number of beads. OK Tubrod 14.27 proves to be a versatile and dependable consumable for this kind of demanding work. Root passes are made almost twice as fast as with stick electrodes, using cylindrical ceramic backing, with excellent ablity to compensate for misalignment of the joint.

*Figure 5: Vertical weld between corrugated tank walls; mechanised welded with OK Tubrod 14.27*

## Figure 2: Principal dock assembly welds




**1 Tank floor from pre-fabricated plates.**

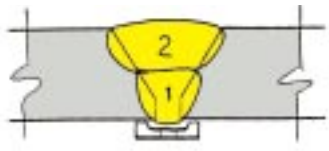


Position: PA/1G
Root & 1st pass: FCAW with OK Tubrod 14.37, welded manually onto ceramic backing strip.
Filling: SAW with OK Autrod 16.86/OK Flux 10.93

**2 Connection between tank floor and carbon steel hull**

Position: PA/1G
Root & 1st pass: FCAW with OK Tubrod 14.22, welded manually onto ceramic backing strip.
Filling: SAW with OK Autrod 16.53/OK Flux 10.93

**3 Connection between corrugated bulkheads and 6 between tank side walls**

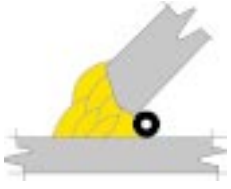


Position: PF/3G
Root: FCAW with OK Tubrod 14.27, welded manually onto ceramic backing strip
Filling: FCAW with OK Tubrod 14.27, welded manually.

**4 Connection between vertical tank wall and angled side wall**

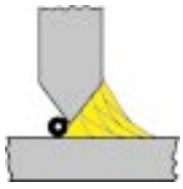
Position: PC/2G
Root: FCAW with OK Tubrod 14.27, welded manually onto ceramic backing strip.
Filling: FCAW with OK Tubrod 14.27, welded manually .

**5 Connection between angled side wall and tank floor**



Position: PC/2G
Multi-layer T-joint; full penetration.
FCAW with OK Tubrod 14.27, manually.
Sealing: SMAW with OK67.50

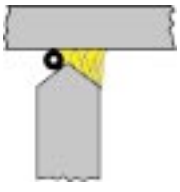
**7 Connection between corrugated bulkheads and tank floor**



Position: PC/2G
Root: FCAW with OK Tubrod 14.27, manually welded onto cylindric ceramic backing.
Filling: FCAW with OK Tubrod 14.27, welded manually.

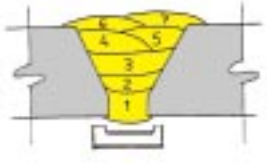
## in duplex stainless steel


**8 Connection between corrugated bulkheads and tank cover**



Position: PC/2G
Root: FCAW with OK Tubrod 14.27, manually welded onto cylindric ceramic backing.
Filling: FCAW with OK Tubrod 14.27, welded manually.

**9 Connection between tank cover and between tank covers and side walls**




Position: PA/1G
Root & 1st pass: FCAW with OK Tubrod 14.37, manually welded onto ceramic backing strip.
Filling: FCAW with OK Tubrod 14.37

*Figure 6: Attachment of a vertical corrugated tank wall to the tank floor; manually with OK Tubrod 14.27 (PC position).*

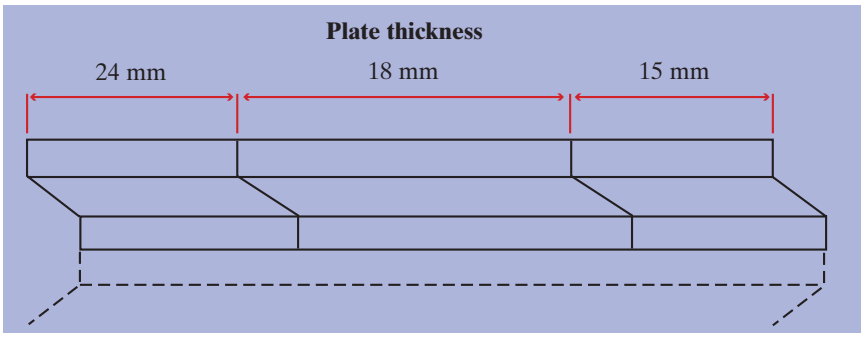



*Figure 7: Corrugated wall segment as purchased from the steel works.*

Assembly weld 8, connecting a small, extending part of the corrugated bulkhead to the deck of the subsequent tank section, is done in a semi-overhead position with exactly the same welding procedure. OK Tubrod 14.27 is one of the best cored wires available for overhead work, because the stiff, fast freezing slag prevents sagging of the weld metal.

