Setting new standards

We have now gained OHSAS 18001 group certification from DNV. Our group Environmental, Health & Safety Management System was already ISO14001 certified. This is believed to be the most comprehensive certification achieved by any global company to date. It includes all production operations, sales and central functions within ESAB at 1 July 2007.

Our system will benefit our customers

It does not matter if our customers operate in China, Germany, US, Brazil or Sweden. Wherever in the world you buy ESAB products, these are produced in accordance with the same global EHS standards where occupational and product health & safety always comes first. Let us show you what a well managed company can do for you!

www.esab.com
Dear reader,

Energy makes the world tick. Its generation and supply is a significant factor in global development, having an intimate effect on life style and quality. The lack of energy availability in many parts of the world, the growing awareness of the necessity to manage the limited resources and excessive and sometimes wasteful human behaviour, all create a challenge for the future.

The limited availability of fossil fuels and their harmful effect on our environment, forces us to develop renewable forms of energy and, also, to explore the still enormous potential savings we can make in energy consumption. The latter is an integral element of ESAB’s environmental management system- rewarded with the ISO 14001 global environmental certification.

Our energy efficiency ratio in production sites and offices (revenues/energy use), for example, has doubled in 10 years (1996-2006) – as a result of focused and planned activities - and we intend to double this again in the coming decade. Another of our long-term strategic objectives is to significantly increase the use of energy from renewable sources (now 5%). This corporate policy guides our development efforts and demonstrates that leading industrial enterprises can take the initiative and can change traditional behaviour.

The exploration of fossil fuel based resources has accelerated and taken on a new path in commercialising previously non-economic areas. Exploration takes place in more remote areas, more challenging environments in terms of climate and we are exposed to deep sea drilling and many more difficult engineering challenges. Wind power has become a global priority and we see renewed worldwide investment in nuclear power generation.

This issue of Svetsaren features articles and application stories that illustrate the success of our clients and the deep involvement of ESAB as a welding and cutting solution provider for the energy generating industry.

Good reading,
Competitiveness in wind tower fabrication is synonymous with the application of productive, high quality welding solutions. With ESAB, you are assured of a partner who understands your challenges and responds with innovative welding and cutting technology.

We design and retrofit column & boom stations for submerged arc welding of circumferential and longitudinal welds – including head and tailstock, automation and integration in existing production lines. These are complemented by welding tractors and equipment for special components.

Tandem - twin technology is our latest development in multi-wire welding heads providing unsurpassed deposition rates and welding productivity.

Developed specifically for your industry, our flux/wire combinations ensure the required weld quality and mechanical properties - be it for land-based, offshore or even arctic wind towers.

Visit us at www.esab.com
Template for monster platform challenges
Heerema.
ESAB low-hydrogen consumable technology crucial in safe and productive welding.

Port of Marseille sees LNG storage tanks erected with ESAB welding technology.
Project, awarded to a joint venture of Saipem and Sofregaz, sub-contracted to the Italian Bentini Group SpA.

SIF Group bv at the foundation of Dutch wind energy
ESAB SAW technology crucial in the production of piles and transition pieces for the Q7 North Sea wind farm.

Zorya-Mashproekt relies on ESAB for arc welding of gas turbine components
Zorya-Mashproekt is a leading Ukrainian producer of industrial and marine gas turbine power plants and engines.

Complete and reliable partner for pipe mills.
The latest ESAB equipment and consumables for longitudinal welding.

Paresa SpA construct spheres for the Kuwait petrochemical industry
Part of integrated petrochemical plant for hydrocarbons processing.

ESW Inconel strip cladding
Solution to clad steel shortage for Maritime Industrial Services, Dubai.

Mechanised pipeline welding in the Saudi desert
Magnatech orbital welding system and ESAB cored wire do the job.

Cladding of valves for petrochemical plants.
Valve manufacture and repair is a growth industry.

Techint and ESAB Brazil - partners in the construction of the PRA-1 jacket.
Technical partnership fundamental to the success of the project.

Manufacturer of mobile gasoline tanks in AlMg5 alloy at ZAO BECEMA, Russia.
ESAB assists in conversion from steel to aluminium.

Belleli Energy SpA reactors at the heart of Qatar’s Pearl Gas-to-Liquids Plant.
ESAB arc welding consumables deliver quality and productivity.

High integrity flowline welding at LMI
ESAB orbital TIG technology crucial.

Product News
- New power sources for orbital welding
- Robust and powerful MIG/MAG Power sources for heavy duty welding
- Caddy™ - the portable solution for professional welding
- New Origo welding machine for demanding applications
- Reactive welding helmets
- AUTOREX – The first, totally encapsulated, automatic plasma cutting centre
- Tramtrac™ II – flexible solution for the repair of embedded city tramway rails.
- New submerged arc fluxes
- OK Tubrod 14.11 – Metal cored wire for high speed thin plate welding
- VacPac gets slimmer
Template for monster platform challenges Heerema.
ESAB low-hydrogen consumable technology crucial in safe and productive welding.

Thicker and heavier, and with sharper tolerances than ever before – this was in essence the challenge Heerema Vlissingen faced in the construction of the template for the Tombua Landana oil and gas platform. The answer was found in smart logistics and precision work, supported by proven welding solutions. (See page 14 for a description of the Tombua Landana project).

Acknowledgement
We thank Heerema Production Manager, Harm Sanstra, for facilitating our visits to the Vlissingen yard.

Heerema Fabrication Group (HFG)
Heerema is a name that requires little explanation – especially not for Svetsaren readers in the oil and gas industry. It is one of the bigger, globally operating players in the engineering and fabrication of large and complex structures for the oil and gas industry. It has been active in the offshore industry ever since oil and gas were discovered in the North Sea in the early 1960’s and enjoys a reputation for state-of-the-art engineering, fabrication and project management.

HFG has yards in the Netherlands (Vlissingen and Zwijndrecht) and in the United Kingdom.
The rows are a network of heavy pipes connecting the four pile sleeve clusters to form a rigid construction. Four leveling jacks, devices to position the template horizontally with great accuracy, are attached to the central columns of the rows. The shim piles on the leveling jacks rest on leveling piles in the sea bed. Leveling is performed by jacking the template up or down relative to the shim piles.

The entire Tombua Landana project is characterised by very narrow construction tolerances, the substructures being placed on top of each other, in nearly 400 m deep waters - a particularly unforgiving environment for any misalignment.

Also, the TBT was subject to strict dimensional tolerances – up to three times more precise than normally required in offshore fabrication. Moreover, it was the first part of the tower and all eyes were focused on Heerema. Two Daewoo representatives and two representatives of Chevron supervised the project and carried out regular inspections.

Steel grades, mechanical requirements and preheat temperatures
Steel grades were purchased according to the “General Specification 1.14 Structural steels and other materials”, issued by the Cabinda Gulf Oil Company for the projects in block 14. In this specification, material types are ranked I and I-X, II and II-X, III, IV and V. Material types I are for structural members and tubular joint cans which are fracture critical and material types II are for structural members and cans where failure would pose a threat to the structure. Material types III, IV and V are for non-critical components. A list of valid steel classifications is given for each material type. Heerema Vlissingen purchased various types of plate according to EN 10225 Grade 355 (thermo-mechanically controlled rolled) and API 2MT1 as rolled, covering the demands of material types I and II, and meeting special constructional requirements such as “through thickness properties”. All main steel was purchased from Dillinger Hüttewerke in Germany.

Mechanical weld requirements are established by Cabinda’s General Specification 1.15 – Structural welding and inspection. Charpy V-notch impact testing of both weld metal and heat affected zone was required on all welding procedure qualifications, with notch locations at the weld centre line, fusion line and FL+2mm. CTOD testing of the WM and HAZ was required for type I and II steels with a thickness greater than or equal to 63 mm (2.5”), to be performed on the thickest steel to be welded while using the highest preheat and interpass temperature permitted by the welding procedure to be qualified.

Table 1 gives an overview of CVN and CTOD requirements. An additional cross weld zone hardness requirement was set at HV10 325 maximum.

In constructions such as these, involving thick material, the prevention of hydrogen induced cracking (cold cracking) is essential. This starts with the purchase of steels with limited hardenability. Cabinda’s General Specification 1.14 for structural steels and other materials therefore specifies a maximum Pcm value of 0.23 (extended CE formula).

In welding, preheating, along with the use of low-hydrogen consumables, is essential in the prevention of cold cracking. Cabinda General Specification 1.15 refers to AWS D1.1, for preheat and interpass temperatures to be applied.
Crucial for Heerema Vlissingen, when selecting FILARC PZ6138, was the fact that ESAB was able to present low-hydrogen test results, consistently within EN hydrogen class H5, for every individual batch of wire produced over many years. This, in combination with a practically unlimited shelf life and minimal moisture pick-up on the shop floor, convinced them this was the best wire for their fabrication.

Heerema Vlissingen also uses FILARC PZ6125 – a basic wire used for the welding of roots without ceramic backing.

Submerged arc welding
For SAW, Heerema Vlissingen selected an unconventional flux/wire combination: ESAB OK Flux 10.47 / OK Tubrod 15.24S - ø4.0 mm - a combination of a fused flux and a basic cored wire.

Fused flux, used with solid wires, has never been popular for demanding fabrication applications, due to poor mechanical properties. They hold certain advantages, though, the most important for offshore fabrication being that they are completely non-hygroscopic (Figure 2) and can be used without re-baking. By engineering the mechanical properties through the basic cored wire, rather than through a high basic agglomerated flux, this combination reaches the following typical mechanical properties:

- Yield strength: 510 MPa
- Elongation: 29%
- CVN: 106 J at -50°C
- CTOD: 0.95 mm at -10°C
  (> 0.25 mm at -29°C obtained by Heerema)

Sufficient for most applications, this allows Heerema Vlissingen to use the flux without re-baking, directly from the packaging, which significantly simplifies the flux handling at the yard. For the Tombua Landana project, welding procedure qualifications were performed at the required temperature and mechanical demands were met with a comfortable margin.

Another huge advantage is that the deposition rate from the cored wire is substantially higher than from a basic flux with solid wire, resulting in fewer layers and a productivity that is ~30% higher, which is a welcome improvement for any fabrication (Figure 2).

Due to the glass nature of the flux, the grain strength is significantly higher than that of the fully basic agglomerated fluxes. This results in less break-down and hence no problems with “dusting” and, therefore, all round improved recycling.

SMAW (MMA) welding
FILARC 76S is universally applied for tack welding and for the first passes in joints with difficult access. It is a basic AC/DC MMA electrode with

<table>
<thead>
<tr>
<th>Table 2. Preheat and interpass procedure.</th>
</tr>
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<tbody>
<tr>
<td>Thickness</td>
</tr>
<tr>
<td>&lt;38mm</td>
</tr>
<tr>
<td>38-65</td>
</tr>
<tr>
<td>&gt;65</td>
</tr>
</tbody>
</table>

For type I and II steel, this resulted in the preheat and interpass procedure of Table 2, according to Table 3.2 of the AWS.

Welding processes and consumables
Offshore fabrication, in general, is characterised by the use of heavy plates and pipes, in all welding positions. A certain number of joints can be brought in the downhand position, but the bulk remains manual work on often complex structures such as the nodes in platform jackets. Heerema Vlissingen applies three principal welding processes:

- Flux-cored arc welding for all-positional manual welding.
- SAW for heavy joints in the downhand position
- SMAW (MMA) for joints with limited accessibility.

The selection of consumables for these processes was guided by mechanical properties, productivity and, very importantly, low-hydrogen characteristics.

Flux-cored arc welding
For manual positional welding, Heerema Vlissingen uses, almost exclusively, FILARC PZ6138-ø1.2mm, an all-position rutile flux-cored wire welded in Ar/CO₂ mixed gas (FILARC is a product name in the ESAB consumables range). It is alloyed with 0.9% nickel and micro-alloyed with titanium-boron for good CVN toughness down to -60°C and good CTOD properties at -15°C.

These all weld metal properties have been sufficient for virtually all the projects Heerema has handled over the many years they have been using this wire. In addition, it gives a deposition rate in positional welding that cannot be met by any other manual process (3-4 kg/h at 100% DC). It is extremely welder friendly, operating in the spatter-free spray arc mode over the full range of applicable welding parameters. Root passes can be produced on ceramic weld metal support.

Sufficient for most applications, this allows Heerema Vlissingen to use the flux without re-baking, directly from the packaging, which significantly simplifies the flux handling at the yard. For the Tombua Landana project, welding procedure qualifications were performed at the required temperature and mechanical demands were met with a comfortable margin.

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SMAW (MMA) welding
FILARC 76S is universally applied for tack welding and for the first passes in joints with difficult access. It is a basic AC/DC MMA electrode with
good CVN properties down to -60°C and is CTOD tested in the AW and SR condition. It has a vast track record that dates back to the years when MMA was the standard for manual welding in offshore fabrication. FILARC 76S is low-hydrogen with low moisture absorption properties. It is supplied to Heerema Vlissingen in VacPac vacuum packaging for ultimate protection.

### Major welding applications in the pile sleeve cluster

Figure 3 shows the fabrication of a pile sleeve cluster. Its main components are indicated. The pile sleeve - the part which guides the foundation piles - has been pre-fabricated by Sif Group bv, in Roermond, along with the foundation piles themselves. Also the parts of the conical “pile catcher” allowing the use of SAW - mostly circumferential welds - are already attached during pre-fabrication. Heerema Vlissingen completes the catchers with stiffener plates (Figure 4). This involves a vast amount of full penetration butt welds, as well as fillet welds, all performed with manual FCAW, using FILARC PZ6138. Where possible, root passes are deposited on ceramic weld metal support.

The welds connecting the pile sleeve to the shear plate involve a symmetrical double-sided K-joint in 51 mm thickness (openings angle 40 degrees, root gap 5mm, root face 1mm), welded with the SAW process, using the OK Flux 10.47/OK Tubrod 15.24S flux/wire combination and ESAB A2 welding tractors. The root pass of these full-penetration welds is done with PZ6125, on ceramic backing, whereas sufficient thickness for the SAW process is obtained by a hot pass with PZ6138. In this stage, the construction can still be turned on roller beds, aided by contra weights, in order to use the productive SAW process on both sides.

Turning the construction is no longer possible when two pile sleeve-shear plate pairs – grit

### Table 3. Overview of low-hydrogen consumables used for the Tombua Landana template.

<table>
<thead>
<tr>
<th>ESAB consumables</th>
<th>EN classification</th>
<th>AWS Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>FILARC PZ6125</td>
<td>758: T 42 6 1Ni B M 1H5</td>
<td>5.29: E71T-5G</td>
</tr>
<tr>
<td>FILARC PZ6138</td>
<td>758: T 46 5 1 Ni P M 1 H5</td>
<td>5.29: E81T1-Ni1MJ H4</td>
</tr>
<tr>
<td>OK Flux 10.47/OK Tubrod 15.24S</td>
<td>EN: S 46 5 AB T3N1H (AW)</td>
<td>5.23: F8A4-EC-G (AW)</td>
</tr>
<tr>
<td>FILARC 76S</td>
<td>499: E 42 6 Mn1Ni B 32 H5</td>
<td>5.5: E7018-G</td>
</tr>
</tbody>
</table>

Figure 3. Fabrication of a pile sleeve cluster.
completed in the overhead position, using FILARC PZ6138 rutile cored-wire.

When the shear plate of the third, and last pile sleeve in a cluster, is connected to the main leg, the joint position is horizontal-vertical. The joint preparation is again a symmetrical K-joint welded blasted and painted - are connected to the main leg. Here a combination of SAW for the down-hand side and FCAW for the overhead side is used (root FCAW on backing). The preparation is a 2/3 – 1/3 K-joint, so that the larger part of the joint volume can be welded in the downhand position with the productive SAW process. The 1/3 side is completely with the FCAW process, using FILARC PZ6138.

The upper and lower yoke plates are connected by means of manual FCAW. It concerns full penetration X- and K-welds with all welding positions occurring. Again PZ6138 is the main consumable (roots on ceramic backing).

TKY-joints in rows
The rows - a network of heavy pipes connecting the four pile sleeve clusters – are pre-fabricated both indoors and outdoors. Their lay-out on the factory floor (Figure 6) exemplifies the great dimensional precision required.

The two columns on the left and right are not part of the structure. They have the same dimensions as the main legs of the pile sleeve clusters and precisely set the dimensions of the row, before (tack) welding. Permissible deviations here are as narrow as ± 1/4" (6 mm) horizontally and ± 1/8" (3 mm) vertically, requiring extreme accuracy. It is a procedure of virtually endless dimensional control. The same procedure is repeated during erection of the template (Figure 7), before rows are finally connected to the legs in the pile sleeve clusters.

All nodes (TKY-joints) are welded in the positions as they occur in figure 7 with FCAW using PZ6125 for the root and PZ6138 for filling. Figure 8 shows the FCAW welding on a special TKY-joint – the lifting trunnions. These are used to attach the lifting cables onto the template during installation. Part of it is welded with SAW with OK Flux 10.47/OK Tubrod 15.24S (Figure 9).
Foundation piles

The foundation piles are pre-fabricated by Sif Group bv, arriving in 83-93 m lengths. To achieve their final length of 170 – 190 m, they need to be welded together (Figure 10 and 11). This is again done by FCAW with PZ6138, but here it is mechanised welding with ESAB Railtrac equipment. The joint configuration is adapted to this method - an unsymmetrical X-joint with most of the weld volume on the outside. The inside part is welded manually, vertically-up. The root pass is deposited on ceramic backing. After removal of the fit-up plates, the majority of the weld volume is mechanised welded from the outside, vertically-up from 6 to 12 'o clock, mostly with a slight weaving motion. Welding parameters are adapted to the several clock positions by the operators.

Dimensional control and weld finish

Normal offshore fabrication, eg, a jacket on top of which the deck and operational facilities are placed, is naturally, subject to strict dimensions, but it is more forgiving than in the case of the Tombua Landana project. The fact is that three substructures, fabricated by three different yards, are stacked on top of each other in almost 400 m deep waters - and simply have to fit. This places extremely high demands on the dimensional control – roughly 3 times as high as normally required.

This is as equally valid for the fabrication of the TBT’s components – the pile sleeve clusters and the rows – as it is for the assembly of the superstructure. To exemplify the dimensional control and its implications for welding, we return to the fabrication of the pile sleeve clusters, shown in Figure 12.

This image shows the completed pile sleeve cluster and the nominal distances between the centre lines of the pile sleeves and the centre line of the main leg (5172.5 and 5173 mm). The maximum acceptable tolerance on these distances is 3 mm. A similar small tolerance is valid on the distances between the pile sleeves themselves, in the X and Y directions and on the mutual distances into the Z direction. This dimensional control is the key requirement, and everything else is subject to it.

Ideally, the pre-fabricated yoke plates, including K-bevel, fit exactly, so that there is a constant root gap between the pile sleeves/main leg and the yoke plate’s K-bevel. In practice, this is extremely difficult to achieve. Practically always, the root gap appears to be more or less eccentric. This must be corrected by grinding on the narrow side and buttering & grinding on the wider side – an extremely time consuming exercise.

Measuring was performed by three parties: Heerema Vlissingen, Passe-Partout (independent contractor) and Chevron, who worked independently according to agreed measuring principles. Chevron were responsible for final measuring and reporting.

Another time-consuming aspect was Class C and Class A grinding of weld surfaces. Grinding is done with an aluminium oxide based disc.

Class C grinding is required for the TKY joints between the braces and the dummy leg (middle of the row) and between the braces and the main leg of the pile sleeve cluster. It is performed to correct excessive convexity, notches or undercut at the toes of the weld. The grinding of the toes of the cap must be performed to the point where a 1 mm diameter wire cannot pass between the disc and the plate (Figure 13).

Class A grinding is performed on the welds connecting the lower yoke plates to the main legs of the pile sleeve clusters – at both sides of the K-joint. Class A means that weld profile is ground back to the theoretical radius. This is checked by using a template with a 45 mm radius, with a gap.
the size of a paperclip not being allowed. The total length to be ground per weld was 2 x 11.5 m for each of the four main legs.

**Conclusion**
The Tombua Landana template was one of the most challenging projects ever undertaken by Heerema Vlissingen. It required a carefully planned factory lay-out and a level of precision not before experienced. The company finished the project within the agreed delivery term and, by the publication date of this Svetsaren, its sister company, HMC, will be involved in sea transportation and installation of the 474 m tall Tombua Landana oil and gas platform.

