Customizing of
RH DEGASSING TECHNOLOGY
demonstrated by examples in Russia

SMS MEVAC
Secondary Metallurgy

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Russia is the biggest steel producer in Europe. The pressure is high on Russia’s steel industry to follow the strict market demands for quality and economy in steel production. Big investments for revamping of existing units or erection of new units for ladle refining of liquid steel are the imperative consequences. Together with SMS Mevac ladle metallurgical units have already been implemented for 40 years. Four new RH units, embedded in different production lines and with different metallurgical tasks, are described as examples of this.

INTRODUCTION

Russia is one of the biggest steel producers in the world. The big advantage of the Russian steel industry is the fact that production costs are low because Russia can independently provide all raw materials for steel production from its own resources. During the last few years, Russian steel companies implemented ambitious investment projects to optimize material and energy consumption and to increase the product quality.

Since 2000 there has been a rapidly increasing world-wide demand for steel and especially vacuum treated steel grades like ULC steels, pipe grades, transformer plates and steels for the automotive industry. Hence, the number of vacuum installations in Russia has increased continuously, figure 1. Until today the SMS group has erected, revamped or gained contracts for additional ten vacuum units of different types as well as seven ladle furnaces (LF) and several ladle treatment stations (LTS). So since 1972, in total 36 ladle metallurgical units have been successfully executed in Russia leading to nearly 40 years cooperation in this field. Currently around 30 units for steel refining under vacuum are operating in Russia – with a growing tendency, because the share of vacuum treated steel rises in Russia as well as everywhere in the world.

RECENT RH PROJECTS

Between 2007 and 2011, four different RH units were erected by SMS Mevac at Nizhniy Tagil Iron and Steel Works (NTMK), Oskol Electrometallurgical Plant (OEMK), Magnitogorsk Iron and Steel Works (MMK) and Novolipetsk Steel (NLMK), table 1. These four steel producers had already many years of experience in the field of RH (most of them also in DH) technology. The new RH units are the second or third RH unit for them.

One design item is common with all of these units: Immersion of the snorkels into the heat is by vessel lifting actuated by a hydraulically moved rocker arm with a counterweight. In Russia this principle of vessel lifting is very popular and was applied to all the DH and RH units supplied by SMS Mevac. The advantage versus the conventional ladle lifting with a bottom ram cylinder is that there is no sensitive hydraulic equipment below the steel ladle which might be damaged in case of a steel breakout.

Meanwhile SMS Mevac has transferred the rocker arm principle to ladle lifting and developed the so called “ladle rocker”. Here the ladle is hydraulically lifted to the vessel by a rocker arm with a counterweight also without any hydraulic equipment being located below the treated ladle.
Within the ranges of both long and flat products, the key products are rail steel, semi-finished products for pipe steels and steels for the railway industry, e.g. for train wheels and tires [3, 4]. Because of the huge deposits of vanadium-enriched ores located close to Nizhniy Tagil, an additional product is vanadium-enriched slag, which forms the raw material for the production of ferro-vanadium.

With a nominal heat size of 160 t, the steel plant has an annual production capacity of up to 5 million t. The older RH unit was commissioned in 1996, the new RH unit in 2007. The latter is designed for a maximum annual capacity of 1.5 million t – an additional share of vacuum treated steel of 30% for NTMK. The share of vacuum treated steel at NTMK is currently around 45%.

DUPLEX VESSEL RH PLANT AT NTMK

Located in the Central Ural, Nizhniy Tagil Iron and Steel Works (NTMK), which was founded in 1934, is an integrated steel plant being a 100% subsidiary of the EVRAZ group. The production line consists of the following processing units [2]:

- four BOFs
- three ladle furnaces,
- one single RH station,
- one duplex RH station,
- four-strand bloom caster,
- two-strand beam blank caster,
- combined slab/bloom caster (2/4 strands),
- single-strand slab caster.

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Concept. Based on more than 15 years of experience with batch type degassers, also the new one is an RH type. Though pipe steel grades, which are a key product at NTMK, are commonly produced via process routes involving tank degassers, NTMK prefers the LF-RH process route because, on the one hand, the requested final sulphur contents of max. 0.005% can be reliably realized by their ladle furnaces; on the other hand, especially for the degassing treatment of rail steels and other semi-killed steel grades, the RH technology is advanta-
geous because of the large reaction chamber, which can do without a big freeboard as in tank degassers. This has a positive effect on productivity.