The last step in the assembly process involves the connection of the tank cover (weld type 9). This is done in the downhand position with OK Tubrod 14.37 (root passes on rectangular ceramic backing strips.

### *Subassembly*

Going back to Figure 4, it can be seen that this prefabricated block section consists of two major parts; the tank cover and a cross of two corrugated bulkheads placed perpendicular to the tank cover.

Starting with the tank top, it is clear that it is composed of a great number of plates. The small yellow lines represent welds made indoor on the panel lines (described later) to form the panels out of which the deck is composed. The thick yellow lines are the pre-assembly welds connecting the panels to form the tank cover. They are made according to exactly the same welding procedure as described for the tank floor in Figure 2 (weld type 1). FCAW is used for the root and first pass (OK Tubrod 14.37 on rectangular ceramic backing strip) and SAW (OK Autrod16.86/ OK Flux 10.93) is used for filling and capping.

The sketch of Figure 7 describes the basic component of the corrugated bulkheads. As such, they are supplied by the steel fabricator, bent to the right geometry with welds connecting the three areas of increasing plate thickness. To form a complete longitudinal bulkhead nine welds are required. Figure 8 shows the fabrication of these welds. Again the combination of OK Tubrod 14.37 on ceramic backing for the root pass and OK Autrod 16.86/ OK Flux 10.93 is applied for the filling layers.

Two pre-assembly welds remain to form the block section. The transverse corrugated bulkheads are connected to the longitudinal ones by means of K-joints welded mechanised in vertical-up

position with OK Tubrod 14.27 using cylindrical ceramic backing to allow fast root pass deposition. The cross of bulkheads created in this way is attached to the tank cover in PB position with OK Tubrod 14.27 using the same welding procedure as applied in the dock assembly for weld type 7.

## Panel fabrication

Panel fabrication is carried out indoors on a panel fabrication line with two ESAB A6-LAE1250-TAC1000 submerged arc welding machines. Panels for the tank floor, the tank cover and for the side walls of the tanks are all prefabricated according to the same welding procedure. The number of plates comprising a panel varies.

At the moment of our visit, there was no duplex fabrication in progress, so we describe the welding procedure by means of the sketch in figure 9a. Duplex plates are bevelled to a Y-joint with a land of 4mm and positioned on the panel line with a minimal root gap. To avoid contamination of the duplex material, AISI 316L plates are placed between the duplex plates and the carbon steel rollers of the panel line.

SAW with OK Autrod 16.86 and OK Flux 10.93 is applied for the complete joint. The first layer is carried out with a tandem system; the two filling layers with single-wire SAW. After completing the above, the panels are turned and sealed with single wire SAW.

At this moment, Factorias Vulcano are experimenting with a new ESAB solution aiming at single-sided welding of the panels, which would provide a substantial time saving. Successful tests have been carried out with a backing rail filled with fine grain OK Flux 10.93 enabling to deposit a good quality root pass that requires no sealing (Figure 9b). Application of this system, however, requires an investment in stainless steel rollers, because it does not allow protection of the duplex material in the way utilised presently. The feasibility study has not yet been completed.

## Steel grade and mechanical properties

All duplex stainless steel used for the construction of the Primo is purchased from Avesta under the brand name Avesta 2205. It is a standard, molybdenum alloyed grade.

Mechanical properties of the welds are overmatching with all

### ESAB OK Tubrod rutile cored wires for duplex stainless steel

The ESAB OK Tubrod series of cored wires for standard duplex stainless steel consist of an all-position type, OK Tubrod 14.27 and one for downhand use, OK Tubrod 14.37. They provide fabricators with optimal welding characteristics and productivity for manual or mechanised welding.

OK Tubrod 14.27 is a very versatile consumable, suited for truly all welding positions, including pipe welding in combination with the TIG process for rooting. Very fast vertical-down welding of fillet welds is possible for parts that allow to be attached without secure root penetration. Many fabricators standardise on this type only, when the majority of the work involves positional welding.

Both types have very clear advantages compared with MMA and GMAW, reviewed below.

