Welding LPG tankers the ESAB way

by Ben Altemühl, editor of Svetsaren, interviewing Stocznia Gdynia production management

ESAB is supplying the Gdynia Yard with a complete consumables package for welding gas tanks in NV 2-4 low-temperature steel.

Acknowledgement

We would like to thank the Gdynia production management for allowing us to visit the yard and for providing us with the information on which to base this article. We would especially like to thank Mr. Zenon Szymanski (EWE*) and Mr. Marek Piechulski (EWE), the welding engineers, for their co-operation and support. We also compliment our colleagues at ESAB Poland on the marketing success achieved at the Gdynia yard. (*European Welding Engineer)

Stocznia Gdynia

Visiting this immense shipyard, located in the Baltic port of Gdynia, and witnessing the enormous activity, the title of the national anthem automatically springs to mind, “Jeszcze Polska nie zginę≥a” – “Still Poland is not lost”.

The history of the Gdynia shipyard, founded in 1922, is associated in many ways with the 20th century misery and uprising of the Polish nation as a whole. It was established in the roaring twenties with ship repairs and was as hard hit as Poland itself by the Great Depression that was soon to follow, smothering any attempt to transform itself into a fully-fledged new building yard. It would take a series of bankruptcies and re-starts under new ownership before, at the end of the thirties, the first Gdynia-designed ships slid off the slipway.

The rapid growth of the Gdynia shipyard was dramatically hampered by the outbreak of World War II. Stocznia Gdynia was placed under the management of Deutsche Werke Kiel AG and was once again transformed into a busy repair yard and submarine building centre.

In 1943 and 1944, allied bombing destroyed the shipyard almost completely. After Gdynia’s liberation by the Soviet and Polish Armies in 1945, the yard rendered all kinds of services, before it reached its present form. Its portfolio of orders included chimney pipes for a portable stove and the repair of cars (among them those powered by wood gas).

The shipyard went on to become the largest repair base for the Polish fleet when merchant and naval vessels started coming back to Poland from their war-time wandering, along with the German ships given to Poland as war reparation and the English and American

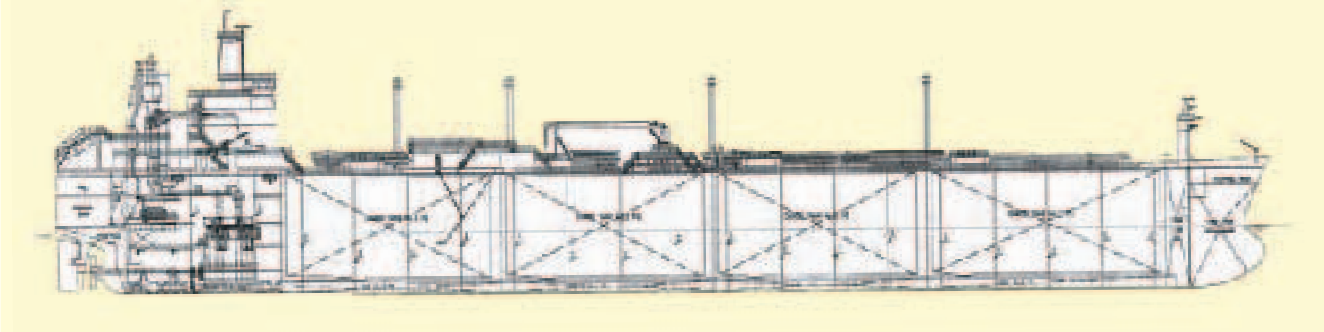

Figure 1. Blueprint of a DNV class 1A1 LPG tanker.

ships received from military stores. In the fifties and sixties, the majority of the ships that were built were delivered to USSR owners. Soon after, a new era dawned when the series production of B-523 type cargo ships was started, fulfilling the special requirements of Norwegian owners. From that time, Stocznia Gdynia had access to its own design department and more and more orders were also received from western countries. From the mid-sixties, Gdynia has broken records designing and delivering up to 117,000 tonne deadweight OBO carriers, liquid gas carriers with prismatic tanks, bulk carriers and bulk tankers. In 1970, shipyard workers in Gdynia, just like their colleagues in Gdansk, undertook, on behalf of the whole nation, a rebellion against the government. A monument still serves as a reminder of the victims who were killed and injured.