One reason for installing a duplex vessel RH degasser was that the maximum daily capacity for the new RH unit is required to be at least 27 heats. Another reason was the negative experience with the refractory life of the first RH degasser. Having only one treatment position available resulted in the blocking of the vacuum degasser. To comply with these demands, the concept of a duplex vessel RH degasser was implemented for NTMK. Figure 2 illustrates the principle of the new RH unit at NTMK. As this RH unit was to also offer the possibility of treating ultra-low carbon steel grades (ULC), both vessels were equipped with SMS Mevac’s multi-functional TOP lances which can either blow oxygen for adjusting the carbon-oxygen relation for decarburization treatments or maintain the required vessel temperature by operating in the burner mode.

Key technical parameters of this plant are as follows:

- inner snorkel diameter: 550 mm,
- deep vacuum: 550 kg/h at 0.67 mbar,
- TOP lance maximum oxygen blowing capacity: 1,500 m³/h (stp),
- hydrogen content after degassing: max. 1 ppm,
- treatment capacity: a minimum of 9 heats within 8 hours.

SINGLE VESSEL RH PLANT AT OEMK

OEMK, the Oskol Electrometallurgical Plant, being erected in the early 1980s, is situated in the area of a unique iron ore deposit, the Kursk Magnetic Anomaly, about 600 km south of Moscow. OEMK is an electric steel plant and a 100% subsidiary of the Metalloinvest Holding. Instead of scrap, the electric arc furnace is charged with DRI – metallized pellets generated by the Midrex direct reduction process in a nearby DRI plant. This is the biggest production complex of this type in Europe. The production line consists of the following processing units [5]:

- four EAFs,
- three ladle furnaces,
- three single RH stations,
- four 6-strand billet casters,
- one 4-strand bloom caster.

The key products are bearing steels, semi-finished products for pipe steels, wire rod, spring steels and...
automotive grades [6]. With a nominal heat size of 160 t, the steel plant has an annual production capacity of up to 3 million t.

The older RH units were erected by SMS Mevac in 2003 and 2004. They had originally been DH units supplied by SMS Mevac in 1984. By the stepwise modification of the vessels, vessel heating systems and vacuum pump systems, they had been revamped to the RH process. The new RH unit was commissioned in 2008. This unit is designed for a maximum annual capacity of 1.1 million t, i.e. an additional share of vacuum treated steel of more than 30%.

Concept. The decision in favour of a single vessel RH unit was made for several reasons. First, the maximum daily capacity for this RH unit was required to be only around 20 heats per day. Therefore, the concept of a single vessel RH degasser was deemed to be sufficient for OEMK. Second, as the customer had more than twenty years of successful experience with batch type degassers, the new process line and the ladle and refractory management were aligned accordingly. Third, the alternative tank degasser concept would not have provided a real advantage because the main task of vacuum treatment at OEMK is the removal of hydrogen. And here the batch type degassers had already been providing excellent results.

Achieving extremely low sulphur and nitrogen contents, starting from high initial values as in other EAF plants, is also not required at OEMK because of the cleaner metallized pellets used as charge material. Each RH unit works in line with an upstream ladle furnace and a downstream ladle treatment station for stirring and wire feeding. All positions can easily be reached by a ladle transfer car.

**Figure 3** shows the principle of a single vessel RH unit. A single vessel unit has one treatment position usually served by one ladle transfer car. The vessel is connected to an alloy addition system and the vacuum pump system. As this RH unit is only intended to be used for degassing treatments, it is only equipped with an atmospheric burner lance to heat up the vessel or keep it at the required temperature. Vessel change can be done by crane or using the vessel lifting equipment. A complete vessel is typically exchanged within about 90 minutes. For snorkel maintenance, a maintenance car is provided.

Key technical parameters of this plant are as follows:
- inner snorkel diameter: 460 mm,
- deep vacuum: 500 kg/h at 0.67 mbar,
- hydrogen content after degassing: max. 1 ppm.
DUPLEX VESSEL RH UNIT AT MMK

Being situated in the southern part of the Ural Mountains, Magnitogorsk Iron and Steel Works (MMK) is an integrated steel plant and one of the biggest steel producers in Russia. The company was founded in 1929. The first tap was in 1932. The production line in the BOF plant consists of the following processing units:

- three BOFs,
- two twin-ladle furnaces,
- one single ladle furnace
- one single RH station,
- one duplex RH station,
- four 1-strand slab casters.