Safety was essential. To step up its performance beyond already tough levels, Heerema Vlissingen took part in Chevron's safety programme – Incident and Injury Free (IIF) – in which Chevron gave workshops and training to the yard personnel aiming at individual development.

For its welding solutions, Heerema Vlissingen relied on low-hydrogen consumable technology from ESAB – a supplier that meets Heerema Vlissingen's demands in any respect, including quality management systems, environmental management systems and occupational management systems. Like Heerema, ESAB is ISO 9001 and ISO 14001 approved world-wide. OHSAS 18001 is the latest approval obtained by ESAB, see page 2.

The final words of this article should be addressed to the welders of Heerema Vlissingen who did such a tremendous job, notwithstanding the high preheat and interpass temperatures and overall tough working conditions.

**Figure 11.** Vertically-up welding with ESAB Railtrac and FILARC PZ6138.

**Figure 12.** Pile sleeve cluster dimensional control.

**Figure 13.** Class C grinding on TKY-joints to correct convexity, notches or undercut at the toes of the weld.

**About the authors:**

**Alfred van Aartsen**, EWE, is Welding Engineer at Heerema Vlissingen B.V., The Netherlands.

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Tombua Landana project

This huge oil and gas platform is due to be operational by the third quarter of 2009 in the Tombua and Landana deep water development areas, off the coast of Angola. The main contractor is Daewoo Shipbuilding & Marine Engineering, on behalf of Cabinda Oil Company and its partners. It is the production centre in the development of the oil and gas reserves in block 14, in Angolan waters. The Tombua Landana development follows the installation of the Benguela Belize-platform, an integrated drilling and production platform for the development of the Benguela and Belize fields. It was the industry’s first application of compliant piled tower structural technology outside the Gulf of Mexico. At 512 m, it is among the world’s tallest man-made structures.

The Tombua Landana project involves the construction of the drilling and production platform, a subsea centre of water injectors and producers and the installation and tie-in of two export pipelines that will connect the Tombua Landana drilling and production platform to the Benguela-Belize oil and gas pipeline transportation system.

The Tombua Landana platform stands 474 m tall, nearly as high as her twin-sister in block 14. The platform engineering, fabrication and installation has been contracted to Daewoo Shipbuilding & Marine Engineering (DSME). DSME will build the the topside in Okpo, Korea and has subcontracted the tower top section (TTS) to Gulf Island Fabricators, the tower bottom section (TBS) to Gulf Marine Fabricators (USA); and the tower base template (TBT) to Heerema Vlissingen, The Netherlands.

Transport of all substructures to Angola and installation has been subcontracted to Heerema Marine Contractors, a sister company of Heerema Vlissingen.
Port of Marseille sees LNG storage tanks erected with ESAB welding technology.

BRUNO MALAGOLI, ESAB SpA., MESERO, ITALY.

Gas de France completed the expansion of their LNG receiving and distribution terminal in Fos Cavaou, near Marseille, in mid-2007. The project, awarded to a joint venture of Saipem and Sofregaz, comprised the engineering, procurement and construction of the overall terminal facilities, including three 110,000m³ LNG storage tanks, sub-contracted to the Italian Bentini Group SpA, whom relied on ESAB LNG welding technology.

The Bentini SpA Group
Established in the 1950s, the Bentini Group SpA, based in Faenza, Italy, expanded rapidly during post-war reconstruction, operating abroad as from 1976, and enjoying continuous growth and diversification in the civil and industrial plant-engineering sector, both as a main and sub contractor. It has a turnover of 150 million Euros and over 1200 employees, operating in France, Algeria, Libya and Nigeria. In Algeria, it has two daughter companies; Gepco SpA, a general contractor in the oil and gas industry, and Benco SpA, a general construction contractor.

LNG tanks
The project consisted of three cryogenic tanks, each with a capacity 110,000m³. They are cylindrical in shape with a diameter of 80m and an overall height of 37m. The maximum liquid level inside the tank is 24m. The inner wall (in contact with the liquid gas) is constructed from X8Ni9 steel (EN 10028-4) - a 9% nickel steel,
typically for cryogenic applications down to -196°C. Here the liquefied natural gas, arriving in LNG tankers, is stored and held at a temperature of -163°C at a pressure slightly above atmospheric. For distribution, the LNG is re-gasified by heat exchange with sea water, odorised and transported through the pipeline network at a pressure of 70-100 bar.

The thickness of the tank bottom plates is 6mm, and the stringer plate 10mm. The metal plates for the primary tank - in contact with the liquid - vary in thickness from 16.6mm (at the bottom) to 12mm (at the top), compensating for the hydrostatic pressure from the stored liquid, which increases gradually towards the bottom. Figure 1, representing the tank cross section, gives an idea of the complexity and types of materials involved in the construction.

Materials and welding
The main component is the primary tank designed to contain the liquid natural gas. The primary tank is surrounded by a corner protection system - lower in height and designed to offer additional safety in the case of liquid leakage from the primary tank. These components are made from 9%Ni steel, resistant to temperatures down to -196°C (coloured red in Figure 1). Further protection, known as the vapour barrier and covering the whole tank internally, is made of carbon steel plates and serves to hold the gas in equilibrium with the liquid.

According to Bentini's Welding Engineer in charge, Mr. Emanuele Ceroni, “The welding was of vital importance – from the initial welding process qualifications right through to the on-site management and monitoring of the human resources - due to the importance of the construction and the potentially associated risks. The welding processes used for construction of the tank are MMA, SAW and semi-automatic GMAW. The latter process was used for welding the suspended aluminium roof with ESAB OK Autrod 5183 wire. After obtaining approval from Saipem we searched for the right consumable. ESAB advised us to use the vertical downhill technique with 1.2mm diameter Tubrod 14.12 wire. In production, this wire allows an appreciable increase in productivity and consequent saving of time, as well as limited deformation.”

As previously mentioned, various materials are involved in the construction, starting with the most strategic component, X8Ni9 steel (EN 10028-4), with 9% nickel. It is steel typically used for cryogenic applications and has been widely used in this type of plant. However, as it is highly sensitive to magnetic fields, it could create potential problems associated with welding. This is the reason why the ESAB OK 92.55 electrode was chosen as it can also be used with AC to minimise the risk of magnetic arc blow. Most of the welding of the 9% nickel steel was done with these electrodes at a consumption of around 32 tons. A smaller quantity of wire and flux was used for submerged arc welding of the bottom plate with a suitable tractor and for circumferential welding with the ESAB Circomatic system, using ERNiCrMo-4 wire.

In construction, carbon steel was used for the metal plates of the outer lining, P275NL1 steel (EN 10028-3) for the base and S 275 J2G3 (EN 10025) for the entire roof structure. Also, part of the piping was made of ASTM A106 Gr. B steel. A total of 21 tons of ESAB Citobasico electrodes, 2600kg of ESAB OK Tubrod 14.12 cored wire and modest quantities of OK Tigrod 12.60 for certain TIG welding operations were used. In addition, a high quantity of stainless steel piping in X2CrNi 18/9 (EN 10028-7) was welded with ESAB OK 61.35. ESAB OK 67.60 (309L) electrodes were used for the dissimilar joints between stainless steel and carbon steel, as well as for the joints between pipes and metal plates.
of the roof, involving an overall consumption of approximately 7-8000kg, in addition to 1400kg of ESAB OK Tigrod 16.10 rods.

Finally, the suspended aluminium roof (Figure 1), made of ASTM B209 alloy 5083, was welded with the GMAW process using 1.2mm and 2.4mm ESAB OK Autrod 5183 wire, total consumption being 1500kg.

Co-operation
“Our relationship with ESAB is excellent”, says Emanuele Ceroni. “Throughout the project, we received full support in terms of presence, assistance, advice, competence and innovation, as in the case of the OK Tubrod 14.12 wire. ESAB lives up to its image in quality, supply and service.”

About the author:
Bruno Malagoli is Product Manager Consumables at ESAB Spa., Mesero, Italy.
SIF Group bv at the foundation of Dutch wind energy

ESAB SAW technology crucial in the production of piles and transition pieces for the Q7 North Sea wind farm.

Q7 is the largest offshore wind farm in the Dutch sector of the North Sea and a step forward in the Netherlands’ renewable energy policy to boost wind energy production to 2750 MW by 2020. Sif Group bv manufactured the foundation piles and the transition pieces.

Source: Offshore Windpark Q7
Acknowledgement.
We thank the management of Sif Group bv for facilitating our visit to the production site.

The Q7 project
The Q7 offshore wind farm has been built some 23 km offshore from IJmuiden, in block Q7 of the Dutch continental shelf. It is unique in the sense that it is the world’s first located at such a distance from the coast (outside the 12-mile zone) and in deeper waters than ever before (19-24m).

This was one of the reasons why its owners, sustainable energy group Econcern, and energy company ENECO Energie, selected the proven technology of the Vestas V-80 2.0 MW turbines. The project comprises 60 wind turbines with a total capacity of 120 MW.

Under the Kyoto Protocol, The Netherlands agreed to reduce greenhouse gas emissions, in the period 2008-2012, by 6% relative to the 1990 levels. The Q7 project will contribute a reduction of 225,000 tonnes of CO₂ emission, annually.

Van Oord, an international dredging and marine contractor, was responsible for the installation of the wind farm; offshore erections starting in May 2007.

The foundation piles (monopiles), 54 m long with a diameter of 4 m and 320 tons in weight, were driven into the sea-bed for over half their length. The transition pieces, weighing 115-tons and reaching 15 m above sea level, were placed onto the foundations using Jumping Jack, a specially designed vessel (Figures 1 & 2).

The masts (105 tonnes), and the turbines (65 tonnes), are produced by Vestas and shipped to IJmuiden for erection. Sea Energy – another dedicated offshore construction vessel – transported two wind towers and two turbines at a time to Q7 for installation.

To minimise turbine interaction, guidelines stipulate that the turbines must be separated by a distance of at least 5 times their rotor diameter (5 x 80m). The Q7 turbines are placed apart at a distance of 550m.

Van Oord was also responsible for the installation of a 520 ton transformer substation on a monopile in the middle of Q7 - the first offshore. Q7 will be fully operational in March 2008.

Sif Group bv
Sif Group bv, located in Roermond, The Netherlands, specialises in the manufacture of heavy tubular structures for the offshore oil and gas industry, offshore windfarm foundations, harbour and jetty facilities, and pressure vessel shells and cones. The company has vast experience in welding, heat treatment and non-destructive and destructive testing of fine grained high strength structural steels commonly used in these industries. Sif Group bv is located on the river Maas with its own docking facilities and direct connections to strategically located main ports, such as Rotterdam and Antwerp, enabling them to ship structures of any dimension and weight, up to 800 tons, using coasters or their own river barges. Anticipating the boom in offshore wind farms, Sif Group bv invested heavily in a new yard lay-out, a new production hall for foundation piles and
modern production lines - a process that is still ongoing. This policy has been extremely successful, judging by the impressive list of offshore wind farms in Western Europe in which the company has been involved. More than 80% of the installed offshore wind farms rely on steel foundations fabricated by Sif Group bv, amongst them the Horns Rev project in Denmark (the second largest farm to date) and the Q7 project.

Sif Group bv maintains an effective quality management system certified in accordance with the ISO 9001: 2000 standard and with the implementation of EN-ISO 3834-2 comprehensive quality requirements for welding. Additional international approvals and authorisations include:

- Structural tubulars: API Spec. 2B
- Pressure vessel parts: ASME U stamp, ASME U2 stamp, ASME S stamp, PED 97/23
- Dynamically loaded Steel Structures: DIN 18800-7 Class E – Ü stamp.

**Dimensions, material grades and mechanical requirements.**

The challenging Q7 project involved the manufacture of 61 mono piles and 61 transition pieces (60 for the wind farm and one for the transformer station). Both are tubular structures; the monopiles are straight and the transition pieces slightly conical. Figure 3 shows a monopile under construction.

The principal weld connections, the longitudinal and circumferential welds are clearly visible. The individual cans are 3-3.5m in length and 4m in diameter with the longitudinal welds staggered at 180° intervals from can to can. The wall thickness varies over the length of the monopile, from 45mm for the thinnest section, to 86mm. Transitions between differing wall thickness were smoothed by chamfering (1:5) and/or weld build-up.

Table 1 gives an overview of steel grades and CVN impact requirements for the several thickness ranges, both for the transition pieces (+ flange) and the monopiles. The design temperature of the transition piece was -10°C (above LAT - Lowest Anticipated Tide) and 0°C (below LAT) for the monopiles, whereas the lowest CVN test temperature was -50°C, valid for the thickest wall sections of the transition pieces. The construction was subject to GL Rules & Regulations IV Part 2: Regulations for the certification of Offshore Wind Energy Conversion Systems Edition 1999.

**Sif fabrication of monopiles and transition pieces.**

The production line starts with beveling by flame cutting or machining and subsequent cold rolling of plates to a ring section. With two bending machines, Sif Group bv can roll plate with a thickness of 20-150mm to shells with a diameter of 0.6 to 8m and a maximum width of 4.2m (Figure 4). The rolling process is performed in several steps to achieve the specified dimensions and roundness; also to facilitate perfect alignment for high productivity welding.

Tubular structures, in general, and monopiles, in particular, are straightforward constructions with heavy longitudinal and circumferential welds. SAW makes up more than 90% of all welding. Serial production depends on an efficient factory lay-out where fabrication is performed in a logical sequence, minimizing internal transportation of components. Factory lay-out is also important to achieve the full production potential offered by the
submerged arc welding process.

Joint preparation is basically the same for all
welds, with only the semi-narrow gap varying in
depth, dependent on the wall thickness. It is similar
for all heavy tubular constructions produced by
Sif Group bv, be it monopiles, foundation piles for
oil rigs, jacket legs or other components for the oil
and gas industry. It makes production predictable,
ensures reproducible weld quality and reduces
the start-up times from project to project.
The semi-narrow gap joints produced through the
milling process are geometrically exact, smooth,
even, and burr-free, their quality surpassing that
of back-gouged joints. Furthermore it has the
advantage that the root of the internal welds can
be taken out, together with any weld imperfec-
tions, in this critical area of the joint (Figure 5).

Narrow gap welding, of course, has the
advantage of a reduced weld volume and, thereby,
a shorter welding time per joint and reduced weld
metal consumption. The option for a semi-narrow
gap, with an included angle of 13°, was made to
avoid access problems for the multi wire SAW
equipment and the welding heads getting
jammed by weld metal shrink (longitudinal welds).

**Submerged arc welding**

Another constant factor is the wire/flux combination.
Sif Group bv generally uses ESAB OK Autrod
12.32 solid wire for medium and high strength
steels (EN756: S3Si) combined with a high basic
flux (EN760: SA FB 1 55 AC H5).
The combination yields good impact properties
down to -60° and is ideal for the various
multi-wire SAW processes applied by Sif Group bv.
Essential is the good slag release, mostly self-
detaching, in the first runs of the narrow gap joints.

OK Autrod 12.32 is supplied on specially
designed bulk spools with 350 or 700kg of wire
– known as spiders - designed to fulfill the specif-
ic Sif Group demands and only supplied to them
(Figure 6). They are colour-coded, separating
them from occasional other wire qualities supplied
on spider, and wrapped in a protective foil that
can remain on the spools without hindering the
wire pay-off. The wire is spooled to discharge in
the direction needed for the multi-wire SAW
systems. The specification of OK Autrod 12.32 is
very narrow in regard to chemical composition
and surface condition - to fulfill offshore
requirements.

The special production line for the manufacture of
wind turbine foundations consists of several multi-
wire submerged arc welding stations, most
equipped with ESAB welding components and
high duty LAF/TAF power sources. Sometimes
ESAB and Sif Group BV cooperate in retrofitting
existing column and boom-type stations or the
provision of complete new automatic solutions.
A recent example was a customer-designed SAW
installation for welding of internal stiffener rings in
tubular constructions.

The portal welders, where the larger piles are
completed, are huge and highly efficient (Figure 8).
Circumferential welds are simultaneously welded
by an operator controlled multi-wire station, the
deposition rates thus achieved being impressive.
The system is equipped with PLC controls and
optical sensors, which monitor and control the
entire welding process and guarantee a consistent
and high weld quality. The operator starts the
welding process manually and the system automatically completes the full welding sequence, including the positioning of split beads across the width of the joint. If necessary, the operator can change to manual control at any time.

Figure 7 shows an example of an absolutely flawless heavy weld obtained in this manner. Weld metal properties at -50°C, from a related welding procedure qualification for Q7 in 70mm plate thickness, are given in table 2.

Sif Group bv is particularly impressed with the performance of the ESAB wire feeders on the narrow gap equipment and the LAF 1250 and TAF 1250 power sources. The installation operates 24 hours a day, with minimal maintenance, and has not given a single problem over a period of 2 years.

A bright future in wind energy
By timely investment in new welding technology and production facilities, Sif Group bv has been able to gain a strong foothold in the Western European offshore wind energy market and made a major contribution to the generation of clean energy. The project list at the end of this article highlights the company’s reputation as a reliable partner for large wind energy projects. With many new wind energy projects anticipated, the future looks bright. Partnered with ESAB for welding technology, the company can be assured of a supplier that understands its needs and can respond to its specific requirements.

### Table 2. Weld metal properties at -50°C in 70mm plate from a WPS comparable to the weld of figure 5.

<table>
<thead>
<tr>
<th></th>
<th>Cv-impact energy [J]</th>
<th>Average</th>
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<tbody>
<tr>
<td>1st welded side V-joint, SAW-twin</td>
<td>111J 94J 90J 98J</td>
<td></td>
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<tr>
<td>2nd welded side U-joint, SAW-triple</td>
<td>110J 102J 104J 105J</td>
<td></td>
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<tr>
<td>Root area 50 mm depth</td>
<td>112J 154J 150J 139J</td>
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</table>

**Figuur 8. Portal welder for circumferential welding, in operation.**

**Sif Group bv Reference list of windfarm projects.**

- **1994 Medemblik, Netherlands**
  - 4 Monopiles Ø 3,500x35x28,000mm
  - Weight 346 ton

- **2002 Horns Rev, Denmark**
  - 80 Monopiles ø 4,000x50x58,000mm
  - 80 Transitions ø 4,240x35x1,500mm
  - Weight 11,080 ton
  - Weight 5,325 ton

- **2003 North Hoyle, United Kingdom**
  - 30 Monopiles ø 4,000x30,70x58,000mm
  - 30 Transitions ø 4,200x35x12,300mm
  - Weight 8,508 ton
  - Weight 1,150 ton

- **2003 Arklow, Ireland**
  - 7 Monopiles ø 5,000x50x45,000mm
  - 7 Transitions ø 5,390x45x15,150mm
  - Weight 1,931 ton
  - Weight 929 ton

- **2004 Kentish Flot, United Kingdom**
  - 30 Monopiles ø 4,300x50x37,000mm
  - 30 Transitions ø 4,540x35x12,080mm
  - Weight 5,013 ton
  - Weight 1,823 ton

- **2005 Barrow, United Kingdom**
  - 30 Monopiles ø 4,750x45,75x51,000mm
  - 30 Transitions ø 5,100x55x21,600mm
  - Weight 11,320 ton
  - Weight 3,460 ton

- **2006 Burbo, United Kingdom**
  - 25 Monopiles ø 4,700x45,75x37,000mm
  - 25 Transitions ø 5,390x45,67x22,350mm
  - Weight 5,307 ton
  - Weight 3,994 ton

- **2006 Beatrice, United Kingdom**
  - 2 sets Central Pipe, Legs & Pile sleeves
  - 8 Piles ø 1,869x60/80x42,500mm
  - Weight 832 ton
  - Weight 935 ton

- **2006 Onshore Tripod Multibrid, Germany**
  - 1 Main column ø 6,000x55/75x26,000mm
  - 3 Pileguides ø 2,900x60/80x9,000mm
  - Weight 203 ton
  - Weight 102 ton

- **2006 Q7, The Netherlands**
  - 61 Monopiles ø 4,000x35,79x54,000mm
  - 61 Transitions ø 4,200x35,57x19,000mm
  - Weight 18,700 ton
  - Weight 5,340 ton

- **2007 Lynn & Inner Dowsing, UK**
  - 54 Monopiles Ø 4,740x50/75x96,000mm
  - 54 Transitions Ø 5,100x45/67x22,050mm
  - Weight 12,100 ton
  - Weight 9,100 ton

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**About the authors:**

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**William Lafleur**, BSc, EWE, is Material & Welding Engineer at Sif Group bv, Roermond, the Netherlands.
Zorya-Mashproekt relies on ESAB for arc welding of gas turbine components

YURIY BUTENKO, SE RPCGTI ZORYA-MASHPROEKT, NIKOLAEV, UKRAINE AND ALEXEI BELIKOV, ESAB RUSSIA, MOSCOW, RUSSIA.