In 1980, the powerful Solidarity movement was born in the neighbouring Lenin Shipyard in Gdansk, triggering martial law in 1981 but also political and social changes, which led to today's market economy.

Stocznia Gdynia is now one of the largest and most profitable European yards, exporting close to 100% of its products to clients from all over the world. It is capable of building ships up to 400,000 dwt and consumes around 150,000 tonnes of steel a year. It builds fishing trawlers, general cargo and multi-purpose container vessels, crude and chemical tankers, OBO carriers, car carriers and large passenger ferries. The yard is ISO 9001 certified and has access to modern design and analysis tools such as CAD/CAM, NAPA, Tribon and Foran systems.

LPG carriers

At the time of our visit, the construction of the first of two 50,000 tonne deadweight DNV class 1A1 LPG tankers was nearing completion. These ships have four tank sections with a total capacity of 78,500 m^3, each of which consists of two independent prismatic tanks (see Figures 1 and 2). The tanks have a double hull and are surrounded by a safety barrier. The red lines in Figure 2 indicate the use of DNV class NV 2-4 low-temperature steel for the tanks and the safety barrier, whereas the green lines represent standard shipbuilding grades according to the Polish Bureau of Shipping (A32 and D32). The tanks are designed for a service temperature of –50ºC at an overpressure of 0.275 bar. The CVN requirement for the steel and the welds is 27J at –55ºC.

Table 1 shows the chemical and mechanical requirements for DNV NV 2-4. Plates according to NV 2-4 specification are purchased from the Polish steel manufacturer Huta Czestochowa in three thickness categories; 12, 20 and 28 mm.

As can be seen from Figure 3, the carriers are constructed in sections according to modern shipbuilding practice involving panel fabrication, the construction of sub-sections, the assembly of grand sections and the final connection of grand sections in the dock. Plates coloured red represent DNV NV2-4 steel and the green ones indicate standard shipbuilding steel. The hull sections are welded together in the dock to form the hull of the ship. The tanks are completed at the yard before being lowered into the hull. After this, the prefabricated top side including the deck is attached, together with the processing installations (Figure 4).

The welding of DNV NV 2-4 low-temperature steel

Although steels according to DNV class NV2-4 are developed for low-temperature service, they contain only a small amount of alloying elements and have a relatively low carbon equivalent. In the thickness range used by the Gdynia Yard (12, 20 and 28 mm) to construct the tanks, no preheating is required. However, to avoid the loss of HAZ impact toughness, there are limitations to the heat input and the interpass temperature.

From the point of view of the weld metal, extra care is required to avoid the loss of low-temperature impact toughness. The consumables used by the Gdynia Yard

Figure 2. Cross-section of an LPG tank consisting of two independent compartments. The red lines are DNV NV 2-4 class steel and the green lines are standard ship-building quality.

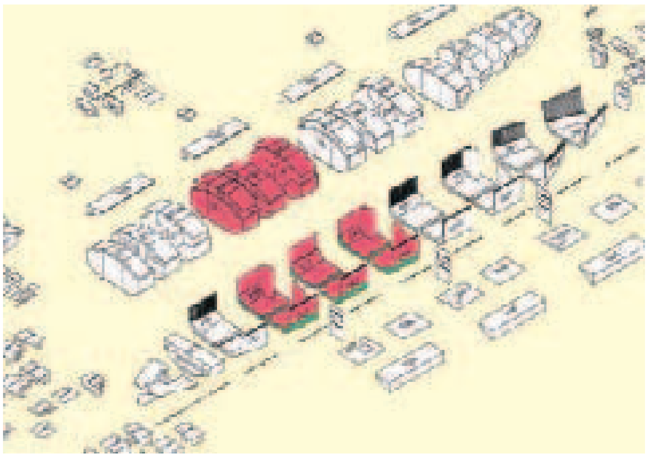

Figure 3. Exploded view of the tanker, showing construction stages.