MMK operates an additional EAF meltshop to produce long products. However, the key products are pipe steels and other medium and heavy plates. With a nominal heat size of 370 t in the BOF shop (and 180 t in the EAF shop), the steel plant has an annual production capacity of up to 14 million t of crude steel.

The single RH unit was commissioned as early as in 1996 [7]; the new duplex RH unit was commissioned in 2010 together with a new twin ladle furnace, which was also supplied by SMS Mevac.

Concept. The steel grades treated in RH unit No. 2 are mainly pipelines grades to feed the new plate mill which started operation end of 2009. Figure 4 illustrates the principle of the new RH unit. As this RH unit was intended to also offer the possibility to treat ULC steel grades, both positions were equipped with multifunctional TOP lances for oxygen blowing and burner applications.

At MMK, the duplex vessel RH unit and its two treatment positions work directly in line with the twin ladle furnace positioned upstream, figure 5 and a ladle treatment station for each line arranged downstream. Each of the two lines is served by two ladle transfer cars. Each car can reach any position of the respective line in order to prevent intermediate handling by crane.

The refining of steel grades for pipelines starts with heating, pre-alloying and desulphurization steps including powder injection, if required, at the ladle furnace. After that, the ladle is transferred to RH for degassing...
and final alloying, and from there to the LTS for calcium treatment. In case very low final sulphur contents must be achieved starting from high initial values, a deslagging station is available close to the ladle furnace.

For line-pipe grades or other heavy plates another concept is more commonly used. These grades are usually produced by means of a tank degasser, especially if ultra-low sulphur contents are required. But it must be considered that MMK has ladle contents of around 370 t which means that for sufficient bath stirring and metal slag reaction at least three porous plugs are required. At MMK there are already two slide gates at the ladle, and therefore only two quadrants are available for porous plugs.

Nevertheless, it is possible to produce all pipe grades with the here described RH process line. This avoids the disadvantages of a tank degasser, as for example a high freeboard, increased ladle erosion, higher temperature losses, shorter cycle times, etc. Additionally, the RH degasser offers the possibility of achieving ultra-low carbon contents, if required for other products in future.

Key technical parameters of this plant are as follows:
- Inner snorkel diameter: 750 mm,
- Deep vacuum: 1,200 kg/h at 0.67 mbar,
- TOP lance maximum oxygen blowing capacity: 3,800 m³/h (stp),
- Hydrogen content after degassing: max. 1.5 ppm,
- Nitrogen content after degassing: max. 50 ppm,
- Carbon content after decarburization: max. 20 ppm.

Figure 6. Schematic illustration of the duplex vessel RH unit at NLMK.
DUPLEX VESSEL RH UNIT AT NOVOLIPETSK STEEL

With a share of around 15% of the Russian steel production, Novolipetsk Steel (NLMK) is the third biggest Russian steel producer. The main production facility is located in the city of Lipetsk, about 500 km southeast of Moscow. The company was founded in 1931, and the first tap was in 1934. The production lines in the two BOF shops consist of the following processing units:

- three 180 t BOFs at converter shop No. 1,
- three single-ladle furnaces
- one single RH station,
- two 2-strand slab casters,
- three 320 t BOFs at converter shop No. 2,
- two single-ladle furnaces
- one duplex RH station,
- three 2-strand slab casters.

NLMK’s key flat products are hot and cold rolled coils and especially grain-oriented and non-oriented SI-steel sheets for electrical applications like transformer grades and dynamo grades. NLMK covers 9% of the global amount of these grades and 75% of the local production.

With a nominal heat size of 320 t in the BOF shop No. 2 and 180 t in the BOF shop No. 1, the steel plant has an annual production capacity of up to 9.4 million t of crude steel. The first 180 t RH unit was already supplied by SMS Mevac in 1985 and revamped in 2005. The new RH unit No. 2 from SMS Mevac was commissioned in 2011. This RH unit is designed for a minimum annual capacity of 4.3 million t.

Concept. The steel grades to be treated in RH unit No. 2 are mainly low carbon and ultra-low carbon grades including electrical sheets with silicon contents of more than 3%. With this metallurgical task, a RH degasser is for sure the optimum solution because ultra-low carbon contents can be achieved in shortest treatment times and huge amounts of alloys can be added in a precisely controlled manner via a vacuum lock with a vibratory feeder. As the maximum daily capacity for this RH unit is required to be at least 39 heats, a duplex vessel system similar to that at MMK was selected. Figure 6 shows the principle of the new RH unit. Both vessels were equipped with multifunctional TOP lances.