#### Advantages over MMA

- higher productivity in general due to higher duty cycle
- productivity for positional welding almost 3 times higher through increased deposition rates
- very economic deposition of root passes, with less welder skill needed
- no stub-end waste and therefore higher efficiency

#### Advantages over GMAW

- up to 150% higher productivity in positional welding
- excellent performance with conventional power sources; no expensive pulsed arc equipment needed.
- use of normal 80%Ar/20%$CO_2$ shielding gas; use of expensive high Ar mixtures is avoided. Fabricators have an option to standardise on one gas when welding both unalloyed and stainless steels.
- less oxydation of weld surface due to protective action of slag
- no grinding or sealing needed for the back side of root passes
- easy parameter setting

### Product data

#### Classifications

| | AWS A5.22: |
|---|---|
| OK Tubrod 14.27 | E2209T1-1/E2209T1-4 |
| OK Tubrod 14.37 | E2209T0-1/E2209T0-4 |

#### Approvals

| | |
|---|---|
| OK Tubrod 14.27 | ABS, Controlas, DNV, GL, LR, RINA, TÜV |
| OK Tubrod 14.37 | DNV, GL, LR, TÜV |

#### All weld metal composition (weight %)

| OK Tubrod 14.27 | | OK Tubrod 14.37 | |
|---|---|---|---|
| C: | ≤0.03 | C: | ≤0.03 |
| Si: | 0.50-0.90 | Si: | 0.60-1.00 |
| Mn: | 0.50-1.00 | Mn: | 0.70-1.20 |
| Cr: | 21.0-23.0 | Cr: | 21.0-23.0 |
| Ni: | 8.0-10.0 | Ni: | 8.0-11.0 |
| Mo: | 2.75-3.25 | Mo: | 2.75-3.25 |
| N: | 0.11-0.17 | N: | 0.10-0.16 |
| P: | ≤0.025 | P: | ≤0.035 |
| S: | ≤0.025 | S: | ≤0.025 |
| FN: | 30-50 | FN: | 30-50 |

#### Mechanical properties in Ar/$CO_2$

| OK Tubrod | 14.27 | 14.37 |
|---|---|---|
| Rp0.2% (MPa) | ≥500 | ≥480 |
| Rm (MPa) | ≥690 | ≥690 |
| A5d (%) | ≥25 | ≥25 |
| ISO-V –20°C (J) | ≥60 | ≥40 |

Shielding gas: Ar/$CO_2$ or $CO_2$

Polarity: DC+

*Figure 8: Welding of a corrugated bulkhead. Root (below) made with FCAW; filling and capping with SAW.*

ESAB consumables used for this project. The Ferrite number of the weld is required to be between 25–70 which is a normal requirement for duplex stainless steel welding, and sufficiently wide for construction practice. The Ferrite number is checked by means of a representative sequence of weld samples in various stages of the construction, using the same welding procedure and consumables as for the actual welds. From the same samples, confirmation of mechanical properties are obtained.

Preheating is not applied, although a minimal temperature of 16ºC is prescribed; sufficient to avoid condensation under the mild climatic conditions of the region. The interpass temperature is limited to a maximum of 150ºC.

Appendix I shows a full WPS for OK Tubrod 14.27 prescribing the manual or mechanised assembly welding in PF position, as described in Figure 2 (weld type 6). It contains useful information for readers that have become interested in this product, as well as a free lesson in welding terminology in the rich and beautiful Spanish language.

## To conclude

When having the privilege of visiting this modern, yet cosy shipyard in Galicia, I fell at home from the start, enjoying the warm and open atmosphere I encountered. It was very rewarding to see that Esab's commitment to be a total supplier works out so well at Factorías Vulcano, and that our products are being applied to the full satisfaction of the yard.

To avoid leaving behind the impression that it is fun to be an editor for Svetsaren, I will refrain from describing the short boat trip across a beautiful bay, after the interview, to the small family restaurant where I received valuable lessons in seafood dining. "Disfrutaba de toda forma y un día regresaré".