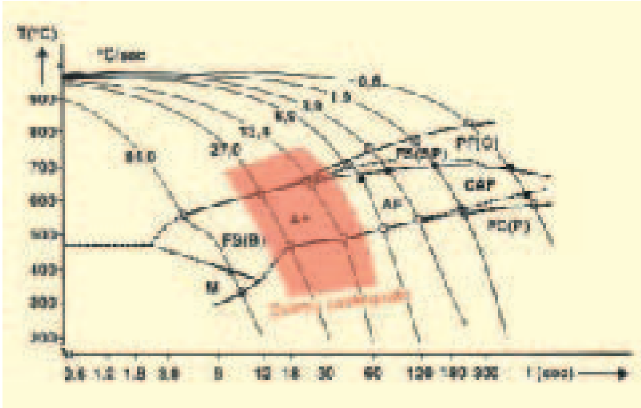

Figure 5. CCT diagram of CMn-Ti-B weld metal.

for welding DNV NV 2-4 steel fall into two categories; basic for SAW and MMA and rutile Ti-B micro-alloyed for FCAW.

Basic consumables produce a low-oxygen ferritic weld metal, consisting mainly of large amounts of somewhat soft grain boundary ferrite and acicular ferrite. The low-temperature toughness depends on the quality of the soft grain boundary ferrite in the microstructure and is further improved by 2.5% Ni-alloying. The microstructure and toughness can be spoilt in two ways. When the heat input is too low, bainite or martensite may appear as a result of the overly rapid cooling of the weld. When it is too high, the ferrite becomes coarse.

For rutile, Ti-B micro-alloyed flux-cored wires, low-temperature toughness is based on the presence of large amounts of fine acicular ferrite. In line with basic consumables, the micro-structure is spoilt when bainite or martensite is introduced when the heat input is too low (see Figure 5). With high heat inputs, however, grain boundary ferrite appears at the expense of acicular ferrite, with an even more detrimental effect on the toughness.

Figure 4. LPG carrier about half way through the production process. On the left-hand side, the top side of the carrier has been attached. On the right, the tanks (covered with insulation material) are still visible.

When it comes to the welding of DNV NV 2-4, this means that the heat input has to be within a certain range to be assured of the correct weld microstructure. ESAB recommends a heat input range of 1 to 2.5kJ/mm for the consumables described under the next heading "welding consumables". The welding techniques that are used to build up the joint differ from normal shipbuilding practice and are more in the direction of welding for offshore fabrication. Although preheating is not required for DNV NV 2-4 (as with many offshore steel grades), the interpass temperature must be limited. Full weaving, a very common shipbuilding technique, should be avoided as much as possible because it can take the heat input beyond critical levels. The split-weave or stringer bead technique, both offshore fabrication methods, may be less productive, but it ensures the correct weld microstructure with corresponding good low-temperature impact values.

ESAB has been involved in many LPG projects as a supplier of welding consumables and equipment. In many cases, the company has provided the welder with training and assistance in setting up suitable welding procedures. It has often proved necessary to instruct welders in the right techniques to obtain the desired low-temperature weld metal impact toughness. Special support was given to Gdynia to get it started with the cored-wire welding of the LPG tanks of the carriers currently under construction.

Welding consumables

To construct the tankers, an innumerable number of panels have to be fabricated, to be connected to subsections and grand sections and finally to arrive at the

%C	%Si	%Mn	%S	%P	%N	CE (C+Mn/10)
<0.14	0.15-0.50	0.70-1.60	<0.035	<0.035	<0.009	<0.32

Rm (MPa)	Re (MPa)	A5 (%)	CVN/–55ºC (J)
400-490	255*	>24	>27

Table 1. Chemical composition and mechanical properties for DNV NV 2–4 low-temperature steel.

dock assembly of grand sections. Various welding processes are applied. Wherever possible, mechanised welding is used for increased welding productivity, but manual welding is obviously indispensable for fit-up work and the connection of sub- and grand sections, as well as in dock assembly. Three welding processes prevail; MMA, SAW and FCAW. For the LPG tanks in DNV NV 2-4 steel and the hybrid connections between the tanks and the normal ship quality steel hull, the ESAB consumables listed in Table 2 are used.

OK 73.68 is a basic, 2.5Ni-alloyed LMA electrode with a recovery of 120%. It provides good impact toughness, even in the vertical-up position.