The Zorya-Mashproekt Gas Turbine Building Research and Production Complex is a leading Ukrainian producer of industrial gas turbines and marine gas turbine power plants and engines. Although, today, naval demand is far from exhausted, particular emphasis is placed on the production of civil equipment. In the wake of associated technical developments, the company recently invested in state-of-the-art ESAB arc welding systems.

The Zorya-Mashproekt Gas Turbine Building Research and Production Complex was founded in the early 1950s in Nikolaev, Ukraine, for the development and production of gas turbine equipment and reducers for vessels of the USSR Navy. In the 1970s, the company was assigned to develop and manufacture gas turbines for use in compressor stations on trunk gas lines and in mobile and stationary power plants. Over more than half a century, Zorya-Mashproekt has produced four generations of gas-turbine engines, used in around 500 battleships and commercial vessels. Twenty-four power plants, with a total capacity of 1120 MW, and over 500 gas compressor units, with a total capacity of more than 6000 MW, are equipped with the company’s gas turbines.

Today, Zorya-Mashproekt products compete with leading fabricators around the world, the main products being engines based on the DO71, DO90 and DO80 gas turbines with a capacity of 6, 16 and 25 MW respectively. A new engine, DN70, with a capacity of 10 MW and an efficiency of 35%, is under development. It will replace technically outdated and less efficient turbines. Another development, demanded by the power generation industry, is a one-shaft engine with a capacity of 45-60 MW.

ESAB assessment and advice
Various steels and alloys are used in modern gas turbines, for example, CMn steels, low-alloyed steels, austenitic and martensitic stainless steels, high-alloyed steels and nickel-base alloys. Some components are made of titanium (eg, turbine fans). When producing turbine parts, minimum weight and maximum material utilisation are

Figure. 1. Zorya-Mashproekt's DN-80 25MW gas turbine.
important factors. Most parts are manufactured using welding technologies and the welded joint is often the crucial element defining the operational capability of the part. Also, with the limited weldability of some of the materials used, the most important consideration for the welding specialist is the selection of the appropriate and most efficient welding process, equipment and consumables.

Electron-beam welding is the principal welding process used in the fabrication of gas-turbine engines. It is performed under vacuum, which protects the weld pool and facilitates weld metal strength, deformation being minimal due to the highly concentrated heat source. However, for many components, arc welding processes are preferred.

Co-operation with ESAB began in 1995, when company management set the task of increasing production output and reducing welding costs. ESAB specialists carried out a technical audit of the welding methods used in production. Its conclusion was that, without up-to-date arc welding technologies - MMA and manual TIG welding being the main arc welding processes – results were high weld metal consumption and unnecessarily low overall productivity. Also, repair rates were high because the superior weld quality standard was hard to meet - even by qualified welders.

The audit resulted in a recommendation for investment in programmable automatic TIG systems, programmable pulse inverter power sources and the replacement of MMA welding by MIG/MAG and cored wire welding (FCAW), wherever possible. In response to this, Zorya-Mashproekt acquired two ESAB automatic TIG systems, consisting of a MKR-300 column & boom, A 25 TIG welding head and A2 Minimaster GMAW head, PEG1 control unit, AristoMig 500 power source (today named AristoMig 5000i) and PEMA-1500 positioners. For manual welding, the company bought various AristoMig 500 multi-process inverters with U8 control unit – one machine covering MMA, TIG, MIG/MAG and FCAW.

**Automatic TIG**

Automatic TIG welding is used for the circumferential and longitudinal welds in gas turbine bodies in 3-8 mm thick austenitic or martensitic stainless steel or nickel-base alloys. It involves pulsed TIG welding of I-joints without a root gap, onto a copper backing bar, and without filler material addition. Plate thicknesses up to 3 mm are welded one-sided and, above 3 mm, two-sided. Argon is both shielding and backing gas – the latter flowing into the root area through holes in the backing bar. Special devices ensure tight clamping of the weld edges onto the backing bar.

Welding parameters and sequence are pre-programmed in the control unit, for the various materials and plate thicknesses. Table 1 gives an example of actual parameter settings and Figure 3 shows a weld deposited with these parameters.

This method has a number of advantages, in addition to a dramatic increase in productivity. By fully controlling the arc, the quality and

<table>
<thead>
<tr>
<th>Table 1. Parameters for automatic pulse TIG welding of steel (347) with 3 mm wall thickness.</th>
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<table>
<thead>
<tr>
<th>Table 2. Consumables classifications.</th>
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<tr>
<td>EN</td>
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<tr>
<td>FILARC P26166</td>
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<tr>
<td>OK Tubrod 14.31</td>
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<td>OK 68.25</td>
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<td>OK 63.30</td>
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appearance of the weld become consistent and repeatable. Also, the lower heat input from pulse welding gives lower welding stresses and consequently lower deformation, as well as a reduced risk of hot cracking in sensitive materials.

As mentioned, the method allows welding without a root gap and without filler materials, but it places high requirements on the preparation of the weld edges:

- the cut, achieved by laser cutting, must be exactly perpendicular to the surface;
- after cutting, machining of the edges is required to a depth of 0.5 mm to remove the oxide film;
- the joint area must be cleaned to metal shine (10-15 mm from both edges);
- the plate edges must be square along the full length, without edge rounding and bevels;
- the root gap may not exceed 0.2 mm;
- the displacement and thickness variation of the plate edges may not exceed 10% of the nominal thickness;
- run-on and run-off plates must be of the same material and thickness as the base metal;
- the axis of the joint should coincide with the axis of the forming groove.

**Cored wire welding**

Flux- and metal-cored wires are widely used for manual and mechanised welding. FILARC PZ6166 metal-cored wire, sometimes combined with the MMA electrode OK 68.25, is used for components in martensitic stainless steel. For austenitic 18Cr-9Ni grades, the company uses OK Tubrod 14.31 rutile flux-cored wire and the MMA electrode OK 63.30 (Table 2).

An example of cored wire welding with FILARC PZ6166 are the rings for the turbine outlet. These are in martensitic stainless steel 20-13 (410) with 14-20 mm wall thickness, a diameter 600-800 mm and a height up to 250 mm. After having rolled a bar to a ring, the ring is closed by manual welding in the downhand position.

Welding is carried out with FILARC PZ6166 - 1.2 mm, using the AristoMig 500 inverter power source. The 98%Ar/2%CO2 shielding gas gives a good weldability and limited burn-off of alloying elements, while leaving behind a relatively clean weld. The joint preparation is shown in Figure 4. The component is pre-heated to 200-220°C.

The weld is started and finished on run-on and run-off plates with the same joint preparation and connected to the ring by strong tack welds. The root pass is welded onto a copper backing bar and the joined is filled with 5-8 passes, depending on the thickness. Each deposited stringer bead must be clear of oxides and the, usually small, amount of slag. The deep and wide penetration provided by PZ 6166 reduces the risk of lack of penetration and slag inclusions.

**The welding parameters used are:**

- stick-out length 15 mm
- welding current 250 A
- arc voltage 30 V
- wire feed speed 11 m/min.

These parameters provide a deposition rate of about 4.5 kg/h, increasing productivity considerably when compared with previously used MMA.

**Stable processes, consistent quality, increased productivity**

During the implementation phase, ESAB demo welders trained Zorya Mashproekt welders to operate the new systems and apply the welding methods. The welding processes are stable and problem-free. Inspection of the welded joints visually, by measurement and by x-ray, consistently reveals extremely low defect rates. ESAB welding technology has enabled Zorya Mashproekt to increase overall welding productivity, improve quality and simplify operations for welders. This positive experience has led the company to order new ESAB equipment, year on year, in particular AristoMig 500 inverter power sources.

**About the author:**

Yuriy Butenko is Chief Welding Specialist at SE RPCGTi Zorya-Mashproekt, Nikolaev, Ukraine, a position he has held since 1995. Alexey Belikov has been Product Manager at ESAB Russia in Moscow, since 1994.
A complete and reliable partner for pipe mills.
The latest ESAB equipment and consumables for longitudinal welding.

EGBERT SCHOFER, ESAB AB, LAXÄ, SWEDEN AND MARTIN GEHRING, ESAB AB, GOTHENBURG SWEDEN.

When it comes to welding equipment for the pipe mill industry, ESAB is known to have delivered hundreds of highly efficient power sources, very strong wire feeders, special internal and external welding heads and customised process controllers. ESAB is particularly strong in the retrofit business, boosting the productivity of existing lines by increasing the amount of wires, both internally and externally, and also by exchanging old controls for new process controllers, including data logging and interface to local network systems.

Nevertheless, ESAB has never attempted to offer complete production lines. The company's aim is clearly to stay in welding – ESAB's core business. However, the drastically increased demand in SAW pipe welding, and our customers' desire to reduce the number of suppliers, has made ESAB strengthen its focus on the segment and extend its range of products with, for example, specialised internal booms and advanced return current systems.

Here, a number of new products are highlighted. They have been supplied exclusively to key customers for longitudinal pipe welding applications - although their benefits are equally valid for spiral welding.

Continuous tack welding equipment
Once rough formed, pipe coming out of the forming machine, can be tack welded by ESAB's continuous tack welding equipment. The tack welding process itself is GMAW with solid wire of 3 or 4mm diameter under CO₂ or a mixture of CO₂ with some 5-10% argon. To enable speeds up to 6m/min, it uses a powerful ESAB type LAF 1600 rectifier. This highly efficient power source has a secondary output of 1600A with 44V at 100% duty cycle and can be used for high efficiency GMAW and SAW welding processes.

The welding head is the well proven A6 S Arc Master, mounted on a heavy duty cross slide, enabling adaptation to different pipe diameters as well as the positioning of the welding head in the middle of the weld preparation (Figure 1).

The SAW wire contact equipment has durable, spring loaded contact jaws and an extra gas nozzle in front of the contact equipment. Together with a wire straightness device at the in feeding side of the motor, this set-up has the great advantage of the most reliable wire contact combined with a spatter protected gas nozzle. The front mounted laser sensor guides the welding head via the cross slide and is also protected with a spatter shield. ESAB's PEH digital process controller steers and controls the welding process under given welding parameters. Up to 10 different welding process parameters can be stored for different pipe dimensions, if needed.

Internal boom
The internal boom has to fulfil many requirements. It needs to carry the welding head, including laser, video system, all current cables, flux support and suction hose, control cables and other parts. It requires the boom to be stable but, at the same time, as small as possible to also fit smaller pipes in 20" dimension. In the past, the maximum length was seldom more than 12m, plus run on and run off plates. Today, we sometimes need up to 18 or even 24m booms (spiral welding),

The demand for SAW-welded pipes has grown steadily over many years, with a significant increase in both 2006 and 2007. Worldwide, more than 150 pipe mills produce an estimated 30,000,000 tonnes of SAW welded pipes. When this production is split between longitudinal and spiral welded pipes, we see a ratio of around 57/43%. ESAB is an established, reliable partner in the pipe mill segment, offering flux and wire as well as equipment components and controls.

Photo courtesy NOKSEL company
The voltage pick-up brushes are quite important to get the right voltage signal back to the process controller, to fulfil the demands of the given WPS. This is believed to be a unique technique to correct the voltage losses over the long distance to the welding head. The stabilisation of the boom is a further effect to keep the weld pool stable.

Due to the high torque of ESAB’s VEC wire feeding motors, the decision was taken to position the wire feeding equipments at the end of the boom, while pushing the wire into the boom. This is different from most solutions in the market, but advantageous from a customers’ point of view. There is more space at the welding head for the positioning of the other components, and less weight at the welding head side. Wire straightness devices and wire feed motors are easily reachable and any service or exchange of feeding or guiding rolls is fast. There is also no temperature effect on the wire feeders and the inbuilt tachometer controls.

**Internal welding head**

ESAB has developed internal welding heads designed for up to 4 wires. As previously mentioned, many different components had to be integrated. The welding head itself is connected with the internal boom via a small cross slide, to always be guided in the middle of the weld preparation. A laser sensor controls the welding head via the cross slide. If a sideways movement outside the limit of the cross slide is necessary, a signal is transferred to the pipe carriage to turn the pipe accordingly. The welding process is supervised on an external monitor via a video camera. Also, the laser signal is distributed on the control panel. The wires are smoothly guided via wire liners into the contact equipment of the welding head (Figure 3). The contact equipment is built up with spring-loaded contact jaws and fixed spacers between the different wires. The spacers have a fixed angle, so that the wires have a defined fixed position for a given welding procedure. If a different set up of the wires is needed when changing pipe dimensions and accordingly the WPS, the spacers can be exchanged for a different set. This is normally not necessary.

**Return Current System**

One of the most important safeguards for a stable welding process is to secure the current flow from...
the power source via the welding head, welding arc, pipe and return to the power source. Magnetic effects such as arc blow, as well as changing distances to the fixed return pole, will affect the quality of the weld shape or even the total weld quality. Therefore, reliable solutions must be considered.

Mounted on a column with a height-adjustable boom, two lines of steel brushes connected to the return current pole with cables, are pressed from the top onto the pipe to secure the return current (Figure 4). The two lines of brushes can be adapted to different pipe diameters. Internal welding requires one of such a system. Outside welding needs two - one in front of the outside welding head and one at the back.

**Power sources for pipe welding**
The high efficiency rectifier, previously described in the GMAW process, in the tack welding station, is used here as a SAW power source for the first wire. The DC-current guarantees deep, reliable penetration due to its straight polarity. The second, and all following wires, have an AC current supply.

The pipe mill version of the TAF 1250 Square Wave Transformer is designed with digital optimisation of the arc characteristic for high efficiency SAW- welding at each welding head. The TAF 1250 Square Wave Transformer can be set and monitored via a LON-BUS-System from the plc-controller of the welding station. Preset welding parameters can be monitored and adjusted during welding.

The TAF Square Wave Transformer has excellent welding characteristics throughout the current and voltage range, with particularly good starting and re-ignition properties. It delivers some 1250A at 44V and 100% duty cycle. The square wave technology avoids any arc blow effect caused by multiple arc currents as well as arc outs in AC zero transfer. The heavy-duty technology ensures maximum lifetime in continuous operation with minimum maintenance. TAF Square Wave Transformers are connected to the mains in so called “Scott-Connection”. Like the LAF 1600 rectifier, the TAF 1250 secures the accuracy of welding data within a limit of +/- 10% variation of the mains voltage.

**Process Controller**
The welding control system includes a SIEMENS Simatic new generation PLC controller, equipped with an efficient processor. The Human Machine Interface (HMI) in the operators desk is freely selectable, either with touch screen or push buttons. A colour screen is included.

**Special features in welding control automation include:**
- Two stage controller allowing for “recovering” of wire in the phase of ignition procedure;
- Current and voltage ramps at the beginning; and at the end of welding;
- Controlled burn-off of wire at the end of welding;
- Sequential start and stop of wires at start and stop of welding;
- Control of return current system functionality;
- Malfunction reporting system.

**Main Procedures:**
Key-in information or select from a database:
- Pipe No.
- Pipe diameter
- Pipe wall thickness
- Start and stop position to be agreed with carriage producer
- (free programmable other parameters)

Key in welding data:
- Voltage of each wire used with up and down limits

Figure 4. Current return system with steel brushes on top of the pipe.
Welding consumables

ESAB has a wide range of fluxes and wires for use in pipe mills, for the complete range of SAW welded pipes - ranging from water pipes with relatively thin walls and usually no toughness requirements, to highest demanding gas pipes with large thicknesses and highest toughness requirements - and for high strength steels X70, X80 and higher. These are:

- OK Flux 10.40 for spiral pipes with low requirements;
- OK Flux 10.71 for spiral and longitudinal pipes with low and medium requirements;
- OK Flux 10.73 for spiral and longitudinal pipes, especially for sour gas service;
- OK Flux 10.74 for highest demanding longitudinal pipes, including sour gas service and for all pipe materials;
- OK Flux 10.77 for highest demanding spiral pipes, for all pipe materials;
- OK Flux 10.81 for spiral pipes with low requirements;
- OK Flux 10.88 for spiral pipes with low and medium requirements; especially for severe surface conditions such as rust and mill scale.

All these fluxes are used for production of pipe with one run from each side. Multi-run welded thick wall pipes are not covered in this article. A large range of consumables, other than those indicated above, are available from ESAB for this type of application.

The wires mostly used in pipe mills are:

- OK Autrod 12.10 EN 756 – S1; SFA/AWS A5.17: EL12
- OK Autrod 12.20 EN 756 – S2; SFA/AWS A5.17: EM12
- OK Autrod 12.22 EN 756 – S2Si; SFA/AWS A5.17: EM12K
- OK Autrod 12.24 EN 756 – S2Mo; SFA/AWS A5.23: EA2
- OK Autrod 13.64 EN 756 – S0 (S3MoTiB); SFA/AWS A5.23: EG

Other wires for special applications are available.

**OK Flux 10.74**

This flux is recommended for longitudinal welded pipes produced by multi-wire-processes with the highest demands on mechanical values as well as bead shape. OK Flux 10.74 is an agglomerated aluminates-basic flux which creates a low bead profile, even at high welding speeds, in SAW multi wire processes with 3, 4 and 5 wires (6 as trial).

A low bead profile without peaks means cost saving in the later pipe coating operation, since...
The coating thickness can be reduced (Figure 5). Moreover, the API specifications for line pipes, and many customer specifications, require a maximum reinforcement of 3.0mm. However, a reinforcement of 0.5 to 2.5mm is desired. The transition angle from weld metal to base material needs to be smooth in order to avoid mechanical notches. All these requirements are fulfilled with OK Flux 10.74 provided the parameters are set properly.

The flux works equally well on DC and AC current. Usually the first wire is welded with DC+ current and all the remaining wires with AC. This is in order to reduce magnetic interference between the wires.

OK Flux 10.74 is suitable for different wires for all pipe materials. The flux is hydrogen controlled which is important for high strength materials such as X80 and X100. OK Flux 10.74 alloys some Si and Mn to the weld metal for the highest toughness levels. Careful metallurgical design ensures that it produces a weld metal without any macro or micro areas with increased hardness. Customers around the globe appreciate OK Flux 10.74 for its excellent weldability, weld bead profile and secure toughness values.

**BigBags**

Fluxes for bulk end-users are usually delivered in BigBags (Figure 6). Standard weight for BigBags is 1000kg. BigBags have a well defined, reclosable discharge spout. Since it takes about 25 seconds on “full open” to empty a complete 1000kg BigBag, customers can easily remove just a few kg at a time. Thus, all kinds of flux supply units can be filled with flux from BigBags. The enclosed BigBags are made of woven polypropylene material which has an internal moisture protection coating to keep the contents dry. The material is fully recyclable. Each palette of flux is additionally protected against moisture by wrap foil or shrink foil.

**Wire and wire package**

For high demanding pipes, OK Autrod 12.24 (EN 756 - S2Mo; AWS EA2) is widely used. For this wire, the chemical elements are specified with more restricted limits than those in both of the standards with which the wire complies. Additionally, impurities are named and limited to a maximum level (which is in the range of a couple hundredths of a percent). This is in order to secure highest toughness values.

Pipe welding with 25.4mm thickness (1 inch) with one run from each side results in very high toughness values with OK Autrod 12.24. In this fabrication, 4 wires are used on the inside and 5 wires on the outside. All wires are 4.0mm diameter. The inside is welded with totally 50 kJ/cm and 170 cm/min. On the outside, 52 kJ/cm are used with a speed of 190 cm/min. The weld metal centre has over 115 J average at -20°C. At -30°C the average is about 100 J. Naturally, the weld bead shape fulfills all requirements as described above.

For some pipeline projects, good toughness values are required at temperatures below -20°C. Or the same requirements are valid for pipes with increased thickness. In these cases, the TiB alloyed solid wire OK Autrod 13.64 is used. The wire contains micro-elements which create a fine grained structure with a lot of acicular ferrite in the solidified weld metal. This results in toughness values which are even higher than those with OK Autrod 12.24.

Important for pipe mill welding is problem-free decoiling of a spool containing a sufficient amount of welding wire. For these applications, the ESAB EcoCoil is the answer (Figure 7). EcoCoil is a bulk spool containing 1000kg of welding wire. The packing material is reduced to a minimum, but still gives full protection for the wire against moisture and dust from inside and outside during transport and storage. All materials are fully recyclable. Since it is a one-way-package, there is no need for return logistics for empty spools. Advantages over high weight spools are achieved because a special technology ensures that the wire is not spooled tightly around the cardboard core. In the start and stop phase, the spool can slowly accelerate and slowly stop while welding wire is fed with constant speed to the welding head. Welding defects are thus reduced.

