F. M. Knoop, C. Boppert and W. Schmidt, Salzgitter, Germany, discuss the production, use and development of Helical Seam Two Step (HTS) pipes.

Salzgitter Großrohre GmbH (SZGR), a 100% subsidiary of Salzgitter AG, is considered to be a worldwide leader in the production of spiral-welded large-diameter pipes. Four decades of close co-operation with the affiliated company Salzgitter Flachstahl GmbH (SZFS) as supplier of coils, as well as the ongoing research and development work of the Salzgitter Mannesmann Forschung GmbH (SZMF), have led to the availability of excellent hot-rolled wide strip pipes with outstanding mechanical and technological properties for the production of large diameter pipes.

In March 2008, SZGR, in co-operation with its sister trading company Salzgitter Mannesmann
Figure 1. Conventional spiral-welded pipe manufacturing.

Figure 2. Two-step spiral-welded pipe manufacturing process.

International GmbH (SMID) based in Düsseldorf, obtained an order to deliver 420 km of spiral-welded pipe with a diameter of 1067 mm for one of the largest gas pipeline projects in the USA, the Rockies Express Pipeline (REX). The demanding production parameters for the pipe, as well as the external Fusion Bonded Epoxy (FBE) coating applied for the first time during the manufacturing process, required close co-operation between all parties, taking into consideration the tight delivery dates and project logistics in the USA.

The current development of the line pipe market is characterised by widespread new construction of oil and gas pipelines worldwide. Thus, the sudden strong demand for high-quality line pipe, despite its being predicted for a long time, resulted in full utilisation of existing pipe and steel capacities. Long-term plant utilisation by leading steel pipe manufacturers at full capacity and the increased revenue of steel pipe has given rise not only to the expansion of existing, but also the building of new, manufacturing capacities. A substantial number of new competitors and pipe manufacturing plants have now modified the structure of the market, a structure that had been considered stable for a long time.

Against this background, a pipe type that many users considered to be of lesser importance now appears in the spotlight. Reservations against spiral-welded pipe do not arise from the pipe type and its production, but rather result from insufficient manufacturing, performance testing and quality standards of existing spiral-welded pipe plants, combined with lack of experience and an insufficient qualification of responsible staff members. The industrial production of spiral-welded pipe is a truly American development. In the first half of the 20th century, the historically-applied process of simultaneous forming and welding resulted in some problems, through the use of pipe that was produced by applying insufficiently-mastered welding processes or that sometimes was only welded on one side.

The so-called two-step process is a technology that has aided considerably the growing acceptance of spiral-welded pipe. This process, developed in Germany and applied by Salzgitter for more than 20 years, is characterised by some fundamental benefits in the effectiveness of the process and the pipe quality. These advantages justify the general distinction between this process and the conventional process used for the manufacture of spiral pipe.

Steel pipes for long distance pipelines, with a diameter of more than 600 mm, are produced either as longitudinally or helically-welded pipes by applying the submerged-arc welding process. Apart from the different manufacturing processes, the main difference between both pipe types results from the type of raw material used. Steel plates are used for longitudinal-seam large diameter pipes, which are produced by the three-roll bending process, the UOE method, or by using C-frame presses. However, for the production of spiral-welded pipes, hot-rolled wide strip is continuously shaped to form a pipe. While the production of UOE pipe requires huge capital expenditure for the manufacturing plant, spiral-welded pipe plants are becoming more common all over the world, due to their relatively low investment cost and simple manufacturing process. Yet, the majority of these pipe manufacturing plants are only fitted with very
basic manufacturing and testing systems that are not suitable for the production of high-pressure line pipes, but could well be used for piling pipe, for instance, and for the construction of water pipelines under moderate performance conditions.

Consequently, many operating companies of gas or oil pipelines had doubts or reservations about the usage of spiral-welded pipes, and some totally refused them. In contrast, SZGR has produced high quality large diameter pipes for international on and offshore pipeline projects for more than 40 years. The pipe manufacturing plant in Salzgitter was originally built in 1959 as a conventional manufacturing plant for spiral-welded pipe (Figure 1) in which pipe forming and welding are performed in a one-step process.

The HTS process

Building on the experience gained with the production of spiral-welded pipe since 1959, SZGR introduced a manufacturing process called the HTS process in 1987 and has been continuously improving it ever since. The two main process steps can be described as follows:

Pipe forming combined with continuous tack welding

The hot-rolled wide strip is formed into a pipe in the pipe-forming machine. This forming unit consists of a

three-roll bending system with an outside roller cage, as illustrated in Figure 3. The function of the roller cage is to set the pipe axis and guarantee the roundness of the pipe.