FILARC PZ6116S is a rutile, all-positional cored wire with Ti-B micro-alloying (+1.5%Ni) for use in CO_2 shielding gas.

OK Flux 10.62 is a high basic agglomerated flux (basicity index 3.4), suitable for single and multi-run welding in both butt and fillet welds. It has excellent slag detachability and smooth side-wall blending. In combination with OK Autrod 12.32 (DIN: S3), it produces good CVN impact properties down to –60ºC.

The typical all-weld metal chemical composition and mechanical properties are shown in Table 3.

Figure 9. FCAW under CO_2 gas protection with PZ6116S.

Figure 10. Outdoor FCAW with PZ6116S.

Figure 11. LPG tank under construction.

Fabrication welding

Two main SAW applications can be found in the fabrication of panels. Figure 6 shows the attachment of profiles using double-sided tandem welding with the SAW combination OK Autrod 12.32/OK Flux 10.62. Figure 7 shows the same wire/flux combination used with a tractor for shorter weld lengths.

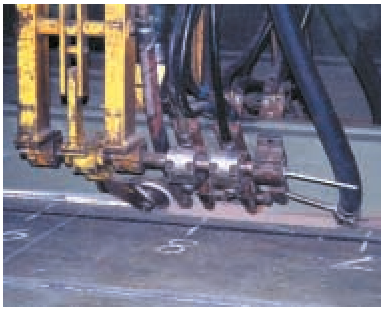

Figure 6. Double-sided SAW welding with OK Autrod 12.32/OK Flux 10.62.

Figure 7. Single-sided SAW welding with OK Autrod 12.32/OK Flux 10.62.

Figure 8. MMA welding with OK 73.68.

Another important SAW application is the connection of plates to panel walls with butt welds using double-sided welding. Figure 12 gives a characteristic welding procedure specification. Note the maximum interpass temperature of 150ºC, which is stipulated for all welding of DNV NV 2-4.

MMA is applied to a limited extent only, mainly for fit-up work in the construction of the sub- and grand sections of the LPG tanks. Figure 8 shows MMA welding with OK 73.68, a very versatile consumable for this kind of work.

FCAW is being used increasingly to replace MMA in order to produce increased welding productivity, especially in positional welding. It provides a fine spray arc at all applicable welding currents, making it easy to control the heat input in vertical-up welding and the welding of root passes on ceramic backing strips, for example. It is used indoors for manual fit-up work (Figure 9), as well as outside in the fabrication of sub-sections (Figure 10) and the connection of tank segments to complete tanks, where it is used for the main vertical assembly welds. The use of CO_2 shielding gas makes the wire more suitable for work outside in windy conditions than types using Ar-based mixed gas. Figure 13 shows a

For MMA	OK 73.68	EN 499: E 46 6 2Ni B 32 H5	AWS A5.5: E8018-C1
For FCAW	PZ6116S	EN 785: T 46 6 1.5Ni P C 1 H5	AWS A5.29: E81T1-K2 J
For SAW			
	OK Flux 10.62/ OK Autrod 12.32	EN 756: S 46 6 FB S3Si	

Table 2. ESAB welding consumables for DNV NV 2-4.

	%C	%Mn	%Si	%Ni	Rm (MPa)	Re (MPa)	A5 (%)	CVN/–60°C (J)
OK 73.68	0.05	1.0	0.35	2.4	610	520	26	105
PZ6116S	0.05	1.3	0.4	1.5	615	550	25	75
OK Autrod 12.32/ OK Flux 10.62	0.07	1.4	0.3	–	580	475	28	90

Table 3. All-weld metal chemical composition and mechanical properties of ESAB consumables for DNV NV 2-4.

welding procedure specification for welding DNV NV 2-4 in the PF position.

Conclusion

ESAB is supplying the Gdynia Yard with a complete package of consumables for welding LPG tanks in DNV NV 2-4 low-temperature steel. The package includes consumables for MMA, SAW and FCAW. ESAB's assistance with educating the welders and the establishment of welding procedures, in particular for FCAW, has contributed to the successful fabrication of the tanks.