The customer and the customer’s challenge are ESAB’s main focus. The products and packages described in this article have been developed in close cooperation with customers and, as a result, OK Flux 10.74 in BigBag, OK Autrod 12.24 and OK Autrod 13.64 on EcoCoil are commonly found in longitudinal pipe mills.

**About the Authors:**

**Egbert Schofer** is Automation Technology Manager at ESAB AB, Laxå, Sweden.

**Martin Gehring** is Group Product Manager Non- and Low-Alloyed SAW Fluxes and Wires at ESAB, Gothenburg, Sweden.
An integrated petrochemical plant for hydrocarbons processing in Al-Shuaiba, Kuwait, is being expanded by the addition of numerous tanks with varying purposes. The Italian construction company Paresa SpA was responsible for the on-site erection of two spherical tanks. One, of 7200 m³ capacity, in carbon steel, is for the storage of polypropylene. The other, of 5500 m³ capacity, in stainless steel, is for the storage of polyethylene. Polypropylene and polyethylene are raw materials for the production of plastics.

Paresa SpA, Cesana, Italy, is an international building company specialising in the on-site construction of underground storage tanks, tanks for cryogenic liquids and cylindrical and spherical pressurised tanks for the petrochemical industry. Paresa is renowned for its highly experienced personnel, research and training and quality and safety programmes. Accreditations include ISO 9001 quality management certification, ISO 14001 environmental management certification, and prestigious ASME authorisation for the use of U and U2 symbol stamps in accordance with the ASME Boiler and Pressure Vessel Code - particularly important for the project in Kuwait.

The spheres

The spherical shape represents the optimal ratio between volume and surface. A natural phenomenon, this characteristic is very popular in engineering. However, copying the quality and perfection of nature in a man-made construction is not easy, as explained by Paresa’s Technical Supervisor, Raffaele Cedioli and Quality Control Manager, Nicolò Amodio.

“The carbon steel tank is 24m in diameter with a wall thickness of 34-38mm. The stainless steel tank is 22m in diameter with a wall thickness of 30mm. The latter is particularly interesting as, to our knowledge, it is one of the largest ever constructed in this material. It needs a series of complicated and closely coordinated operations to be able to meet the final building and quality requirements.”

“The choice of stainless steel”, says Mr. Cedioli, “is not primarily governed by the aggressiveness...
of the chemical substance it is to contain, but merely by the operating conditions. The contained product reaches a temperature of -89°C and therefore the selected material is stainless steel SA 240M type 304 (EN 10204 3.2/BV).

“A sphere is essentially constructed from a great number of segments forming the two hemispheres, completed with two caps; the north and south poles. In the design stage, the ratio between number of segments and dimensions has to be decided. More pieces of smaller dimensions simplify the welding operations - but complicate transport and movement. Once decided, not all suppliers may be capable of supplying sheets in the required material grade and dimensions. Considerable experience is needed to solve this puzzle.”

Prefabrication
In Paresa’s Cesana production facility, the steel sheets were cold-pressed to the required curvature after which the edges were bevelled. In the case of stainless steel, to achieve the required cut quality, this operation was performed by plasma cutting using an ESAB Suprapex SXE-P cutting machine equipped with a plasma VBA-Expert head. It is the first cutting station of this type in Italy and only the second in Europe. Finally, the components were transported to Kuwait for assembly, each individually marked with its complete chemical and mechanical history, acceptance tests performance and with a code for its eventual position in the construction.

Welding and assembly
For practical and environmental reasons, the decision was taken to use the MMA (SMAW) process with 2.5, 3.2, 4.0 and 5.0 mm diameter ESAB OK 61.35 (EN1600: E 19 9 L B 22/SFA/ AWS A5.4: E308L-15) electrodes. Due to safety regulations surrounding the project, the weld material was supplied with 3.2 chemical and mechanical testing certification carried out in the presence of the Bureau Veritas inspection authority.

The welding operation involves joining the segments (62 for the stainless steel sphere) into the two hemispheres to form a globe and joining the caps to the hemispheres - easier said than done!

Deformation control was a major obstacle in obtaining perfect globe dimensions. It affected a large number of components and welds, with different joint designs (1/3 and 2/3 X-joints) at various positions in the construction. Even though starting from an ideal situation, in which all the components of the structure have been prepared with extreme precision, the human element becomes the decisive variable.

Where possible, certain segments were pre-assembled flat on the ground, coupled in pairs for the northern and southern parts of the hemispheres and in trios for the equatorial zones. This considerably simplified the welding and dimensional control, but complicated the assembly, because heavy weights, often in excess of 20 tonnes, needed to be lifted and aligned with the construction. It involved full penetration welds with opposite runs, but the bead sequence needed to be judged case by case, in order to control deformation and obtain a perfect shape.

Quality control
Quality control requirements were extremely high, due to the safety criteria surrounding this project. “Fortunately we have long experience in control, safety and quality”, says Dr. Amadio. “The requirements of the inspection authorities on site were tough. Ultrasound testing, magnetic partical testing, dimensional control, and control of physical and chemical properties, were carried out in accordance with the ASME stamp under the supervision of the authorised inspection agency. It has been an excellent opportunity, though, to show our capability and create an excellent reference for future projects”.

“ESAB’s OK 61.35 stick electrode is a quality product with a great reputation in our industry – a really dependable factor. Furthermore, VacPac vacuum packaging enables us to skip re-baking procedures which, otherwise, would have been unavoidable under the warm and humid climatic conditions in Kuwait. Moreover, ESAB has given us valuable support, throughout the project”.

ABOUT THE AUTHOR:

Bruno Malagoli is Product Manager Consumables at ESAB Spa., Mesero, Italy.
ESW Inconel strip cladding – solution to clad steel shortage for Maritime Industrial Services, Dubai.

SANDISH SALIAN, ESAB MIDDLE EAST, DUBAI, UNITED ARABIC EMIRATES

A world shortage of Inconel clad steel forced Maritime Industrial Services to explore the possibility of in-house cladding of SA 516 Gr. 70 vessel steel. ESW proved to be the most productive way to reach Inconel 625 composition standard, within the two layers specified by its client.

Acknowledgement.
We thank Ramesh Kumar, Welding Engineer, Hassan Bader, QC Divisional Manager and Mohsen El Sherif, Senior Divisional Manager for their valuable support.

Well established in the Middle East, with operations in Dubai, Saudi Arabia, Kuwait and Qatar, Maritime Industrial Services Co. Ltd. (MIS) enjoys a long standing reputation in the petroleum related construction and services industry. The company provides a complete range of engineering, procurement, fabrication, construction, safety, operating and maintenance services to the oil, gas, petrochemical, power generation, marine and heavy industries. The success of MIS is underlined by an order book exceeding $700 million in 2007 - more than double that in 2006 - including major contracts from international drilling companies for F&G designed Super M2 Jackup rigs. MIS is listed on the Oslo stock exchange and has around 3500 personnel.

SAW or ESW strip cladding?

During 2006, MIS was forced to consider options to overcome the world shortage of Inconel clad steel when they received an order for the fabrication of three vessels for the Katachanak desalination project, in Kazakhstan. The three vessels - a condensate stabiliser, a 1st & 2nd stage desalter and a 1st & 2nd stage desalter/degaser - had various dimensions, but were all made in SA 516 Gr.2 steel with a thickness of 36 mm and to be produced under the ASME Sec. VII Div. 1 design code.

SAW and ESW strip cladding were the two obvious options to fully cover the inside of two vessels, and part of the third, with a protective Inconel 625 layer. The client’s specification stipulated a minimum of two layers and an Fe content of 5% maximum at the weld overlay surface and 7% maximum at 2 mm sub surface. This is the highest requirement within the petrochemical industry, covering both heat and corrosion.

Subsequently, both methods were trial tested by MIS, assisted by ESAB for consumable selection and choice of parameters. As no overlay thickness was specified, MIS had the freedom to reach the final composition in the most economic way.

The trial tests clearly indicated that it was not possible to meet the Fe requirements with SAW strip cladding in two layers (Table 1). A third layer would have been needed, involving an extra, time-consuming fabrication step and more expensive weld metal. With ESW cladding, however, parameters could be found to fulfill the chemical requirements in two layers (Table 2), due to less dilution with the parent material.

The basis of trial test number 4, welding parameters were fine-tuned and a welding
The minimum ESW overlay thickness was set at 6 mm, in two layers. Welding parameters: 1050-1180A, 24-25V, 19.8-21.9cm/min. Strip dimensions OK Band NiCrMo-3: 60 x 0.5mm. Tables 3, 4 and 5 give, the chemical compositions of, respectively, Inconel 625, OK Band NiCrMo-3 and the weld overlay achieved by MIS.

With ESW, MIS has access to a productive method for the clad restoration of Inconel 625, overcoming the shortage and long delivery times for explosion cladded steel. The three vessels, including curved top and bottom ends, were supplied to the client at the agreed delivery time. Figures 1 and 2 show examples of ESW during the project.

**OK Flux 10.11**

OK Flux 10.11 is a very high basic agglomerated flux (basicity: 5.4) for ESW strip cladding. It has a low viscosity and is ideal for cladding with Ni base, Cr and fully austenitic alloys, due to its excellent wetting behaviour. The flux allows ESW cladding at very high travel speeds.

Svetsaren 1/2007, page 7, provides detailed information on both the SAW and ESW cladding processes, together with more application examples.

**Table 2. ESW cladding with OK Flux 10.11/OK Band NiCrMo-3**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Layer</th>
<th>Thickness</th>
<th>Fe content surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1st</td>
<td>4.9 mm</td>
<td>9.05%</td>
</tr>
<tr>
<td>2</td>
<td>1st</td>
<td>4.3</td>
<td>10.41%</td>
</tr>
<tr>
<td>3</td>
<td>1st</td>
<td>4.0</td>
<td>11.91%</td>
</tr>
<tr>
<td></td>
<td>1st &amp; 2nd</td>
<td>8.0</td>
<td>3.28%</td>
</tr>
<tr>
<td>4</td>
<td>1st</td>
<td>3.1</td>
<td>11.93%</td>
</tr>
<tr>
<td></td>
<td>1st &amp; 2nd</td>
<td>6.2</td>
<td>5.15%</td>
</tr>
</tbody>
</table>

**Table 3. Chemical composition Inconel 625 (%)**

<table>
<thead>
<tr>
<th>Alloy</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Cr</th>
<th>Fe</th>
<th>Mo</th>
<th>Nb</th>
<th>Ni</th>
<th>P</th>
<th>S</th>
<th>Si</th>
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<tbody>
<tr>
<td>N6625</td>
<td>0.40</td>
<td>0.10</td>
<td>20.0</td>
<td>5.0</td>
<td>0.50</td>
<td>8.0</td>
<td>3.15</td>
<td>rem</td>
<td>0.015</td>
<td>0.015</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>max</td>
<td>max</td>
<td>max</td>
<td>max</td>
<td>max</td>
<td>max</td>
<td>max</td>
<td>max</td>
<td>max</td>
<td>max</td>
<td>max</td>
</tr>
</tbody>
</table>

**Table 4. Chemical composition OK Band NiCrMo3 (EN ISO 18274: B Ni 6625 (NiCr22Mo9Nb)).**

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>Fe</th>
<th>Nb+Ta</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.10</td>
<td>&lt;0.20</td>
<td>&lt;0.50</td>
<td>20.0-23.0</td>
<td>&gt;60</td>
<td>8.0-10.0</td>
<td>&lt;2.0</td>
<td>3.15-4.15</td>
</tr>
</tbody>
</table>

**Table 5. Chemical analyses of the ESW weld overlay (%)**

Inconel 625 chemistry met at 3.5mm from the fusion line, so 2.5mm sub surface.

<table>
<thead>
<tr>
<th>C</th>
<th>Ni</th>
<th>Cr</th>
<th>Mo</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02</td>
<td>59</td>
<td>22</td>
<td>8.5</td>
<td>4.0</td>
</tr>
</tbody>
</table>

**About the Author:**

Sandish Salian is Area Sales Manager at ESAB Middle East, Dubai, United Arab Emirates.
Mechanised pipeline welding in the Saudi desert

Magnatech orbital welding system and ESAB cored wire do the job.

In 2006, Nacap-Suedrohrbau Saudi Arabia Ltd. (Nacap-SRB), a subsidiary of Dutch international contractor Nacap BV, was granted a Euro 70 mio contract by Saudi Aramco, the state-owned national oil company of Saudi Arabia, for the engineering, procurement and construction of the Khurais Sea Water Injection & Distribution Headers Project. This included the construction of 507 km of 8 inch to 36 inch non sour and sour sea water transfer lines and headers. For 16 inch pipes and above, (Nacap-SRB) applies automatic uphill welding for filling, relying on Magnatech’s Pipeliner II orbital welding system and ESAB’s PZ6113 all-position rutile cored wire.

The Khurais field is an existing field with an output of some 300,000 barrels per day. It is located in the area of Khurais, halfway along the motorway between Dammam and Riyadh in the middle of the “red dunes” desert. It is envisaged that water injection will boost production to 1.2 million barrels per day. The seawater is supplied from the Arabian Gulf, and is then distributed throughout the Khurais field. The project is scheduled for completion in October 2008.

Welding in the desert

In principle, welding in the Saudi desert is not very different from cross-country pipeline construction anywhere else. It follows the same pipeline laying principles; pipe stringing, bending, positioning, welding, NDT, and cleaning and coating – the front-end speed being the decisive factor. One of the complicating factors to overcome, however, is often the remoteness and the associated logistical problems in the supply of nourishment and technical services to the front-end teams. Another, very obvious problem is the tough working conditions. During summer, temperatures reach 40 degrees and upwards, requiring the utmost from the welding and supply

BY GERALD GARCIA, PANGULF WELDING SOLUTIONS, AL KHOBAR, SAUDI ARABIA AND WIJNOLD WIJNOLDS, MAGNATECH INTERNATIONAL BV, DRONTEN, THE NETHERLANDS.
teams, in order to maintain the laying speed of a pipeline. In this respect, mechanised welding helps considerably, as it reduces the physical effort required to weld an often pre-heated pipeline.

### Mechanised welding - Aramco requirement

For various reasons, Saudi Aramco stipulates the use of mechanised welding equipment on its pipelines – the most important being that they are in a great hurry to boost oil and gas production, making them demand short time frames for their projects. Mechanised welding makes the planning more predictable, and, since it is less strenuous for the welders, leads to better weld quality. Also, manual pipeline welders, hired mainly from Asian countries, are not as plentiful as in the past. Mechanised welding requires less welders and simplifies the associated logistical organisation. Another reason is the increasing use of X70 quality pipeline steel and higher, requiring low-hydrogen welding consumables and therefore excluding the use of cellulosic downhill electrodes.

### The Magnatech Pipeliner II

Aramco’s requirement for mechanised welding applies to the filling of the joint – the root pass may be done manually, semi-automatic or mechanised. The Magnatech solution for filling, used by Nacap-SRB and brought on the Saudi market by Pangulf Welding Solutions, is based on uphill welding with flux-cored wires (FCAW). For the Khurais project, it is applied on pipe diameters of 16 to 36 inch in X65 and X70 grade steel, accounting for 331 km of pipeline. The root pass is performed by semi-automatic, controlled downhill welding with the STT process (modified short circuit transfer mode). The Magnatech solution can, however, equally be used in combination with downhill or uphill MMA for the root pass.

Table 1 gives an overview of solutions available for the filling of pipeline joints, along with their individual advantages and disadvantages. The characteristics listed for FCAW are valid for all-positional rutile cored wires, such as ESAB’s FILARC PZ6113 (AWS A5.20: E71T-1 H4/E71T-1M H8) It has a fast solidifying slag system that supports the fluid weld metal well and allows the placement of thicker beads, so less passes, but at a high deposition rate. The wire always operates in the spray arc mode, making it a tolerant process with a low weld defect rate.

Figure 1 reviews the Magnatech Pipeliner II. It is easy to understand and operate, light-weight equipment that is easily mounted and dismounted. The head is removed from the guide ring in seconds with a push button switch using the gas bottle pressure. The patented guide ring is not to be seen as a consumable, because it does not wear out, and is tolerant for weld spatter and grinding debris. The Positive Drive System guarantees a uniform rotation speed. The 300A water-cooled torch can be programmed in three independent ways; travel speed, weaving width and endpoint dwell. A remote control allows cross-weld steering and vertical adjustment, as well as the facility to override the programmed weaving width and travel speed.

![Magnatech Pipeliner II orbital welding system](image)
welders simultaneously, from 6 to 12 o’clock – clockwise and counter clockwise. They are ‘true artists’, able to continue welding with a weaving motion, while changing from standing, to squatting, to sitting, until they lie under the pipeline. When hands meet, one of the welders grinds away his end crater while the other finishes the weld. These are the operators that determine the front-end laying speed of the pipeline. No time to be lost. When ready, they immediately move to the next weld. The internal clamp is removed directly after the root pass. They make about 30 root passes a day, in a 12 hour shift.

From here, mechanised uphill FCAW with the Pipeliner II takes over, accounting for almost the full weld volume. There are two operators depositing only the hot pass and filler pass (Figure 3) with two Pipeliners walking the guide ring, from 6 to 12 o’clock. The total hot pass and first fill team comprises not only two welders, but also a number of helpers and the truck driver. The hot pass is deposited at a high travel speed (19.5 inch/min) to avoid burning through the root pass, and the first filler pass at 10 inch minimum.

Six additional teams are individually responsible for filling the joints left behind by the hot pass and welders simultaneously, from 6 to 12 o’clock – clockwise and counter clockwise. They are ‘true artists’, able to continue welding with a weaving motion, while changing from standing, to squatting, to sitting, until they lie under the pipeline. When hands meet, one of the welders grinds away his end crater while the other finishes the weld. These are the operators that determine the front-end laying speed of the pipeline. No time to be lost. When ready, they immediately move to the next weld. The internal clamp is removed directly after the root pass. They make about 30 root passes a day, in a 12 hour shift.

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The Pipeliner II can be used on pipes from 6 inch up to 36 inch diameter and above, simply by changing the guide ring - an advantage relative to downhill mechanised equipment which starts at approximately 30 inches. Another advantage is that its use becomes economical with significantly shorter pipeline lengths. Moreover, pipeline contractors will own the equipment and not have to rent it.

The Pipeliner II forms the heart of a complete welding system with a digital power source with synergic programmes for FCAW, a floor standing wire feeder for 16 kg spools (less spool changes compared with common head-mounted 5 kg spools), a programming unit with memory positions for four individual beads, a gas mixing unit and a power generator. All can be mounted on a truck or tractor for transport along the pipeline, together with the welding heads, while the guide ring is the only component remaining on the pipe. It is easily removed, by hand.

**Back to the desert**

Figure 2 shows the semi-automatic STT root pass welding of a 36 inch diameter, 28 mm WT pipeline for the Khurais Sea Water Injection & Distribution Headers Project. It is welded by two welders simultaneously, from 6 to 12 o’clock – clockwise and counter clockwise. They are ‘true artists’, able to continue welding with a weaving motion, while changing from standing, to squatting, to sitting, until they lie under the pipeline. When hands meet, one of the welders grinds away his end crater while the other finishes the weld. These are the operators that determine the front-end laying speed of the pipeline. No time to be lost. When ready, they immediately move to the next weld. The internal clamp is removed directly after the root pass. They make about 30 root passes a day, in a 12 hour shift.

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Six additional teams are individually responsible for filling the joints left behind by the hot pass and filler passes. The welder supervises the process and, when needed, fine-tunes the parameters with the remote control. For the first filler pass, the Pipeliner is transported back to 6 o’clock and the second set of pre-programmed parameters is chosen.
filling team, to a total of 10 layers. Split beads (two) start after 4 layers and weaving is applied following the hot pass. All passes are performed at the same current of about 200-240 A at a wire feed speed of 7.5-10 inch/min. The cored wire diameter is 1.2 mm and the shielding gas is Ar/20% CO₂.

Productivity
Mechanised uphill welding with the Magnatech Pipeliner II and FILARC PZ6113 rutile cored wire is very productive. Nacap-SRB takes full benefit from the high deposition rate of 3-4 kg/h at 250 A, by achieving a duty cycle of 80%, due to clever organisation of the filling procedure.