In the forming unit, the converging strip edges of the pipe are joined with a continuous-shielded-arc tack weld. As the continuously-tack-welded pipe leaves the forming machine, a plasma cutter moving with the tube cuts the individual lengths required by the customer. Tack welding is carried out automatically and by means of a laser-guided welding head. To optimise the pipe and weld gap geometry, the run-out angle is also permanently controlled and adjusted by an automatic gap control system. Any changes in the coil width because of variations in the coil dimensions before or after milling do not affect the final pipe geometry.

Internal and external submerged arc welding on separate welding stations

The formed and continuously-tack-welded pipes are then subsequently fed into one of the three computer-controlled, internal/external submerged-arc welding stations for final welding (Figure 4). Each pipe rotates on a special roller table with a precise screw-like motion while submerged-arc welding is carried out — first internally, then externally, with a multi-wire technique. A laser-controlled seam tracking system guarantees exact positioning of the weld seam with optimised overlapping and penetration of the weld. The tack weld made during the pipe-forming stage serves as a backing for the weld and is fully melted again.

Process development and automatisation

As a result of the separation of the pipe forming and the considerably slower submerged-arc welding process, one production bottleneck of conventional manufacturing could be avoided. Both process steps can be optimised without affecting each other. Close tolerance values are achieved by concentrating on the pipe geometry within the pipe-forming machine without being influenced by the submerged-arc welding process. Today, pipe-forming velocities of up to 12 m/min are actually possible. Refined power sources in welding to achieve pipe-forming velocities of up to 15 m/min are presently in experimental stages.

In addition to process velocity, the improved stability of the welding processes is an important advantage of the two-step technique. Unlike the conventional process, interruptions or failures during pipe forming do not necessarily result in defects in submerged-arc welded seams. Weld seam repairs or cracks due to edge movement during the forming process are excluded. With high wall thicknesses in particular, process stability and precision are much higher.

All welding processes, including automatic weld seam renewal, are digitised. Production-related quality
data and parameters of pipe forming, welding, non-destructive testing, as well as data originating from pipe coating and mechanical and/or chemical tests, are acquired, recorded and archived in an integrated data system.

An automatic pipe-diameter-measuring system is currently in its introductory phase. As a result of this system, it is possible to record the pipe diameter and ovality in a large-pipe manufacturing plant and to use them for control purposes for the first time.

Although this process has existed for more than 20 years, even today only few manufacturers master this process. On a worldwide basis, SZGR is considered to be a leader in areas of technology and quality in this field, specialising in the production of line pipes for demanding gas and oil pipeline projects. Essential points of the philosophy pursued by Salzgitter are the consequent introduction, usage and continuous development of the latest automated manufacturing and testing methods, together with an emphasis on product quality. This reputation has been considerably strengthened through a unique and exclusive orientation towards the production of pipe for high-pressure pipe lines compared to all other spiral-welded pipe manufacturers.

Worldwide acceptance of HTS pipes

SZGR supplies all important operators of high-pressure pipeline networks in the European core market, where the highest possible safety is required due to high population density. Long-term delivery agreements and successfully passed qualification procedures, often extended over several years, are the basis of this high acceptance in Europe. As a consequence of many supplies for pipeline projects in Africa, Asia, South America, and at present in the USA, this acceptance could also be obtained in the remainder of the global markets. Deliveries to the North American market for the Rockies Express Pipeline and the Louisiana LNG...
Pipeline are current examples of successful utilisation of HTS pipes from S2GR.

**Current projects in the US market**

In the US, the Rockies Express Pipeline for transporting natural gas, is currently being built with a total length of approximately 2700 km and an estimated cost of more than US$ 4.8 billion. After its completion in June 2009, more than 51 million m³/d of gas will be transported through this pipeline from natural gas sources in Wyoming in the west to Ohio in the east of the US. The REX pipeline (Figure 6) is the largest pipeline under construction in the USA for more than 20 years. Initiator, part owner and operator of the pipeline is Kinder Morgan, which is thus responsible for one of the longest pipeline networks in North America. At the same time, Kinder Morgan is building another pipeline in the south of the US. The Louisiana LNG pipeline, will supply more than 57 million m³/d of gas over a distance of 185 km into the pipeline networks of different gas transporting companies, starting from an LNG terminal (Liquefied Natural Gas). Cost estimates for this project amount to more than US$ 500 million. Commissioning of the pipeline is planned for Q1 2009.