At NLMK the duplex vessel RH unit and its two treatment positions work directly in line with an upstream ladle treatment station. After the RH treatment the ladles are transferred by crane to one of the three continuous slab casting machines. Each of the two lines is served by one ladle transfer car.

The ladle furnace units are located in the BOF bay for ladle refining of other steel grades, e.g. for pipelines and shipbuilding. From there the ladle is transferred to the RH unit for degassing and final alloying, if required. Finally at the ladle treatment station, Ca treatment and addition of insulation material takes place. Heats requiring only slight treatment or decarburization are usually supplied directly to the RH.

Key technical parameters of this plant are as follows:
- inner snorkel diameter: 750 mm,
- deep vacuum: 1,150 kg/h at 0.67 m bar,
- TOP lance maximum oxygen blowing capacity: 3,200 m³/h (stp),
- hydrogen content after degassing: max. 1.5 ppm,
- carbon content after decarburization: max. 15 ppm.

SUMMARY AND COMPARISON OF PLANTS

Whereas all the above described plants using the BOF route have duplex vessel RH units, the EAF plant at OEMK has a single vessel RH unit. The reason is that the tap-to-tap time in BOF plants is usually in the range of 30 – 35 minutes or even less than 30 minutes and therefore shorter than the EAF which is nowadays usually between 45 – 60 minutes. Only a duplex unit can keep pace with the BOF tap-to-tap times, whereas the EAF tap-to-tap times only require a single unit.

Regarding the metallurgical targets, all the RH units certainly fulfil both degassing, i.e. removal of hydrogen and nitrogen, and decarburization with the same level of performance. Additional tasks like adjustment of temperature and analysis, homogenization or vessel heating can also be executed equally by all types of RH. The possibility of oxygen blowing for forced decarburization or chemical heating depends on the type of TOP lance. At OEMK, a pure long steel producer, decarburization is not required, and for heating up of steel sufficient LF capacity is available. All other units are equipped with
multifunctional TOP lances which can blow oxygen under vacuum for metallurgical purposes.

The vessels are usually of the block type with welded snorkels. Only at MMK, a split type vessel with separated upper and lower vessel was supplied according to the customer’s request. Also in this case the snorkels are welded to avoid leakages and accelerated refractory erosion. The outer diameter of the vessel and the inner diameter of the snorkels are limited by the respective ladle refractory dimensions. Therefore also vessels or snorkels for the same ladle content can have differing dimensions. For the vessel height, the required metallurgical tasks are decisive. Units where the main task is degassing have a smaller total height than those where decarburization is the main job.

The capacity of the vacuum pump system at different pressure levels is determined by the heat size and the metallurgical tasks of the RH unit. The type of the vacuum pump depends on the availability of steam. Usually at BOF plants a sufficient amount of steam can be supplied to operate a 4-stage steam ejector system without water ring pumps, whereas EAF plants normally have a lack of steam, making a combination of steam ejectors and water ring pumps with reduced steam consumption the preferred solution. As shown in table 1 there is one exception. The reason for having a steam ejector system without water ring pumps at OMEMK is that there two vacuum units have already been in operation for many years and the existing steam capacity has recently been expanded to compensate for the steam demand of the new RH unit. At the three BOF plants, the steam generated by the BOF shop is either not available all the time in stable conditions to feed both the existing and the new vacuum unit or is needed for other purposes, e.g. district heating. At MMK a steam boiler had to be installed to have at least enough steam for the combined vacuum pump system.

CONCLUSION

Though several components of an RH unit have meanwhile been standardized, the complete RH unit is still a tailor-made unit, designed according to the individual demands of the user with regard to production capacity, metallurgical performance and specific availability of media. Steelmakers in Russia have been modernizing and extending their existing steelmaking technology through various measures, in addition to the here described RH projects. Pervouralsk Pipe Works (PNTZ) installed a new tank degasser and OMZ Special Steels in St. Petersburg new LF and VOD units, just to mention two examples. This development is certain to continue in the future.

REFERENCES:

[1] Plantfacts 2011, Stahlinstitut VDEh, Düsseldorf


The information provided in this brochure contains a general description of the performance characteristics of the products concerned. The actual products may not always have these characteristics as described and, in particular, these may change as a result of further developments of the products. The provision of this information is not intended to have and will not have legal effect. An obligation to deliver products having particular characteristics shall only exist if expressly agreed in the terms of the contract.