Equally important, it is a very secure technique. Uphill welding with PZ6113 in the spray arc mode, at a relatively high welding current, is a very tolerant method for filling when compared to mechanised downhill short circuit welding. The latter method is faster due to a reduced weld volume, but is based on a more expensive J-preparation, and one must expect comparatively high defect rates and associated repair work. Moreover, Aramco would additionally require 100% ultrasound testing, which is costly and, often, difficult to organise in remote areas. Using the uphill technique, Nacap-SRB has recorded their weld defect rate to be consistently below 0.5%, measured by common X-Ray testing - prescribed by Aramco to be 100% for the first 40 joints and 10% thereafter.

Magnatech
Magnatech International BV is the sales and service organisation for Magnatech Limited Partnership, East Granby, USA, for Europe, Middle East and Africa. Magnatech Limited is the manufacturer of specialised equipment for Orbital Pipe and Tube welding, using the GTAW, FCAW and GMAW welding process. Magnatech International BV is located in Dronten, The Netherlands. It supplies innovative systems to both manufacturers and contractors, who require precision welding tools for tasks from simple fusion welding to multipass applications requiring wire feed, torch oscillation and arc voltage control.

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Wherever chemical or petrochemical plants exist, pipes and valves are needed to convey fluids or gas and control flows. Both must meet particular requirements such as pressure, temperature, resistance to corrosion and wear due to abrasion. As the world oil demand forces oil companies to explore reserves that are more difficult to extract, the crude oil often becomes richer in foreign matters and impurities, increasing the wear of transportation systems - particularly the valves which are generally the most critical components. As a result, valve manufacture and repair is a growth industry.

The nature of the fluids flowing through the valves dictates materials selection, ranging from austenitic stainless steel to nickel-base alloys such as Inconel. Over the last decade, the use of noble materials for the entire valve has shifted to the cladding of a forged or cast CMn steel load-bearing body with a resistant alloy. The quality of the facing varies with the valve application. In the case of valves for transporting gas, the final layer is grade 316 stainless steel, as it is only subject to corrosion, whereas a final layer of Inconel 625 is a common choice when it involves crude oil mixed with sand, causing both chemical attack and abrasion.

Increasingly, valve manufacturers outsource the cladding to companies with specialist knowledge and equipment. This has given birth to a completely new industrial segment of smaller production sites devoted to the surface cladding of valves on a contract basis. Some of these operate in the high-end of the market – equipped with highly efficient systems and tools and capable of dealing with large scale production. They are lean companies whose driving force is specialisation, quality and productivity.

**Oxy Welding Engineering**

“Snello è bello” (lean is best), is the motto of Oxy Welding Engineering SpA with headquarters in Magnago, Italy. With 7 cladding operators and 8 continuously working welding and cladding stations, it is one of the few companies capable of cladding balls with a diameter of up to 60 inches and a weight up to 15 tonnes, for valves with a
flow port of 1.5 metres wide. The company was founded in 2002 by Mr. Fabio Genone - a former distributor of welding materials and equipment to the valve industry – when outsourcing of valve cladding began. Oxy Welding Engineering focused on the cladding of the balls forming the movable part of the valve which, on rotation, either allow or shut off access to the fluid.

Mr. Genoni explains the change in valve manufacturing towards cladding. “Replacing stainless steel or Inconel valves with a carbon steel body surfaced with these materials is not only dictated by cost considerations. As CMn steel is stronger, over-dimensioning is avoided, as are typical defects associated with the forging or casting of fully stainless valves.”

A normal requirement is that the cladding meets the required chemical composition to, at least, a depth of 3 mm. The final layer must have an over-thickness to provide a safety margin and to allow for machining to a perfectly spherical shape. Also the deformation caused by weld metal shrinkage and stresses, during cladding, needs to be taken into account. “There is no magic software which can calculate this”, says Mr. Genoni. “It is pure experience.”

**Cladding processes**

Careful choices were made to optimise the productivity of the surfacing process. The MIG process is not the most productive process for this application, but it has the advantage of not requiring the continuous attention of the operator - thus allowing him to operate another station, simultaneously. For Oxy Welding Engineering, the MIG process proves economic up to a valve ball diameter of approximately 24 inches. For larger diameters, ESW strip cladding is the better choice, even if it means the total commitment of the operator to the machine.

There is considerable versatility and synergy between operators and systems; it is not unusual for a single operator to supervise two or more workstations, simultaneously. Depending on dimensions and accessibility, the machine most suitable for the work is used, ie, for each application, the process adopted is the one offering the greatest possible productivity. The level of quality reached is wholly satisfactory, while productivity is maximised and repairs are practically zero. “The same practical logic was applied towards robotisation”, explains Mr. Genoni. “It is not necessary to have a large batch to justify the use of a robot. As long as there are sufficient working hours, the process is also advantageous for a single workplace - especially when the programming effort is limited. The cladding cycle starts in the evening and, by the next morning, the work finished!”

Since its inception, Oxy Welding Engineering has understood that the tools for success are product quality and high process productivity. On this basis, the company opted for highly automated systems or automation and high productivity processes, such as electro slag strip cladding - the most productive cladding process available (see Svetsaren 1/2007 page 16 for detailed ESW cladding benefits).

Currently, there are three ESAB ESW systems at work, each consisting of an LAF 1600 power source supplying 1500-1600 A at 100% duty cycle, an A6 cladding head for 30-60 mm strips, and a PEH control unit.

**Consumables**

The flux/wire combinations used for ESW strip cladding with 316L end composition are:

- single layer: OK Flux 10.10/OK Band 309LMo.

The flux/wire combination used for ESW strip cladding with Inconel 625 end composition is:

- OK Flux 10.11/OK Band NiCrMo3.

This combination ensures optimum results in terms of analysis and surface appearance for both single and double layers.

The MIG wires used are ESAB OK Autrod 309LSi, OK Autrod 309LMo, OK Autrod 316LSi and OK Autrod 19.82. Use of 100 kg and 250 kg Marathon Pac bulk drums provide a valuable increase of the duty cycle in the automated and robotic applications. Also, the innovative matt surface technology applied by ESAB for stainless steel wires provides effective process stability.

The high demands of valve manufacturers and engineering companies have led Oxy Welding Engineering to investigate each combination of consumables used by carrying out additional tests (eg, corrosion tests, micrographs for determination of the structure, macro-hardness, etc), in addition to the tests required for qualification of the welding process in accordance with AWS, EN and API standards. These tests have always been passed satisfactorily.

**Co-operation with ESAB Saldatura SpA**

Support from ESAB Italy is well regarded by Oxy Welding Engineering. ESAB understands that the application and its special requirements require close dialogue and a direct relationship. This results in the supply of sophisticated welding and cladding equipment and high quality filler materials, enabling Oxy Welding Engineering to fully exploit their experience and professionalism.

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Techint and ESAB Brazil - partners in the construction of the PRA-1 jacket.

ENG. CLÁUDIO TIRANI VAZ, MSc. ESAB BRAZIL ENG. SÉRGIO MUNHÓS, TECHINT SA ENG. JOSÉ ROBERTO DOMINGUES, ESAB BRAZIL

PRA-1 is a fixed offshore platform and autonomous re-pumping station, created as an alternative for the drainage of oil from the platforms in the Campos Basin to the continent. Its jacket was built by TECHINT SA. The technical requirements and operational aspects significantly influenced the choice of welding consumables. The technical partnership between TECHINT and ESAB - as the welding products supplier - was fundamental to the success of the project.

PRA-1 was installed about 100 km offshore at the Marlim Sul Field in the Campos Basin to pump, during peak periods, approximately 630 thousand bpd (barrels of petroleum per day) produced by platforms P-40, P-51, P-52, P-53, P-55 and RO-module 4 in the Roncador, Marlim Sul and Marlim Leste fields. Its jacket - a structure in API 2W-50 steel with a total weight of 7,500 tons - was ordered by Petrobrás and built by Techint SA at its construction site in Pontal do Paraná/Paraná. The jacket was shipped to its final location on the last day of 2006.

Technical features
A new concept, featuring optimised use of materials through weight reduction, the PRA-1 jacket has a typical asymmetrical structure. This aspect represented an enormous challenge to the builders during the 24 months of assembly work. Nodes and pipes used in the jacket were prefabricated and delivered to the construction site in Pontal do Paraná overland.

On-site, to simplify the structural complexity of the project, a detailed construction plan was prepared to cover the assembly of the faces at

Figure 1. Overview of the Techint construction site in Pontal do Paraná/Parana at the time of the construction of the PRA-1 jacket.
ground level, “roll up”, cable support and final consolidation by the fixation of tubular elements.

The assembly sequence was established after structural analysis of the faces and levels of the jacket. Welding, mostly of circumferential joints, was performed following strict quality criteria and productivity. Wherever possible, the welding of the tubular elements was executed in the pipe shop using the submerged arc welding process (SAW). The remaining welds were performed in the field using TIG welding (GTAW) or stick electrodes (SMAW) for root passes, and flux cored wires (FCAW) or stick electrodes (SMAW) for filling and capping.

The jacket’s production complied with the Petrobras norm N-1852 construction criteria (Oceanic structures - production and assembly of fixed units). This norm states that steels used in construction should be classified in conformity with Petrobras norm N-1678 (Oceanic Structures - steel). The jacket’s design temperature was 10°C. The API 2W-50 steel used in the production of the jacket was re-classified in accordance with norm N-1678.

**Welding consumables**

Welding consumables used in the construction of the platform jacket were supplied in agreement with the conditions defined by Petrobras norm N-1859 - Welding consumables with quality assurance. In order to meet these requirements,
Table 2. OK 48.08 technical features

<table>
<thead>
<tr>
<th>AWS Classification</th>
<th>E7018-G</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemical Composition (Typical values)</strong></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.05%</td>
</tr>
<tr>
<td>Si</td>
<td>0.37%</td>
</tr>
<tr>
<td>Mn</td>
<td>1.25%</td>
</tr>
<tr>
<td>Ni</td>
<td>0.90%</td>
</tr>
<tr>
<td><strong>Mechanical Properties</strong></td>
<td></td>
</tr>
<tr>
<td>Yield strength*</td>
<td>555 MPa</td>
</tr>
<tr>
<td>Tensile strength*</td>
<td>630 MPa</td>
</tr>
<tr>
<td>Elongation*</td>
<td>28%</td>
</tr>
<tr>
<td>Charpy</td>
<td>153 J</td>
</tr>
<tr>
<td>Yield strength* - Average**</td>
<td>545 MPa (AW)/ 560 MPa (PWHT)</td>
</tr>
<tr>
<td>Tensile strength* - Average**</td>
<td>633 MPa (AW)/ 645 MPa (PWHT)</td>
</tr>
<tr>
<td>Elongation – Average**</td>
<td>30% (AW)/27% (PWHT)</td>
</tr>
<tr>
<td>Charpy – face** (-30°C)</td>
<td>85 J (AW)/79 J (PWHT)</td>
</tr>
<tr>
<td>Charpy – root** (-30°C)</td>
<td>109 J (AW)/146 J (PWHT)</td>
</tr>
<tr>
<td>CTOD – average**</td>
<td>0.86 mm (AW)/ 0.50 mm (PWHT)</td>
</tr>
</tbody>
</table>

(*) AWS test plate
(**) N-1859 test plate

Table 3. OK Flux 10.71 technical features

<table>
<thead>
<tr>
<th>Wire</th>
<th>EM13K</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AWS Classification</strong></td>
<td>F7A4-EM13K</td>
</tr>
<tr>
<td><strong>Chemical Composition ( typical values)</strong></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.05%</td>
</tr>
<tr>
<td>Si</td>
<td>0.50%</td>
</tr>
<tr>
<td>Mn</td>
<td>1.40%</td>
</tr>
<tr>
<td><strong>Mechanical Properties</strong></td>
<td></td>
</tr>
<tr>
<td>Yield strength*</td>
<td>542 MPa</td>
</tr>
<tr>
<td>Tensile strength*</td>
<td>644 MPa</td>
</tr>
<tr>
<td>Elongation*</td>
<td>30%</td>
</tr>
<tr>
<td>Charpy</td>
<td>76 J</td>
</tr>
<tr>
<td>Yield strength* - Average**</td>
<td>498 MPa (AW)/ 510 MPa (PWHT)</td>
</tr>
<tr>
<td>Tensile strength* - Average**</td>
<td>626 MPa (AW)/ 620 MPa (PWHT)</td>
</tr>
<tr>
<td>Elongation – Average**</td>
<td>26% (AW)/25% (PWHT)</td>
</tr>
<tr>
<td>Charpy – face** (-30°C)</td>
<td>59 J (AW)/ 91 J (PWHT)</td>
</tr>
<tr>
<td>Charpy – root** (-30°C)</td>
<td>115 J (AW)/147 J (PWHT)</td>
</tr>
<tr>
<td>CTOD – average**</td>
<td>0.81 mm (AW)/ 0.94 mm (PWHT)</td>
</tr>
</tbody>
</table>

(*) AWS test plate
(**) N-1859 test plate

not only were tests necessary for consumable classification performed but, in addition, tensile tests, impact (Charpy V-notch) and CTOD tests on weld metal coupons in the AW and PWHT (2h/600-650°C) conditions. Maximum heating and cooling rates were 110° and 130°C per minute.

Petrobras’ norm N-1859 stipulates a weld test plate with minimum thickness of 50 mm made in the same steel as used in the project to produce the coupons. Figure 3 shows the joint geometry and Figure 4 shows the dimensions and location where the test plate coupons should be removed.

Two groups of six coupons were prepared for the impact tests (Charpy V-notch); each consisting of three coupons removed from the weld root and three taken at 2 mm subsurface in the weld centre. Two groups of two coupons were made for the tensile tests - one coupon was removed on side A and another on side B of the joint. Finally, two groups of three coupons were made for
CTOD testing. These were performed at design temperature (Tp = 10°C). The CVN impact testing took place at 30°C and -40°C.

Norm N-1859 also requires test plate welding and mechanical tests for checking the consumable classification in accordance with the AWS specification.

The consumables used in this project were OK 48.08 stick electrodes, OK Flux 10.71 agglomerated flux and FILARC PZ 6138S flux-cored wire. Technical features and results obtained in the tests are shown in Tables 2, 3 and 4.

In addition to the initial entry approvals for the consumables, each individual consumables lot was mechanically tested by ESAB. The test results were supplied to TECHINT with the consumables.

**Welding Procedure**

Figure 5 shows the joint and weld bead sequence of a qualified welding procedure used on this project where OK 48.08 stick electrodes were used for the root pass and FILARC PZ 6138SR flux-cored wire was used for filling and capping passes. On the welding procedure qualification was welded a test plate in the vertical (3G) up position.

The welding procedure parameters are shown in Table 5 and mechanical tests results obtained on the welding procedure qualification are indicated in Table 6.

**Technical support**

In addition to approval of welding consumables by norm N-1859, the welding procedure qualification and welder’s training qualification were produced by ESAB and TECHINT. This technical partnership was fundamental to the project’s success.
Manufacture of mobile gasoline tanks in AlMg5 aluminium alloy at ZAO BECEMA, Russia.

ESAB assists in conversion from steel to aluminium.

SERGEY CHAMOV

ESAB Russia, Moscow.

After a road accident in Moscow, in the mid-1990s - when a gasoline truck crashed, overturned and caught fire, killing many people – it became clear that some USSR designed trucks posed a threat to life. This, together with rigid weight limitations established on Russian roads, created a demand from transportation companies for safe trucks having low weight and as large as possible cargo volumes. Across the world, aluminium-magnesium alloys are proven to be a viable alternative for tanks. They have a high strength/weight ratio, are ductile and corrosion resistant, and do not spark and catch fire, if an accident occurs. However, the use of these alloys in tank construction requires special welding skills and dedicated welding equipment and consumables.

ZAO BECEMA, located in Krasnogorsk, near Moscow, manufactures tank trucks for heavy or light mineral oil transportation. Founded in 1932, the company originally produced armoured concrete products. In 1945, it was transformed into a machine-building factory. Presently, it produces a wide range of road transport vehicles, including semi-trailers for transporting powder materials and liquids, tank trucks for light and heavy mineral oil transportation, tippers, road construction machines and technological equipment for cement, metallurgical and chemical industries.

In 1996, it began steel tank production, especially for gasoline transportation, complying with all European safety norms and technically supported by HOBUR (Netherlands) and LAG (Belgium). From the year 2000, the rapid growth in the Russian economy generated a huge demand for aluminium gasoline tank trucks, which were imported from Europe. With healthy market conditions, ZAO BECEMA management decided to develop aluminium manufacturing, resulting in their own range of aluminium gasoline trucks, see Figure 1. ESAB supported the company during this period of development.

Challenges in aluminium fabrication

The first challenge was to change employees’ “psychology” from steel to aluminium fabrication. They
Table 1. Mechanical properties: butt welds by semi-automatic two-sided pulse MIG-welding

<table>
<thead>
<tr>
<th>Sample Nr</th>
<th>Sample size [mm]</th>
<th>Rupture effort [kN]</th>
<th>Tensile strength [MPa]</th>
<th>Rupture zone</th>
<th>Angle of bend for D=12 mm [degree]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.0 x 6</td>
<td>35.48</td>
<td>296</td>
<td>Basic metal</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>19.9 x 6</td>
<td>33.91</td>
<td>284</td>
<td>Basic metal</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>20.0 x 6</td>
<td>35.28</td>
<td>294</td>
<td>Basic metal</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>15.0 x 6</td>
<td></td>
<td></td>
<td>Seam</td>
<td>91</td>
</tr>
<tr>
<td>5</td>
<td>15.0 x 6</td>
<td></td>
<td></td>
<td>Seam</td>
<td>93</td>
</tr>
<tr>
<td>6</td>
<td>15.0 x 6</td>
<td></td>
<td></td>
<td>Seam</td>
<td>90</td>
</tr>
</tbody>
</table>

- Basic metal: AlMg5, s=6 mm thickness
- Welding wire: OK Autrod 5183 ø 1.2 mm
- Welding type: MIG pulse
- Shielding gas: Ar 99.99%, consumption: 20 l/min
- Welding current: 220-240 and 190-210 for back weld

Figure 2. Process plasma welding of plates with the ESAB FD60HP Plate Seamer.

needed to understand and apply complete separation of steel and aluminium – be it in storage, transport or production. ZAO BECEMA invested in a new factory lay-out, new machines for aluminium fabrication, and tools and clothing for workers, only for use on aluminium. New routines were established, such as the cleaning of common equipment, before starting aluminium fabrication, and the prohibition of abrasive materials, e.g., for bevel grinding. Another challenge was to find the right aluminium quality. Aluminium alloys produced to Russian standards either have insufficient strength – requiring thicker construction with a sharply reduced weight advantage relative to steel – or have insufficient ductile properties (elongation below 17%). It was also difficult to purchase plate sufficiently wide to avoid welding on the caps and internal separation walls of the tank, and the associated risk of crack propagation during cold pressing and flanging. However, the Russian Samara aluminium works was able to supply wide AlMg5 plates with sufficient strength and ductility (Rm: 285-300 MPa/ elongation: 22-26%).

The need to automate the welding and rolling processes for the aluminium tanks resulted in the purchase of an ESAB FD60HP plate seamer with PT-8 plasma torch, which allows one-sided, full-penetration welding of aluminium plates up to 8 mm thick (Figure 2).
FACCIN, Italy, supplied a CNC-controlled bending machine with four 6 m long rollers.

The last serious item to be resolved was the safety of the welders, particularly for those performing MIG-welding within a vessel where ventilation is difficult or impossible. This was solved by the combined use of local extraction, a MIG torch with fume extraction and a fresh air helmet.

Welding material selection

Although type 5356 welding wire matches the plate composition chemically, practice shows that it yields a 5-10% lower weld strength. Since the tanks do not experience high temperatures, type 5183 wire could be selected, giving matching strength and good ductility - OK Autrod 5183 for MIG and automatic plasma welding and OK Tigrod 5183 for TIG welding. Tables 1 and 2 show the results of tensile and bend tests on coupons welded with respectively two-sided pulse MIG and one-sided plasma welding on a stainless backing.

Tank construction and manufacture - variety of welding used.

A tank consists of a long cylindrical body, closed on both sides by caps. Internally the vessel is divided into several sections by walls with the same form as the caps, according to the contractor’s requirements (Figure 3). If the volume of a section exceeds 8 m³, extra deflector plates divide it, to break waves in case of an abrupt stoppage of the truck.

The automatic plasma welder fabricates plates with a width up to 6 m, which are rolled to a cylinder. To close the cylinder, a final double-sided longitudinal run is performed by pulse MIG welding. The first run is performed on self-adhesive ceramic backings, PZ 1500/70, supplied by ESAB. Subsequently, the root area is removed mechanically, followed by a final run on the opposite side.