The order amounted to 420 km of large diameter pipes with a diameter of 1067 mm, and wall thicknesses between 14.1 and 18.8 mm. This corresponds to approximately 170 000 t. During the course of awarding the contract, Kinder Morgan also placed an order for the Louisiana LNG Pipeline, which is located in the south of the US and has a total length of 185 km.

**Project logistics – loading and transport**

The pipes for the REX project were transported by train from Salzgitter to Bremen and by ship from Bremen to Toledo on the Great Lakes. The pipe was handled by suction traverses in order to avoid loading damage that could have occurred by conventional loading and unloading of the pipe with lifting hooks. This refers to all loading and unloading in Salzgitter and Bremen. Figure 8 shows the pipe transport from the temporary storage facility in the harbour in Bremen (Neustädter Hafen) into the ship’s hatch. All pipes were protected by separators at the pipe body and end protector rings at the pipe ends, so as to avoid damage during transport and handling. Figure 7 shows the pipe being transported by train to Bremen. Four trains with 25 railroad cars and 125 pipes each were shipped per week. This corresponds to 500 pipes, or a 8.8 km per week.

The marine transport of the pipe to Toledo had to be carried out with ‘Lakers ships’. This type of ship is able to navigate the St. Lawrence Seaway locks leading into the Great Lakes. There are only seven of these ships in existence. Five of them have been chartered as a shuttle service by SMID, which is responsible for the marine transport. Due to their construction type, the loading capacity of these ships is limited to 1171 pipes with a pipe diameter of 1067 mm. Due to seasonally-restricted navigability of the Great Lakes, transportation logistics were made more difficult. The cargo could only be shipped into the Great Lakes during ice-free months, e.g. between the end of March and the beginning of November. However, if the customer’s request, and with regard to the dates and volume of delivery stipulated by contract, the pipe was continually produced during the winter months despite the restrictions on shipment. In order to assure continuous delivery during the ice-free months, the pipe was stored in the meantime either at the storage facility in Salzgitter or in Bremen.

**Experience in pipe laying and installing the pipes**

After unloading in Toledo, the pipe was temporarily stored in the harbour area and then transported by rail to the building site. Both the company laying the pipes and the final customer highly complimented the quality of pipe geometry, the pipe’s weldability and flexibility, as well as the quality and robustness of the pipe coating. Automated welding processes are mainly used for welding the circumferential seams. The pipes were judged to be extremely regular and reliable for the production of cold bends. The existing geological profile along the surveyed pipeline route...
required a vast number of cold bends. Total angles of bending of up to 30° for pipes having 18 m in length could be realised (Figure 9).

Not withstanding all of the repeated handling of the pipe in the manufacturing plant during loading and transport by rail, ship and truck, and during storage in the harbour areas and in the pipe storage facilities, the FBE-coated surfaces remained in top condition. Major damage could be avoided because of the precautionary measures taken for pipe handling and of the high quality of the Akzo Nobel material (Resicoat R 726).

The consistency of the material, the coating and the geometrical properties, such as pipe diameter, ovality and average pipe length, were important factors for achieving the total construction progress and for staying on the total time schedule. Therefore, the economic advantage is obvious when taking the estimated daily costs for the pipeline construction of more than US$ 1 million into consideration. HTS pipes from Salzgitter were also used in the field for special building structures like river crossings.

Present and future developments

The successful utilisation of HTS pipe for pipeline projects in the US is once again evidence of the worldwide acceptance of this type of pipe. Due to

the obvious qualitative and economic advantages, six new two-step pipe manufacturing plants are actually at the planning stage or under construction worldwide. With regard to the great relevance of environment and safety aspects of line pipes, particular importance is attached to the experience and qualification of the personnel concerned in addition to the basic process engineering.

As evidenced by current development projects and research, certainly neither the process nor the product development has come to an end. In addition to the measures already mentioned to increase pipe forming velocity, work continues to optimise pipe geometry, which is actually already considered to be excellent, and the limitation of production tolerances. Further, automated quality controls and process regulation, as well as the usage of finite element methods to provide a better understanding of forming and manufacturing procedures, provide starting points for future improvements (Figure 11).

The potential of HTS pipes is documented by collapse tests performed on HTS pipes, giving impressive proof that product characteristics having equal or even better quality than the ones of longitudinal-seam or seamless large-diameter pipes can be achieved, provided that the applied processes are well mastered.}

References

1. The Iron Age, Spiral Weld Tube Machine; March 1, 1888, 359-360.