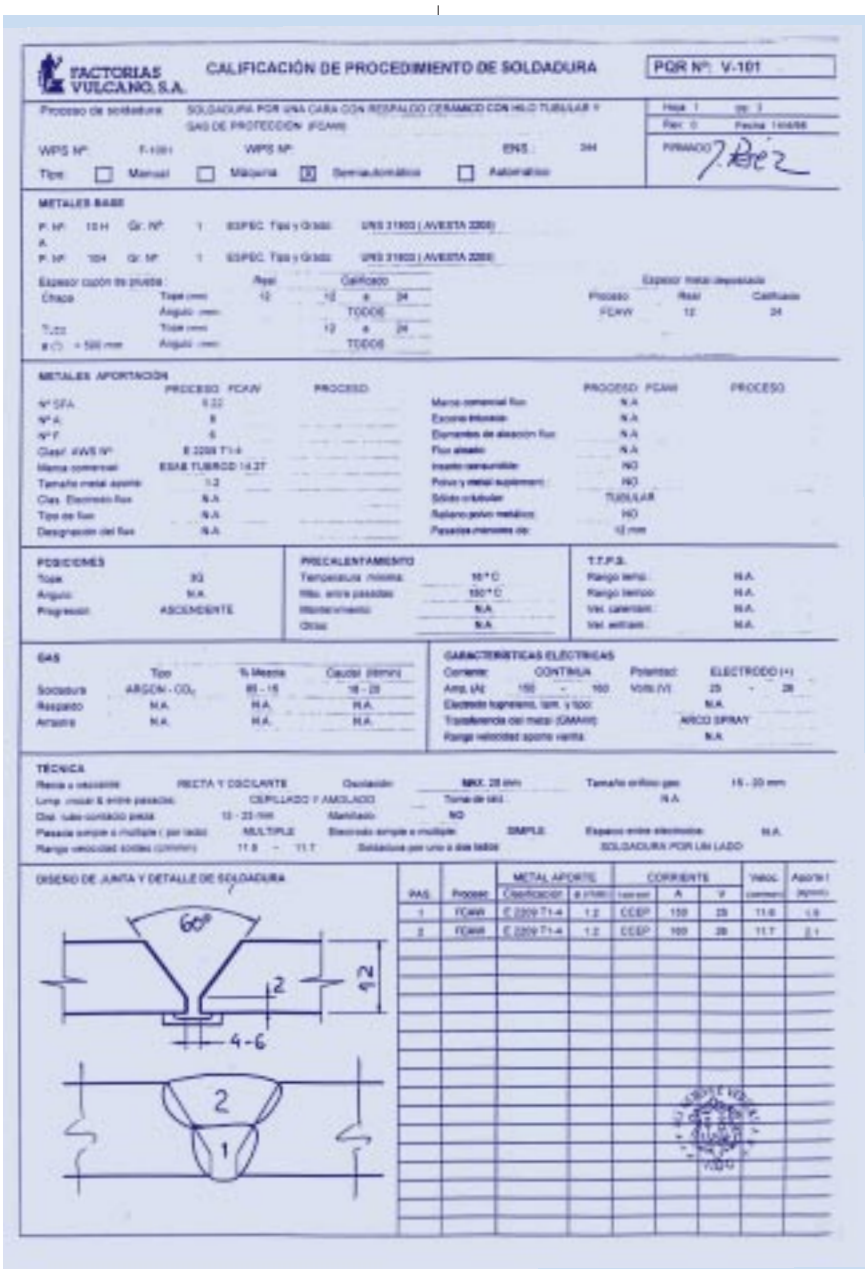



*Figure 10: Welding Procedure Specifications.*

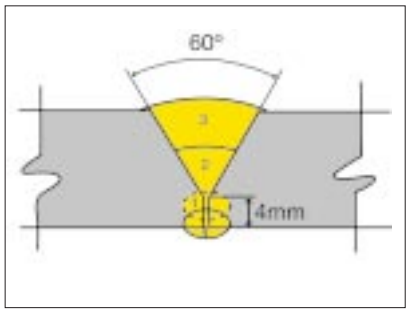



*Figure 9a: Double sided SAW panel fabrication.*

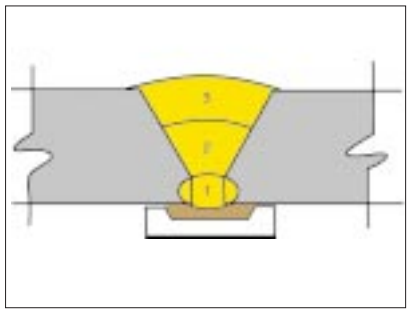


*Figure 9b: Single-sided SAW panel fabrication. Root pass on gutter filled with fine grain OK FLUX 10.93*