All caps, separation walls and deflector plates are connected to the tank with fillet welds made by pulse MIG. If the tank length exceeds 6 m, cylinders are joined with a circumferential weld made in the same way as the longitudinal welds – pulse MIG on ceramic backing strip.

All boxes, ladders, fences, etc, are welded onto the tank using pulse MIG. Only tubes and inlets to the tank are welded using the TIG process.

Automatic plasma welding

The semi-automatic MIG welding of plate sections with a size of 6000 x 6300 x 6 mm from separate sheet plates proved not to be feasible because of strong distortion and many defects. This problem was effectively solved with the ESAB FD60HP plate seamer and PT-8 plasma torch. This equipment welds carbon and stainless steel without weld pool support and shielding gas while, for aluminium plate, a copper backing bar is normally used.

However, the standard ESAB copper backing bar did not give good results in this application. The specific groove shape (Figure 4), promotes free

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formation of the root. The welding parameter range for a stable process - giving full penetration welds and no weld pool collapse - was too narrow for practical use. The tip-wear of the tungsten electrode, resulting in a less focused arc, already caused lack of fusion within a weld length of 6 m. The operator had to manually compensate by increasing gas flow, whilst seeing only the surface of the weld – not the root.

OAO Kriogenmash, a Russian company with great experience in aluminium vessel fabrication, provided the solution. They recommended a special stainless backing bar with a very specific root shape, which promotes a forced root formation (Figure 4b). This increased the process stability sufficiently and widened the parameter range. It made the welding operation less sensitive to heat input, with reduced risk of burning through or the entrapment of oxides.

Figure 5 compares the root passes produced on the stainless backing bar with those made on a copper backing bar. Both are I-joints with zero gap. The photographs reveal that a bigger weld pool is possible on the stainless backing bar, creating a nice bead width, while the root solidifies uniformly, instead of in droplets. The better shape is confirmed by the macrosections of Figure 6. The transition of the bead onto the base material is smoother.

Table 3. Welding data for automatic plasma welding.

<table>
<thead>
<tr>
<th></th>
<th>Forced root formation</th>
<th>Free root formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma gas consumption</td>
<td>1.6 l/min</td>
<td>1.4 l/min</td>
</tr>
<tr>
<td>Welding current</td>
<td>250</td>
<td>235</td>
</tr>
<tr>
<td>Welding speed</td>
<td>16 cm/min</td>
<td>19 cm/min</td>
</tr>
</tbody>
</table>

Fruitful co-operation

ZAO BECEMA partnered with ESAB for their welding needs, when changing from carbon steel to aluminium fabrication. Within two months, this resulted in the installation and use of high technology equipment, the selection of the right filler materials and the successful training of welders and operators. This enabled the company to quickly convert tank truck production from carbon steel to aluminium, taking full advantage of high market demand.

About the author:

Sergey Chamov is Product Manager Consumables at ESAB Russia, in Moscow.
Belleli Energy SpA reactors at the heart of Qatar’s Pearl Gas-to-Liquids Plant.

ESAB arc welding consumables deliver quality and productivity.

Acknowledgement

We thank the Belleli Management and Belleli Welding Superintendent, John Andersson, for facilitating our visit to their manufacturing facility and for providing the information for this article. Former ESAB Product Manager, Johan Ingemansson, and ESAB Product Manager, Sandish Salian, are thanked for their support.

Belleli SpA

Belleli SpA, an Exterran Group company, is a major manufacturer and supplier of equipment for the power generation, oil and gas, chemical/petrochemical, power and desalination industries. Its head office, together with a large production facility, are located in Sharjah, in the United Arabic Emirates. Other plants are in Dubai, Saudi Arabia and Qatar.

Belleli products include reactors, pressure vessels, towers, columns, steam drums, brine heaters, MED & MSF desalination units, pressure parts for heat recovery steam generators and complete process modules. State-of-the-art welding technologies are adopted while using low-alloy, cladded, Incoloy and Monel materials.

In more than 40 years of business, worldwide, Belleli Energy has created a reputation for the quality of its supplies and services. Belleli Energy operates a Quality Management System that

Over a period of three years, Belleli SpA, in Dubai, UAE, will fabricate 12 reactor vessels for Qatar Petroleum and Shell’s Pearl Gas-to-Liquids plant which is under construction in Ras Laffan Industrial City, in Qatar. The reactors are constructed from high wall-thickness pressure vessel steel and are produced to the very high quality required by the oil and gas industry. Narrow gap SAW and mechanised SAW are the dominant welding processes.
meets the requirements of ISO 9001 (BS 5750 Part 1). The independent Quality Control Department, through inspection and continuous surveillance, monitors the correct implementation of fabrication and construction activities.

**HPS reactors - construction**

Figure 1 illustrates a Heavy Paraffine Synthesis reactor, divided into seven sub-assemblies, consisting of heads, shells, tube sheets, inlets, outlets and manholes. It is over 20 m tall and over 7 m in diameter. Shells, heads, tube sheets and nozzles are constructed from pressure vessel steel 20MnMoNi 4-5 (ISO 15608: 2000), ranging in thickness from 54 – 150 mm. This Q&T steel grade is commonly used for pressure vessels for service at elevated temperatures (Table 1).

The steel requires a post weld heat treatment at 610°C +/- 10°C /1h for every inch of thickness. The bottom head is clad with a 304L stainless protective layer.

The reactor contains a total of 29386 tubes for catalyst loading, running vertically through the reactor shell, through an upper and lower tube sheet. The tube material is DIN 17175: 19Mn5 Grade 1.

The reactor is built-up from seven sub-assemblies – top head and bottom head, two conical shells with a pipe sheet and nozzles, and three more straight shells. Sub-assembly eight is the foundation onto which the reactor is placed.

**Welding**

The welding of the reactors involves five types of principal joints for which Belleli utilises individual solutions:

- Longitudinal welds in shells;
- Circumferential welds to joint shells to shells, shells to heads, and shells to tube sheets;
- Conical welds to join top and bottom head petals;
- Circular welds to connect nozzles;
- Tube to tube sheet welds.

Welding procedures for these welds were developed and qualified in close co-operation with ESAB, based on three universally used consumables:

- SAW: OK Flux 10.62/OK Autrod 13.40 (ø4.0 mm)
- TIG (GTAW): OK Tigrod 13.13 (ø2.4mm)
- MMA (SMAW): PH88S (ø2.5/3.2/4.0 mm)

Welding procedures include procedures for the restoration of 304L clad steel.

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**Table 1. Chemical composition and mechanical properties of 20MnMoNi 4-5**

<table>
<thead>
<tr>
<th>%C</th>
<th>%Mn</th>
<th>%Si</th>
<th>%Mo</th>
<th>%Ni</th>
<th>%Cr</th>
<th>Rm (MPa)</th>
<th>Re (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.17-0.23</td>
<td>1.0-1.5</td>
<td>&lt;0.4</td>
<td>0.45-0.60</td>
<td>0.4-0.8</td>
<td>&lt;0.5</td>
<td>750-750</td>
<td>&gt;430</td>
</tr>
</tbody>
</table>

**Table 2. Overview of consumable classifications and typical all weld metal mechanical properties (as welded).**

<table>
<thead>
<tr>
<th>Consumable</th>
<th>Classification</th>
<th>Rm (MPa)</th>
<th>Re (MPa)</th>
<th>A4/A5 (%)</th>
<th>CVN (J/ °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OK Flux 10.62/</td>
<td>EN 760: SA FB 1 55 AC H6</td>
<td>650</td>
<td>730</td>
<td>23</td>
<td>70/-40</td>
</tr>
<tr>
<td>OK Autrod 13.40</td>
<td>S3Ni1Mo / EG</td>
<td></td>
<td></td>
<td></td>
<td>60/-50</td>
</tr>
<tr>
<td>OK Tigrod 13.13</td>
<td>EN 12534: Mn3NiCrMo</td>
<td>750</td>
<td>585</td>
<td>27</td>
<td>150/0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>85/-20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>69/-40</td>
</tr>
<tr>
<td>PH 88S</td>
<td>EN499 E 50 6 50 Mn 1 Ni B32 H5</td>
<td>620</td>
<td>550</td>
<td>27</td>
<td>&gt;60/-60</td>
</tr>
</tbody>
</table>

Welding procedures include procedures for the restoration of 304L clad steel.
Table 2 gives an overview of consumable classifications and mechanical properties.

Belleli applies automatic SAW whenever possible, taking advantage of the high deposition rate of this process, making use of ESAB automation solutions. Longitudinal, circumferential and conical welds – the majority of weldments on the vessel – are all produced with a combination of TIG for the root pass, a few layers of MMA deposition, followed by filling with SAW using OK Flux 10.62/OK Autrod 13.40. This flux has a high basicity for good low-temperature mechanical properties and an excellent slag detachability in narrow gap joint preparations. The welding sequence is discussed below for the circumferential welds joining shells to shells, shells to heads, and shells to tube sheets.

The welding starts with a full penetration TIG root pass, followed by a 10 mm thick MMA weldment to acquire sufficient thickness for the SAW process. The surface of the MMA weldment is ground back for a maximum of 1 mm followed by a dye penetrant check of the root area on both sides. Subsequently the inside of the narrow gap joint is filled with single wire SAW, followed by the cap layers on the other side, also done with the single SAW process (Figures 3, 4 and 5). Table 3 gives an overview of welding parameters used.

All welds are 100% ultrasound (US) tested, both before and after PWHT. US after PWHT is a Shell requirement, but Belleli decided to also test before PWHT to ensure that welds are sound and avoid repair procedures after PWHT. Mechanical weld metal requirements are given in Table 4.

For the top and bottom heads, a different welding procedure was used. The petal-to-petal welds (2/3-1/3 X-joints were welded with SMAW using Ph 88S stick electrodes, while the petal-to-crown welds (same joint preparation) were made with stick electrodes for the root area and SAW for the two-sided filling.

For the many nozzles, Belleli uses custom-made ESAB SAW machines for the welding of circular joints, providing superior productivity compared with manual welding, using the universally applied OK Flux 10.62/OK Autrod 13.40 flux/wire combination (Figures 6 and 7).

Preheating
Preheating is applied for all welds – the preheat temperature and interpass temperature depend on the wall thickness shown in Table 4.

Preheating procedures are very strict to avoid hydrogen induced cold cracking. In the event of a weld interruption (e.g., break time or shift change), the preheat temperature must be maintained above the stipulated temperatures. Where weld interruption cannot be avoided, for a longer period of time, the weld must not be allowed to cool down (under insulation) until at least half the wall thickness has been welded. Preheating is to be restored and maintained for 30 minutes before the welding can restart. Preheat maintenance (soaking) is a procedure to remove hydrogen from the weld area before cooling down to ambient temperatures. Figure 4 shows preheating on constructions of this size and wall thickness.

MMA electrodes and SAW flux are all low-hydrogen types and, for all consumables, strict, recommended storage and handling procedures are followed to avoid moisture pick-up in the extremely warm and humid Dubai climate.

Useful support
Located centrally in the Middle East, Belleli Energy SpA is well positioned to serve the oil and gas industry in the area, the same being true for ESAB which provides the industry with solutions for their welding and cutting needs.

Over the years, ESAB has been the only welding company to invest in a Dubai-based organisation - close to its Middle East customers and capable of supporting high technology companies such as Belleli. Timely and adequate stocks of welding and cutting products are supplied from two large
local warehouses. Success of this policy is underlined by the many fabricators in the area using ESAB technology and products.

### Table 3. Welding parameters used for welding the reactor shells.

<table>
<thead>
<tr>
<th>Process</th>
<th>Polarity</th>
<th>Current (A)</th>
<th>Arc voltage (V)</th>
<th>Travel speed (mm/min)</th>
<th>Heat Input (kJ/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIG</td>
<td>DCEN</td>
<td>90-180</td>
<td>9-14</td>
<td>50-83</td>
<td>0.97-1.82</td>
</tr>
<tr>
<td>MMA</td>
<td>DCEP</td>
<td>60-180</td>
<td>18-25</td>
<td>53-112</td>
<td>1.22-2.41</td>
</tr>
<tr>
<td>SAW (fill &amp; cap)</td>
<td>DCEP</td>
<td>450-580</td>
<td>27-33</td>
<td>450-480</td>
<td>1.62-2.39</td>
</tr>
</tbody>
</table>

### Table 4. Preheat and interpass temperatures applied.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Preheat temperature (<em>°C min.</em>)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T&lt;30mm</td>
<td>80</td>
</tr>
<tr>
<td>30&lt;T&lt;50mm</td>
<td>100</td>
</tr>
<tr>
<td>T&gt;50</td>
<td>150</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interpass temperature (*°C)</th>
<th>Preheat maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-180</td>
<td>all welds, 300 °C for two hours under insulation.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Room temperature</th>
<th>Preheat temperature</th>
<th>Rp0.2</th>
<th>A</th>
<th>CVN test Temperature</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>&gt; 590</td>
<td>&gt; 460</td>
<td>&gt; 18</td>
<td>80-180</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>&gt; 480</td>
<td>&gt; 18</td>
<td></td>
<td>100-220</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>&gt; 402</td>
<td>&lt; 18</td>
<td>20</td>
<td>150-220</td>
<td></td>
</tr>
</tbody>
</table>

### Table 4. Weld metal mechanical requirements after PWHT.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Rm</th>
<th>Rp0.2</th>
<th>A</th>
<th>CVN test Temperature</th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room temperature</td>
<td>590</td>
<td>460</td>
<td>18</td>
<td>20</td>
<td>+20</td>
</tr>
</tbody>
</table>

### Table 4. Preheat and interpass temperatures applied.

<table>
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<tr>
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<tbody>
<tr>
<td>Preheat temperature (<em>°C min.</em>)</td>
</tr>
<tr>
<td>Interpass temperature (*°C)</td>
</tr>
<tr>
<td>Preheat maintenance</td>
</tr>
</tbody>
</table>
The Shell Gas-to-Liquids (GTL) Process

Over the past few years, there has been substantial and sustained growth in proven natural gas reserves around the world. Today, the combined size of gas reserves is close to that of oil and, if this trend continues, looks likely to exceed them. When markets are remote, however, the gas needs to be converted into Liquefied Natural Gas in order to be transported economically, requiring an expensive infrastructure of LNG tanks and tankers and receiving terminals.

Alternatively, the gas can be converted chemically into high performance liquid hydrocarbon fuels and products. This has the advantage that existing distribution systems can be used to access the oil products market.

At macro economic level, the conversion of gas into synthetic fuels and products brings strategic advantages. Natural gas is abundant, although much of it is locked in remote regions that are difficult and costly to access. Moreover, transporting it long distances is costly because of its volume. GTL technology makes accessing such resources attractive, opening up alternative markets for gas and reducing dependence on oil. And for countries, like Qatar, with huge gas fields on their doorstep it offers the opportunity to diversify the development of energy resources.

Shell’s GTL process is a three-stage process. In the first stage - the Shell Gasification Process (SGP) - synthesis gas is obtained by partial oxidation of natural gas using pure oxygen. In the next stage - Heavy Paraffin Synthesis (HPS) - the synthesis gas is converted into liquid hydrocarbons. In the final stage, these liquid hydrocarbons are converted and fractioned into high quality products, predominantly middle distillates, by means of the Heavy Paraffin Conversion (HPC) process.

GTL technology goes beyond present day crude oil refinery in the sense that it produces combustion fuels with virtually no aromatic and sulphur components, giving significant reductions in regulated emissions (NOx, SOx, HC and particulates). It can also be blended with conventional diesel or, with minor modifications, be used as a neat fuel in diesel engines.

Belleli is manufacturing twelve 1st and 2nd stage HPS reactors for the GTL plant Shell is building with its partner Qatar Petroleum in Ras Laffan Industrial City, Qatar.
High integrity flowline welding at Luster Mekaniske Industri
ESAB orbital TIG technology crucial

Rune Pedersen and Torstein Wiber, ESAB Norway.

The Norwegian fabricator Luster Mekaniske Industri AS (LMI) was responsible for the production of the subsea pipelines connecting the Skinfaks and Rimfaks oil & gas fields to the Gullfaks C platform in the North Sea. This involved the mechanised TIG welding of an 18 km flowline in 13% Cr super martensitic stainless steel, 12 km of which was in 10” diameter pipe, 4 km in 8” diameter and 2 km in 4” diameter. The coated pipe segments to be joined had a length of 12 m and were supplied to LMI by Statoil. The complete project handled by LMI involved the beveling, welding, sealing, reeling on spools and transportation to Statoil’s Scandi-Navica lay barge, for installation of the subsea flowlines.
Quality and productivity.
Weld quality was the number one requirement for this project. Welds needed to be absolutely flawless and were subjected to 100% ultrasound testing (mechanised, performed by Dutch bureau RTD). In consultation with ESAB, it was decided to opt for mechanised TIG welding, combining a high weld quality with a good level of productivity.

Subsequently, welding procedure qualifications were developed and approved for the narrow gap welding in the vertical-down position (5G/PG). Figure 1 shows the joint preparation and bead sequence for 8 and 10” pipes with a wall thickness of 14.5 and 15.6 mm respectively. The cap layers are deposited in the vertical-up position, (stringer bead) to obtain sufficient bead width and good tie-in with the pipe material.

The welding consumable selected was a super-martensitic type (25.5%Cr - 9.5%Ni - 3.7%Mo) – a common choice for welding super-martensitic flowlines. It avoids ductile phases in the weld metal and gives an overmatching weld strength – needed to avoid weld deformation during reeling and de-reeling of the pipe spools. The shielding gas was a 70%Ar/30% He mixture – the backing gas Argon 4.0 and preheat and interpass temperatures were 50 and 150 degrees respectively.

Orbital TIG welding – the way to automate tube welding
The Orbital TIG welding equipment that was used is based on Railtrac components, running on a ring mounted on the tube with a standard ESAB TIG welding torch, which can be attached quickly to the equipment. Up to five different welding programmes can be stored and handled by the light-weight remote control. The following parameters can be monitored and adjusted:

- Start and stop
- Shift programme
- Travel direction
- Welding speed
- Weaving width
- Zero line displacement
- Welding current
- Welding voltage
- Backfill function

The welding of flowlines at LMI, takes place at four stations simultaneously, with one extra station being kept in reserve. Each station has two Orbital TIG tractors running from 12 to 6 o clock, clockwise and counter clockwise, operated by two individual operators (see photo on title page).

Each Orbital TIG welder is connected to an Aristo™ Mig 5000i inverter with Aristo™ U8 control unit – a multi-process digital power source.

This method is very reliable and productive, according to LMI. Throughout the Skinfaks/ Rinfaks project, some 2500 welds were US tested with only 5 showing a weld defect. It took about 15 minutes for a complete weld to be finished on an 8 or 10” pipe.

Figure 1. Narrow gap J-groove and welding parameters for mechanized TIG welding.

Figure 2. Vertical-down welding of a flowline in super-martensitic stainless steel, using orbital TIG welding equipment. The operator can control the welding parameters without lifting his helmet.

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RUNE PEDERSEN IS COUNTRY MANAGER AND TORSTEIN WIBERG IS SALES REPRESENTATIVE AT ESAB NORWAY, LARVIK, NORWAY.
Product News

NEW POWER SOURCES FOR ORBITAL WELDING

ESAB is launching three new products to increase productivity and reduce costs in orbital welding. First, the Aristo™ MechTig C2002i is a compact, robust, user-friendly power source that features an integral water cooler and high-specification controller with graphical interface, program library and auto-generation of welding programs.

Second, the Aristo™ MechControl 2 control unit has the same control features as the Aristo™ MechTig C2002i but with a separate power source and cooler. Third, the Aristo™ MechControl 4 is similar to the Aristo™ MechControl 2, with additional arc voltage control (AVC) and weaving control. When used with suitable welding heads, all three are highly efficient at producing top-quality tube welds in the food, beverage, dairy, chemical, pharmaceutical/biochemistry, semiconductor, aerospace, shipbuilding and general engineering industries.

Mechanised TIG welding is an efficient way to increase productivity, improve quality and reduce costs when welding tubes. ESAB’s new modular Aristo™ MechTig C2002i power source is highly adaptable, enabling systems to be configured to precisely match customers’ requirements. The machine delivers 180 Amps at a 35% duty cycle, or 110 Amps at a 100% duty cycle. Both the rotation motor and the wire feed motor are controlled by the control unit, which ensures that the welding parameters remain close to the ideal.