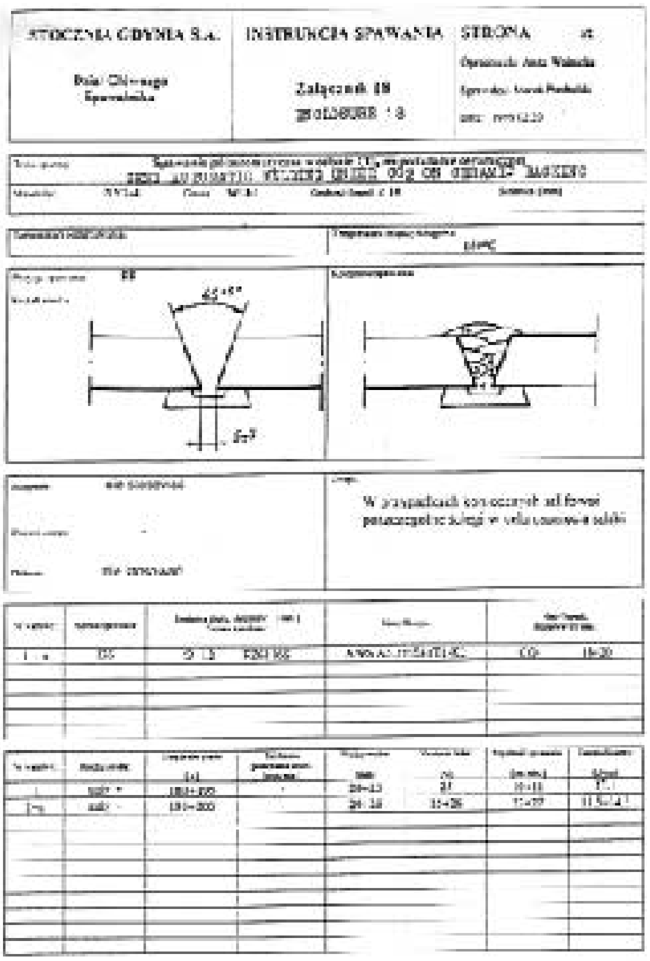
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Figure 12.

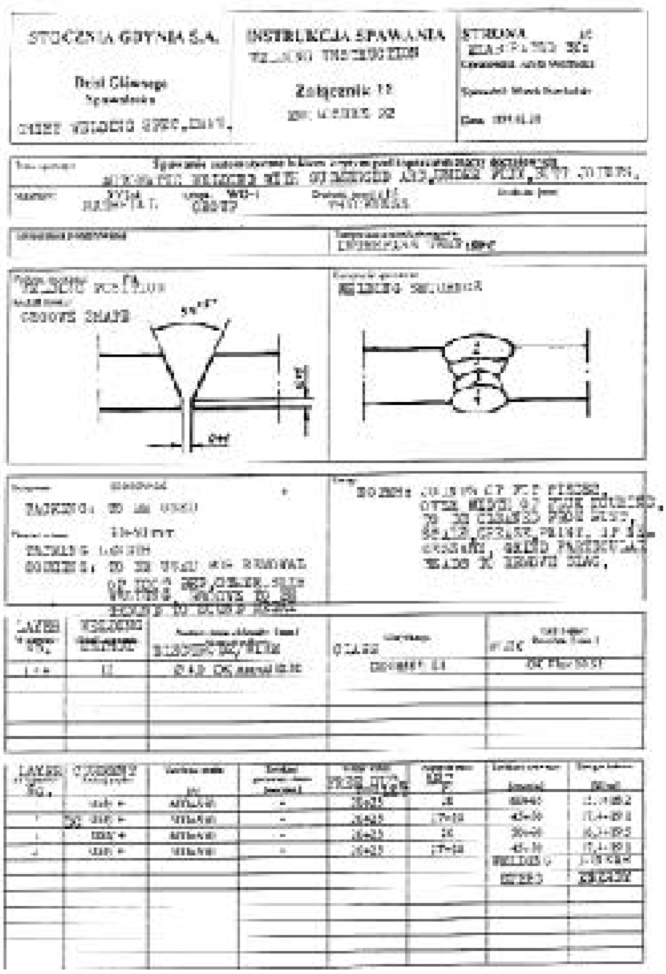
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Figure 13.