Getting the most out of the power source is simple by virtue of the 10inch colour display; a Windows-like user interface enables operatives to call up a program from the built-in library or generate a program automatically by entering data such as the material, outer diameter and tube thickness. Programs generated this way can be added to the library. Alternatively, all welding parameters can be set manually via a graphical or spreadsheet interface.

Another feature of the Aristo™ MechTig C2002i is the integral printer that can output a hard copy of the programmed welding parameters and the measured values for speed, current, voltage, wire and power. Time and date stamps, plus the power source ID, run number and total weld time, aid compliance with traceability requirements.

A USB connection enables users to transfer welding programs between machines, store backups and update the welding programs.

If the customer needs higher current then we can offer the power sources Aristo™ MechTig 3000i or Aristo™ MechTig 4000i together with the control unit Aristo™ MechControl 2. The user interface is the same as for the Aristo™ MechTig C2002i power source.

For applications requiring arc voltage control and/or weaving, the Aristo™ MechControl 4 control unit provides the necessary additional functionality when used together with a suitable power source.

ESAB offers numerous welding heads that are compatible with the three new machines, enabling complete orbital welding systems to be assembled to match the requirements of particular applications.

Further options include the Weldoc WMS 4000 Welding Monitoring Documentation System for compliance with the ISO 9000/SS-EN 729 international welding quality standard. Alternatively, the SPS 4000 package records just the parameter settings. If required, ESAB also offers the MechT 1 with CAN remote control and display functions.
FLEXIBLE HEAVY-DUTY SOLUTIONS FOR MIG/MAG, MMA AND ARC GAUGING

Choppers
Origo™ Mig 402c/502c/652c are sturdy, robust switching converter (chopper) power sources for heavy duty MIG/MAG welding, MMA welding and air-arc gouging. Proven technology and ESAB developed software provide high reliability and outstanding welding performance. A strong metal casing makes these units the perfect solution for harsh environments. Large wheels, sturdy lifting eyelets and an undercarriage, designed to allow the Origo™ Mig to be lifted by a forklift, make these units highly manoeuvrable.

Easy to use
The wide current and voltage range together with stepless, dial adjusted inductance make it easy to optimise settings for a wide variety of filler materials and gases. The patented ESAB ELP LogicPump automatically starts the machine’s cooling water pump when a water-cooled torch is connected to either the Origo™ Feed 304, M13 or Origo™ Feed 484, M13 wire feeder. It helps to eliminate the risk of the welding torch overheating and prevents costly repairs. When an air-cooled torch is used, the pump will automatically shut off, giving a lower noise level and longer working life for the cooling pump. The machines are designed for heavy industries such as civil construction, mobile machinery, foundries, pipe workshops, ship and offshore yards.

Flexibility
In many industries, quick production line changes are essential. The need for flexibility and high productivity can be met by the ESAB Origo™ Mig as the unit is capable of MIG/MAG welding, MMA welding and air-arc gouging. The Origo™ Mig 402c, 502c and 652c meet the demands of the cost-conscious fabricator for high productivity, versatility and high quality production with low overall welding costs. IP23 makes it a perfect solution for tough, outdoor working environments. The unit switches off automatically to prevent overheating and it conforms to EN 60974-1, EN 60974-10.

ROBUST AND POWERFUL MIG/MAG

POWER SOURCES FOR HEAVY DUTY WELDING

Origo™ Mig 4002c/5002c/6502c
Aristo™ Mig 4002c/5002c/6502c
These are sturdy, robust switching converter (chopper) power sources for heavy-duty applications. MIG/MAG and MMA are the main processes – process selection being related to the choice of Origo™ MA23, Origo™ MA24 or Aristo™ MA6 control panel. Proven technology and ESAB developed software provide high reliability and outstanding welding performance. The unit is constructed using a strong metal casing to withstand harsh environments. Large wheels, sturdy lifting eyelets and an undercarriage designed for transport by forklift make the unit easy to move. The digital (CANbus) communications and control system means fewer cables which, in turn, increases operational reliability. The power sources are optimised to operate with Origo™ Feed 3004, Origo™ Feed 4804 and Aristo™ YardFeed 2000 wire feeders. The patented ESAB ELP LogicPump automatically starts the cooling water pump in the machine when a water-cooled torch is connected to the wire feeders. This helps to eliminate the risk of the welding torch overheating. When a self-cooled torch is used, the pump is automatically shut off giving a lower noise level and longer working life for the cooling pump. Extended connection cables can provide a working radius of up to 35 metres to suit all individual welding needs.

The TrueArcVoltage™ System, in combination with an ESAB PSF™ torch, guarantees welding with the correct arc voltage independent of any voltage drop in the welding cables. This ensures the same arc voltage and weld result, regardless of whether a short connection cable or extended cables are used. The machines are designed for use in heavy industries such as civil construction, mobile machinery, foundries, pipe workshops, ship and offshore yards.

- Reliable, smooth starts and ends supported by efficient hot-start and crater fill functions.
- Efficient man-machine communication via user-friendly Origo™ MA23, Origo™ MA24 and Aristo™ MA6 control panels.
- Wide range of pre-programmed synergic lines (MA24 and MA6).
- Memory for three (MA23/24) or 10 (MA6) welding parameters.
- QSet™ function in the MA24 panel: unique, automatic setting of parameters in short arc.
- ESAB ELP LogicPump secures automatic start of the water pump using a water-cooled torch.
- TrueArcVoltage™ System, measures the correct arc voltage value.
- Multivoltage – allows mains supplies from 230/400/460/500 V - 3ph.
- Dust filter handles dirt, grinding-dust and metal particles from entering the chassis.

- The A13 panel to select MIG/MAG, MMA, scratch start TIG and air-arc gouging - a cost efficient combination;
- Sturdy metal casing with optional air filter - for tough, corrosive and dirty environments;
- Multivoltage – allows mains supplies from 230/400/460/500 V - 3ph;
- Stepless voltage control – for precise settings from the feeder panel or remote control
- Built-in water cooler (“w” version)
- ESAB ELP LogicPump - automatically starts the water pump when using a water-cooled torch;
- Digital V/A meter (option) in the A13 power source panel or the M13 feeder panel – extended functionality.
CADDY™ - THE PORTABLE SOLUTION FOR PROFESSIONAL WELDING

Caddy™ is the perfect partner in both MMA and TIG welding. From the single-phase Caddy™ Arc 151i A31 to the top-of-the-line Caddy™ Tig 2200i AC/DC, this family of portable welding units offers robust, reliable and flexible performance. Compact and efficient inverter technology, user-friendly multifunctional control panels and intelligent software assure optimal welding parameters and a consistently stable arc. And when things get hot, the Caddy™ stays cool – thanks to smart design.

Designed to last
Caddy™ features user-friendly control panels and compact, portable, impact and flame-resistant polymer housing. Inside, large heat sinks and smart design ensure cool operation for extended service life in harsh environments, while all sensitive components are fully shielded from dust and other particulates. Equipped with large high-durability OKC 50cable connectors, these IP23 compliant Caddy™ units can be used outdoors – even in rain. Superior performance, unsurpassed reliability – day after day.

Power Factor Correction (PFC)
The Caddy™ units are equipped with PFC circuits. These enable operation at full capacity on standard 16 A or 10 A fuses, for improved economy. Complying with the latest EMC (Electromagnetic Compatibility) legislation, PFC protects the machine from fluctuating primary voltage, for consistent performance and enhanced safety, even when connected to a generator. Caddy™ permits the use of mains cables longer than 100 metres to extend working radius.

Caddy™ Arc 151i/201i
Offering fully professional performance (150 A-170 A at 25% duty cycle), the portability and attractive pricing of these robust and compact single-phase machines places them in reach of skilled enthusiasts as well as seasoned professionals.

The Caddy™ Arc 151i/201i is the perfect welding tool for on-site installation, maintenance, repair or fabrication – indoors and outdoors.

Gloves-on control
Whether you choose the basic one-knob A31 or the advanced A33 panel you need never take your gloves off: both are easy to understand and set. The digital display A33 is a true multifunctional panel, featuring hot-start and arc force control (to fine-tune the welding process), choice of MMA or TIG welding, LiveTig™ start in TIG mode, two program function and an analogue remote control option. Control panel Caddy™ A33 has the latest regulator, ArcPlus™ II that gives a more intense, yet smooth and stable arc that is easy to control.

The go-anywhere welding partner
The single-phase Caddy™ Arc is the ideal MMA partner for welding most metals, including alloyed/ non-alloyed steel, stainless steel and cast iron. Designed for most grades of electrodes, from Ø1.6 up to Ø 4 mm, these machines offer exceptional reliability and consistent performance. The multifunctionality of the advanced A33 control panel and enhanced welding characteristics of the ArcPlus™ II software (smoother burning arc, less
spatter, smaller droplets and pause-free weaving) ensure superior weld quality and minimal post-treatment, whatever the primary power source. And a more than 100 m long mains cable offers a generous working radius!

**TIG too**

Just add a TIG-torch with gas valve, gas regulator and gas cylinder, and your Caddy™ is ready for TIG welding. Now you can weld mild or stainless steel, with or without filler material. Use scratch-start with the A31 panel, or electronically controlled LiveTig™ start with the A33 for safe starts without tungsten contamination.

**Caddy™ Tig 1500i/2200i**

These top-of-the-line single phase Caddy™ Tig machines are available with two different control panels. Both feature all key TIG (DC) welding functions, alternative arc ignition (HFstart or interference-free LiftArc™) and MMA. These machines offer increased functionality for demanding TIG applications in the repair and maintenance, manufacturing, civil construction and process industries. All are equipped with ArcPlus™ II regulator, ensuring less spatter, smaller droplets and pause-free weaving.

**The ‘do-it-alone’ control panel**

The easiest route to TIG welding? Choose a machine with the Caddy™ TA33 control panel. Just set plate thickness. Your TA33 will handle all the other settings, to ensure you produce a high-quality TIG weld. Welding current, slope down and post-gas can also be adjusted manually.

**The ‘do-it-all’ control panel**

The more advanced TA34 control panel offers pulsed-TIG, to improve control of the weld pool and heat input when welding thinner materials. Other TA34 features include Micro Pulse (to reduce the heat-affected zone) and a two-program function, allowing the operator to pre-store settings and switch between the programs, either from the panel or the torch trigger, even during welding. It can also be used for slope-up/slope-down and post-gas settings, and operated by CANbus remote control. You can even keep your gloves on.

**Caddy™ Tig 2200i AC/DC**

Optimum functionality, a complete range of accessories and full AC/DC flexibility make the Caddy™ Tig 2200i AC/DC single phase power source, the ultimate mobile unit for high quality TIG welding. Choice of panels and broad operating range (all types of material and thicknesses up to 5 mm) make it ideal for almost any repair or maintenance application – large or small. DC Pulsed or Micro Pulse TIG, or true MMA (with Hot Start and Arc Force) - The Caddy™ Tig 2200i AC/DC puts the choice in your hands.

**QWave™ optimisation**

A stable arc is critical to quality AC TIG welding. Featuring QWave™ optimisation, the Caddy™ Tig 2200i AC/DC ensures exceptional arc stability, in both AC and DC mode. The optimised AC wave form provides a smooth arc for a clean arc strike, low noise and excellent weld result. True AC rating ensures that set current and true current are always the same.

**Pick your panel**

Choice of two panels. Both provide full TIG DC, AC/DC and MMA welding capabilities, with logical easy-to-use controls. The Caddy™ TA33 AC/DC control panel offers the fast route to AC TIG
Welding. Just set plate thickness and the machine will handle all necessary parameters, to ensure that the AC TIG weld is top quality. Looking for advanced functionality? The Caddy™ TA34 AC/DC has it all. AC Balance control for arc cleaning and penetration, AC Frequency control to set arc width. It also features an electrode preheating control for differently shaped electrodes, for better starts and extended electrode life. Both panels feature the latest ArcPlus™ II regulator, ensuring less spatter, smaller droplets and pause-free weaving.

**Light and easy**
In a repair shop or aboard an oil rig, with the tight deadlines and constant movement from site to site, you need a lean machine. Like the rest of the Caddy™ family, this top performer is smart and agile. Its high-durability housing also makes it tough, surprisingly light and corrosion-free.

**Caddy™ Arc 251i**
The most powerful Caddy™ of all, this heavy-duty 400 V three-phase power source can be operated on a 10A fuse, thanks to its PFC circuit. This very portable machine can also be operated at sites where power comes from a generator or with fluctuating mains voltage, and far from its primary power source (over 100-metre mains cables). The rugged Caddy™ Arc 251i is the natural choice for portable applications in the shipbuilding, offshore, power generation and process industries.

**Welds the most demanding electrodes**
The Caddy™ Arc 251i is the ultimate portable for the professional welder. Although with the same compact format as the rest of the Caddy™ family, the potent Arc 251i generates an impressive 250 A at 30% duty cycle. Featuring an exceptional power reserve, this high capacity multifunctional unit offers excellent results with even the most demanding electrodes, including cellulosic and high-recovery, in dimensions from Ø1.6 to 5 mm. The improved welding characteristics of its ArcPlus™ II regulator simplify the job, ensuring pause-free weaving, better weld quality and less post-treatment.

**Choice of panel**
Caddy™ Arc 251i is available with two control panels, A32 and A34, featuring digital displays and a remote control function. The Caddy™ A32 features MMA or TIG welding options with LiveTig™ electronic start in TIG mode. Just set the welding current and you’re ready. The more advanced Caddy™ A34 features additional functions such as hot-start and arc force control and two program function. The specific electrode type may be selected in MMA mode, automatically optimising welding performance.
ESAB LAUNCHES NEW ORIGO WELDING MACHINE FOR DEMANDING TIG APPLICATIONS

A new TIG welding machine from ESAB for applications where high-quality TIG welds are required when operating in AC and DC mode. The Origo™ Tig 4300iw AC/DC welding power source can be used on virtually any weldable metal. Typical applications include production, repair and maintenance in industries ranging from automotive and mobile machinery, to shipbuilding, tube and pipe fabrication and civil engineering.

For AC TIG welding, the TA24 control panel offers facilities for setting the AC balance and the AC frequency so as to optimise the weld pool - or if True AC rating is selected, the true current is automatically maintained at the set current level. In addition, the QWave function optimises the AC wave form to give a smooth arc and very low noise, and electrode preheating enables the level of preheating to be adjusted to suit the selected tungsten electrode. Another useful feature is the two-program function that enables the operator to pre-set two welding programs and switch between them during the welding operation.

The TA24 control panel provides all of the necessary controls for AC TIG, DC pulsed TIG and MMA welding in an intuitive layout. As well as the TIG settings already mentioned, the panel enables the user to select AC or DC MMA welding, hot start, arc force and polarity switch (in DC mode).

When the water cooling unit and water-cooled torch are specified, users can also take advantage of the ELP (ESAB Logic Pump) that automatically starts the cooling unit when the torch is being used. Furthermore, the Energy Save mode ensures that the pump and fan only operate on demand.

Operating from a 400V three-phase supply, the Origo Tig 3000i AC/DC and Origo Tig 4300iw AC/DC welding power source have a setting range of 4-300A and 4-430A for TIG AC/DC welding, respectively, or 16-300A and 16-430A for MMA, AC/DC welding.

ESAB offers a range of accessories for use with these welding machines, including trolleys, remote control units, remote interconnection cables up to 25m long, and various TIG torches.

REACTIVE WELDING HELMETS BENEFIT FROM OPTION TO ADD HEAD AND RESPIRATORY PROTECTION

ESAB’s innovative new Eye-Tech II reactive welding helmets give customers the option to add full head protection and/or a respiratory protection system. This versatile family of welding helmets builds on the first-generation Eye-Tech’s reputation for high performance and comfort.

New features of the Eye-Tech II include a curved front cover lens that helps to prevent spatter from sticking, and a contoured design that protects the lens from damage if the helmet is placed face-down on the floor or workbench.

The helmets also benefit from a solar-powered cartridge that ensures the batteries are always charged. Furthermore, there is no need to remember to switch on or off, as the electronics automatically switch off if the helmet is left in a dark place for more than 10 minutes. The helmet reactivates itself when brought back into the light.

Four models of Eye-Tech II helmet are available to suit different welding and cutting applications and the free literature shows which models are suitable for use with which welding and cutting currents. In addition, the internal head harness can be removed and replaced with a specially designed protective helmet for use in situations where this additional protection is required.

For applications where full-face respiratory equipment is necessary, ESAB offers a choice of two air feed units that deliver up to 190 litres of air per minute. Both of these can be used with all four models of Eye-Tech II helmet.

The Eye-Tech II helmets can also be used in conjunction with an air-fed, grade B energy impact grinding visor, which is believed to be a unique feature for a welding helmet, complete with head and face seals.
The ideal addition to any laser cutting system.

It is not necessary to use expensive laser cutting systems for every job. Used in combination with the AUTOREX automatic plasma cutting centre, unnecessarily high operating costs can be avoided. Automatic cutting with plasma is fast, precise, energy efficient and, above all, very economical. The innovative AUTOREX plasma cutting centre is a turnkey, compact production cell that offers leading-edge solutions and cost-efficiency.

Less work, more automated productivity

Steel, stainless steel and aluminium, up to a thickness of 25 mm, can be cut with a standard plasma torch. ESAB’s CNC-controlled plasma system guarantees optimum use of material, outstanding quality cuts and perfect preparation of weld seams. Workpieces can also be marked without changing the tool. All processes run automatically, the standard integrated exchange table ensures a continuous supply of material parallel to cutting.

An automatic loading and unloading device for the exchange table and an automated shelf system are also available as optional extras. AUTOREX, therefore, offers simple, low-cost, production automation. A major advantage is that all components are matched, everything works together smoothly and can be integrated into existing systems.

Less noise, more safety

The complete cutting technology including machine portal and torch are hermetically separated from the working environment in a compact manufacturing cell. The noise level thus falls below the limits specified in the Technical Instruction on Noise Abatement. A welcome saving is that special noise protection measures are superfluous. The effective visor also contributes to greater safety in the workplace.

**AUTOREX – THE FIRST, TOTALLY ENCAPSULATED, AUTOMATIC PLASMA CUTTING CENTRE**

**Less ecological damage, more success for us all**

Companies, employees and the environment profit equally from cleanliness in the workplace. This is the reason why the AUTOREX exchange table has a powerful fume and dust extractor, and a fine dust filter system, guaranteeing clean air.

ESAB CUTTING SYSTEMS offer the AUTOREX in two different versions, each as a complete package:

**AUTOREX 3000**
- Suitable for sheet sizes of 1500 x 3000 mm, maximum
- Material thicknesses from 1 to 25 mm
- Fitted with one plasma torch
- VISION 52 control
- Exchange table with fume and dust extraction
- Fine dust filter system
- ESAB Columbus programming system
- Optional automatic loading and unloading device
- Automated shelf system

**AUTOREX 4000**
- Suitable for sheet sizes of 2000 x 4000 mm, maximum
- Material thicknesses from 1 to 25 mm
- Fitted with one plasma torch
- VISION 52 control
- Exchange table with fume and dust extraction
- Fine dust filter system
- ESAB Columbus programming system
- Optional automatic loading and unloading device
- Automated shelf system
**Tramtrac™ II – a cost-efficient and flexible solution for the repair of embedded city tramway rails:**

Tramtrac™ II is ESAB’s latest welding equipment for the repair of embedded grooved city tramway rails. It utilises the FCAW process with self-shielded wires, instead of the conventional SAW process, which provides a number of advantages in terms of ease of use and cost-efficiency.

The FCAW process allows Tramtrac™ II to be small and with an ultra light-weight compared with the heavier SAW solution. It is easily stored and used from a pick-up truck together with a petrol/diesel generator and welding power source. The tractor can be hand-carried and is easily installed and removed on and off the rail, allowing trams to pass within a controlled safety situation.

Welding embedded grooved rails in cities implies that preheating the rail cannot be performed. With rail grades ranging from 700 (R220) to 900A (R260) consumables for difficult to weld steels are recommended with a weld deposit that can accommodate high carbon without cracking. ESAB OK Tubrodur 15.65 and OK Tubrodur 14.71 are two wires that have been successfully used by tramway repair contractors for many years. Once the beads have been deposited there is no need to grind to the final profile of the rail.
The deposition rate is approximately at the same level as with the SAW process, but the duty cycle increases due to quick installation, no flux handling and reduced slag removal effort.

- **LIGHT WEIGHT**
- **COST-EFFICIENT**
- **PRODUCTIVE**
- **EASILY INSTALLED AND REMOVED**
- **EASY TO OPERATE**

The Tramtrac™ II is operator friendly with a four-wheel drive carriage that rides the single rail, a wire feeding unit for 1.2 or 1.6 mm Ø wires and adjustable traction wheels to fit most worn flanges and railheads. The control box, on top of the feeder encasement, features clearly marked symbols for wire feed speed, travel speed and start and stop welding functions, as well as wire inching.

The curved slide on which the welding head is enables easy and exact positioning of the wire extension between 0 to ± 65° while the horizontal and vertical slides enable positioning in the x- and y-planes.

Tramtrac™ II needs a 42V AC control voltage supplied from an Origo™ Mig or 410 step controlled welding rectifier with a total of 40 voltage settings.

10m long control and welding cables, allowing the tractor to travel up to 17 m when the power source is positioned close to the rail.

---

**Tramtrac™ II – technical data.**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control voltage</td>
<td>36-46 V AC</td>
</tr>
<tr>
<td>Power</td>
<td>90 W</td>
</tr>
<tr>
<td>Welding speed</td>
<td>30-100 mm/min.</td>
</tr>
<tr>
<td>Dimensions (l x w x h)</td>
<td>600 x 300 x 150 mm</td>
</tr>
<tr>
<td>Weight without consumables</td>
<td>12 kg</td>
</tr>
</tbody>
</table>

**Ordering information**

- **Tramtrac™ II**
  - 0814 721 880
- **Connection cable 10m**
  - 0457 360 884
- **Origo™ MIG 410**
  - 0349 302 408
- **Origo™ MIG 320**
  - 0349 303 562
- **Magnetic earth return cable & clamp**
  - 0000 500 415
- **OK Tubrodur 14.71, 1.6mm**
  - 1471 167 730
- **OK Tubrodur 15.65, 1.6mm**
  - 1565 167 730

---

**Cored wires – technical data.**

<table>
<thead>
<tr>
<th>Type</th>
<th>Classifications &amp; approvals</th>
<th>Typical chemical composition all weld metal (%)</th>
<th>Hardness HB</th>
</tr>
</thead>
<tbody>
<tr>
<td>OK Tubrodur 14.71</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Rutile</td>
<td>EN14700 T Fe 10</td>
<td></td>
</tr>
<tr>
<td>Polarity</td>
<td>DC+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.026</td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>Si</td>
<td>0.48</td>
<td></td>
<td>400</td>
</tr>
<tr>
<td>Mn</td>
<td>5.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td>19.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>8.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mo</td>
<td>250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>as welded</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>work hardened</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A stainless rutile 18.8.6Mn, self-shielded cored wire for cladding and joining 13% Mn steels and steels with limited weldability. It is also useful for buffer layers prior to hardfacing. Supreme welding characteristics and excellent slag detachability.

| OK Tubrodur 15.65     |                             |                                               |             |
| Type                  |                             | EN14700 T Fe 9                               |             |
| Polarity              |                             |                                               |             |
| C                    | 0.03                        |                                               | 250         |
| Si                   | 0.6                         |                                               | 450         |
| Mn                   | 13.5                        |                                               |             |
| Cr                   | 15.5                        |                                               |             |
| Ni                   | 1.8                         |                                               |             |
| Mo                   | 8.8                         |                                               |             |
| as welded             |                             |                                               |             |
| work hardened        |                             |                                               |             |

A stainless rutile self-shielded cored wire depositing a martensitic-austenitic, work hardening deposit, used for the rebuilding of mild, low-alloy and 13% Mn steels. The weld metal combines excellent metal to metal abrasion and impact resistance. Supreme welding characteristics and excellent slag detachability.

---

Light-weight Tramtrac™ II equipment can be hand-carried and is easily installed and removed.
OK Flux 10.77 is an agglomerated, basic flux designed primarily for the production of spiral welded line pipes.

The flux alloys some Si and Mn to the weld metal and it works equally well on DC and AC current. It is used in single wire, tandem and 3 wire systems, which makes it also suitable for longitudinal welded pipes of limited plate thicknesses.

OK Flux 10.77 produces welded joints with shallow reinforcement; low transition angles and smooth surface finish even at high welding speeds. A shallow reinforcement means cost saving in the later pipe coating operation, since the coating thickness can be reduced. With different wires it is suitable for all mild and high strength line pipe steels.

Classification

<table>
<thead>
<tr>
<th>Wire</th>
<th>Weld metal</th>
<th>Single wire, ø 4.0 mm, DC+, 30 V, 60 cm/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>OK Autrod EN/ AWS</td>
<td>EN / AW A5.17: F7A4-EM12</td>
<td>420 500 28 80 65 55 AW</td>
</tr>
<tr>
<td>12.20 S2 / EM12</td>
<td>S38 4 AB S2 A5.17: F7A4-EM12</td>
<td>-46˚C: 50J</td>
</tr>
<tr>
<td>12.22 S2Si / EM12K</td>
<td>S38 4 AB S2Si A5.17: F7A5-EM12-K</td>
<td>-46˚C: 50J</td>
</tr>
<tr>
<td>12.24 S2Mo; S Mo / EA2</td>
<td>S46 2 AB S2Mo A5.23: F8A4-EA2-A2</td>
<td>-29˚C: 50J</td>
</tr>
<tr>
<td>12.34 S3Mo; S MnMo / EA4</td>
<td>S50 3 AB S3Mo A5.23: F8A4-EA4-A4</td>
<td>-40˚C: 40J</td>
</tr>
</tbody>
</table>

Typical weld metal chemical composition (%), DC+

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.20</td>
<td>0.06</td>
<td>0.3</td>
<td>1.4</td>
</tr>
<tr>
<td>12.24</td>
<td>0.07</td>
<td>0.3</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Typical weld metal mechanical properties, DC+

<table>
<thead>
<tr>
<th>ReL / Rp0.2 (MPa)</th>
<th>Rm (MPa)</th>
<th>A4-A5 (%)</th>
<th>CVN (J at °C)</th>
<th>AW / SR</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>With OK Autrod</td>
<td>-18 -20 -29 -40</td>
<td>500 28 80 65 55</td>
<td>CVN at</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.20</td>
<td>420</td>
<td>520</td>
<td>26</td>
<td>130</td>
<td>110</td>
</tr>
<tr>
<td>12.24</td>
<td>495</td>
<td>580</td>
<td>25</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>12.34</td>
<td>540</td>
<td>630</td>
<td>25</td>
<td>70</td>
<td>60</td>
</tr>
</tbody>
</table>

For more information view the Product Data Sheets or contact ESAB.
OK Flux 10.87 is an agglomerated, low-basicity flux for submerged arc welding. It gives perfect wetting and excellent weld bead appearances in butt, overlap and fillet welds at high welding speeds.

OK Flux 10.87 is used for single and multi-wire procedures and works equally well on DC and AC current. It is intended for a limited number of passes and plate thickness up to 25mm.

The main application area for OK Flux 10.87 is in the production of air compressor tanks, LPG bottles and fire extinguishers. This flux gives a flat weld bead and an even, clean surface with excellent slag detachability, also when the second run has been pre-heated by the first run. Other industries with similar requirements also make use of OK Flux 10.87, including general construction and the automotive industry.

### Classification

<table>
<thead>
<tr>
<th>Wire</th>
<th>Weld metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>OK Autrod</td>
<td>EN / AWS</td>
</tr>
<tr>
<td>12.10</td>
<td>S1 / EL12</td>
</tr>
<tr>
<td>12.22</td>
<td>S2Si / EM12K</td>
</tr>
</tbody>
</table>

**Typical weld metal chemical composition (%)**, DC+

<table>
<thead>
<tr>
<th>Wire</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.10</td>
<td>0.05</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>12.20</td>
<td>0.05</td>
<td>0.8</td>
<td>1.0</td>
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<tr>
<td>12.22</td>
<td>0.05</td>
<td>0.9</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Typical weld metal mechanical properties, DC+**

<table>
<thead>
<tr>
<th>Wire</th>
<th>Rel / Rp0.2 (MPa)</th>
<th>Rm (MPa)</th>
<th>A4-A5 (%)</th>
<th>CVN (J at °C)</th>
<th>AW/SR</th>
</tr>
</thead>
<tbody>
<tr>
<td>With OK Autrod</td>
<td>+20</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.10</td>
<td>370</td>
<td>470</td>
<td>25</td>
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<tr>
<td>12.20</td>
<td>410</td>
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<td>345</td>
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<td>400</td>
<td>490</td>
<td>25</td>
<td>50</td>
<td>25</td>
</tr>
</tbody>
</table>

For more information view the Product Data Sheets or contact ESAB.
**OK Flux 10.18 + OK Band NiCu7**  
**NEW AGGLOMERATED FLUX DESIGNED FOR CLADDING WITH MONEL TYPE OF STRIPS.**

Agglomerated flux designed for strip cladding with Monel type strips. The flux is primarily designed for strip cladding with NiCu7-strip. This flux/strip combination gives good welding characteristics, smooth bead appearance and easy slag removal, with either 60 mm or 90 mm x 0.5 mm strips. Typical applications are found in desalination plants, chemical and petrochemical industry and pressure vessels.

**OK Flux 10.31 + OK Band 7018**  
**NEW FLUX STRIP COMBINATION FOR SUBMERGED ARC STRIP CLADDING WITH UNALLOYED CMn-STEEL STRIPS.**

Neutral, agglomerated, slightly molybdenum alloyed flux for strip cladding with unalloyed CMn-steel strips. This flux/strip combination gives acceptable weldability, excellent slag detachability with no residuals, with either 60 mm or 90 mm x 0.5 mm strips. Weld metal deposited in one layer on non-alloyed plate shows that the flux adds nominally about 0.4% Mo. The hydrogen content measured in accordance with EN ISO 3690, is max. 2.9 ml/100 g of weld metal. The flux is used for the repair and maintenance of shafts, pistons, repair of production errors, buffer layers, pressure vessels.

The table show that the weld metal analysis, performed under various welding conditions and up to 3 layers, does not significantly change the deposit analysis.

---

**Classification flux**  
**Basicity index**

<table>
<thead>
<tr>
<th>Classification flux</th>
<th>Basicity index</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 760 SA CS 2 DC</td>
<td>1.0</td>
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</tbody>
</table>

**Slag type**  
**Polarity**  
**Alloy transfer**

<table>
<thead>
<tr>
<th>Slag type</th>
<th>Polarity</th>
<th>Alloy transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium silicate SiO2- CaO-CaF2-(MnO-A2O3)</td>
<td>DC+</td>
<td>Molybdenum alloying</td>
</tr>
</tbody>
</table>

**Strip/ parameters**

<table>
<thead>
<tr>
<th>Strip/ parameters</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Ni</th>
<th>Cu</th>
<th>Fe</th>
<th>S</th>
<th>Al</th>
<th>Ti</th>
<th>Side bend test (4x1,180*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monel alloy 400</td>
<td>&lt;0.3</td>
<td>&lt;0.5</td>
<td>&lt;2.0</td>
<td>&gt;63</td>
<td>28-34</td>
<td>&lt;2.5</td>
<td>&lt;0.024</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AWS A5.11 NiCu7</td>
<td>&lt;0.15</td>
<td>&lt;1.5</td>
<td>&lt;4.0</td>
<td>62-69</td>
<td>Rem</td>
<td>&lt;2.5</td>
<td>&lt;0.015</td>
<td>&lt;0.75</td>
<td>&lt;1.0</td>
<td></td>
</tr>
<tr>
<td>NiCu7 (Monel) 60x0.5 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Strip</td>
<td>0.020</td>
<td>0.31</td>
<td>3.50</td>
<td>65</td>
<td>28</td>
<td>0.5</td>
<td>0.001</td>
<td>0.030</td>
<td>1.80</td>
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</tr>
<tr>
<td>AWS A5.14 NiCu7</td>
<td>&lt;0.15</td>
<td>&lt;1.25</td>
<td>&lt;4</td>
<td>62-69</td>
<td>Rem</td>
<td>&lt;2.5</td>
<td>&lt;0.015</td>
<td>&lt;1.25</td>
<td>1.5-3.0</td>
<td></td>
</tr>
<tr>
<td>750A/29V 14 cm/min so 25-30 mm</td>
<td>Layer 1</td>
<td>0.029</td>
<td>1.0</td>
<td>3.0</td>
<td>Rem</td>
<td>23</td>
<td>17</td>
<td>0.002</td>
<td>0.04</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Layer 2</td>
<td>0.016</td>
<td>1.1</td>
<td>3.2</td>
<td>Rem</td>
<td>26</td>
<td>6.4</td>
<td>0.001</td>
<td>0.04</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>Layer 3</td>
<td>0.013</td>
<td>1.1</td>
<td>3.4</td>
<td>Rem</td>
<td>28</td>
<td>2.4</td>
<td>0.001</td>
<td>0.08</td>
<td>0.31</td>
</tr>
</tbody>
</table>

* NR: No remarks

The test plate chosen was a non-alloy grade (C ~ 0.10-0.12%, Mn ~ 1.1% and Si ~ 0.3%).

**Classification flux**  
**Basicity index**

<table>
<thead>
<tr>
<th>Classification flux</th>
<th>Basicity index</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 760 SA CS 3 Mo DC</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Slag type**  
**Polarity**  
**Alloy transfer**

<table>
<thead>
<tr>
<th>Slag type</th>
<th>Polarity</th>
<th>Alloy transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium silicate SiO2-MgO-A2O3(CaF2)</td>
<td>DC+</td>
<td>Molybdenum alloying</td>
</tr>
</tbody>
</table>

**Layer**

<table>
<thead>
<tr>
<th>Layer</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Ni</th>
<th>Cu</th>
<th>Fe</th>
<th>S</th>
<th>Al</th>
<th>Ti</th>
<th>Side bend test (4x1,180*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>750A-28V-12cm/min</td>
<td>850A-24V-13cm/min</td>
<td>1150A-28V-15cm/min</td>
<td>Strip Analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Layer 1</td>
<td>0.074</td>
<td>0.072</td>
<td>0.070</td>
<td>0.073</td>
<td>0.070</td>
<td>0.068</td>
<td>0.071</td>
<td>0.065</td>
<td>0.064</td>
<td>0.10</td>
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<tr>
<td>Layer 2</td>
<td>0.34</td>
<td>0.36</td>
<td>0.41</td>
<td>0.36</td>
<td>0.41</td>
<td>0.43</td>
<td>0.40</td>
<td>0.42</td>
<td>0.26</td>
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<tr>
<td>Layer 3</td>
<td>0.21</td>
<td>0.09</td>
<td>0.09</td>
<td>0.31</td>
<td>0.13</td>
<td>0.15</td>
<td>0.32</td>
<td>0.14</td>
<td>0.12</td>
<td>0.38</td>
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<tr>
<td>Layer 4</td>
<td>0.020</td>
<td>0.023</td>
<td>0.024</td>
<td>0.017</td>
<td>0.020</td>
<td>0.021</td>
<td>0.017</td>
<td>0.021</td>
<td>0.022</td>
<td>0.014</td>
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<tr>
<td>Layer 5</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Layer 6</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.04</td>
<td>0.05</td>
</tr>
<tr>
<td>Layer 7</td>
<td>0.06</td>
<td>0.06</td>
<td>0.07</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>Layer 8</td>
<td>0.51</td>
<td>0.61</td>
<td>0.66</td>
<td>0.36</td>
<td>0.48</td>
<td>0.49</td>
<td>0.35</td>
<td>0.54</td>
<td>0.59</td>
<td>0.00</td>
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<tr>
<td>Layer 9</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

**Hardness**

<table>
<thead>
<tr>
<th>Hardness</th>
<th>186</th>
<th>187</th>
<th>196</th>
<th>174</th>
<th>188</th>
<th>186</th>
<th>186</th>
<th>178</th>
<th>185</th>
</tr>
</thead>
</table>

**Bead height**

<table>
<thead>
<tr>
<th>Bead height</th>
<th>3.9</th>
<th>4.0</th>
<th>4.5</th>
</tr>
</thead>
</table>

**OK Band 7018, 90x0.5mm, 1000A/30V/13cm/min.**
New ESAB cored wire technology outperforms solid wire with respect to quality and productivity.

OK Tubrod 14.11 in diameter 1.2mm is the first of a new generation of cored wires based on ESAB’s revolutionary cored wire surface technology. It has been developed for the welding of thin-plate with a minimum thickness of 1.0mm and provides fabricators with a substantially faster and higher quality welding solution to 1.0 and 1.2mm solid MAG wire. OK Tubrod 14.11 is a unique product that markedly lowers the welding costs for mechanised and robotised fabrication.

The many advantages relative to solid wire relate to the extremely wide spray arc parameter envelope that begins as low as 160A. With solid wire spray arc starts at around 200A for diameter 1.0mm and 230A for diameter 1.2mm. These features are valid for the standard shielding gas M21 (Ar/15-25% CO2), although optimal results are obtained in 92%Ar/8%CO2 mixtures.

Changing from solid wire to OK Tubrod 14.11 will in most cases, require no changes in the positioning of the welding gun so the conversion time is limited to the adjustment of welding parameters.

OK Tubrod 14.11 is available in MarathonPac bulk drums for major downtime savings compared with using standard 300mm spools.

Faster welding

The majority of thin plate applications are welded with solid wire in the short arc or globular arc mode at moderate travel speed because high travel speeds in spray arc results in a deterioration of weld quality. With OK Tubrod 14.11 travel speeds of 150-250 cm/min. are perfectly feasible as shown in the tables for fillet and overlap welds. This difference in travel speed is equally valid for curved and circumferential welds.

Low spatter

OK Tubrod 14.11 1.2mm operates in the spray arc mode at a current level as low as 160A enabling thin plate to be welded with very low spatter levels compared with solid wire welded in the short arc or globular arc mode, resulting in the elimination of post weld cleaning. An additional advantage is that OK Tubrod 14.11 does not require the use of expensive pulsed power source technology.

An important feature is the ease of spray arc parameter setting. The voltage for thin-plate welding in spray arc is 22 - 24V for the entire range of wire feed speeds, from 7 to 14 m/min.

The excellent restriking characteristics of OK Tubrod 14.11 also promotes low-spatter welding for components with many short welds. A stable arc establishes almost instantaneously after the arc is initiated.

Welding in spray arc generates more silica islands necessitating post weld cleaning for applications with cosmetic requirements. The islands however tend to appear in the center of the weld surface making them easier to remove.

Penetration and tolerance to poor fit up.

OK Tubrod 14.11 gives a high quality weld penetration profile. OK Tubrod 14.11 is also very forgiving with respect to poor fit-up, bridging gaps even at very high travel speeds - resulting in less post weld repair work and less rejects.

Low heat input welding

The extremely low arc voltage combined with a very high travel speed results in a relatively low heat input. Associated with this are fewer problems with workpiece deformation commonly found when welding with solid wires using the pulsing technique. Fillet welds in the PB (2F) position in 1.5mm plate can be welded at travel speeds in excess of 200cm/min resulting in heat inputs as low as 0.2kJ/mm. Overlap welds using the same plate thickness can be welded at speeds up to 160cm/min.

Compared to solid MAG wire, OK Tubrod 14.11 1.2mm offers:

- Faster welding speeds
- Increased productivity
- Less deformation
- Excellent gap bridging
- Less spatter
- Lower repair/reject rates
VacPac gets slimmer

ESAB’s new slim outer carton for vacuum-packed stainless and nickel-base MMA electrodes brings you the same high level of protection and quality you are used to, but in more practical quantities that will keep your stock value low.

ESAB stainless steel and nickel-base electrodes, up to diameter 3.2mm and in the lengths 300 and 350, are now standard packed in a new slim outer carton containing three half VacPac’s or six quarter VacPac’s, dependent on the electrode diameter. This provides a number of advantages.

- **ECONOMIC ORDERING VOLUMES**
- **LOWER STOCK VALUE**
- **LESS RISK OF TRANSPORT DAMAGE**
- **EASIER TO HANDLE**

One of the main advantages is the more convenient and economic ordering volume for high value MMA electrodes in smaller dimensions. The average outer carton weight is reduced to approximately 4 kilos. This means a more acceptable quantity of electrodes, tying up less capital in stocks of slower moving consumables.

The strong outer corrugated carton provides good protection for the vacuum packages during transport and storage. The lighter weight makes these packages easier to handle.

Stainless steel and nickel-base electrodes above the diameter 3.2mm continue to be supplied in the current larger outer boxes containing four 3/4 size VacPacs. The new outer carton represents the smallest delivery unit available. Please contact ESAB for the full overview of MMA electrodes available in the new slim outer box.