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RUSSIA – REFINING, NOT ONLY RESOURCES[1]

Thomas Eichert [2]

Abstract
Russia is the biggest steel producer in Europe and, with around 60 Million tons of steel in 2009, the third biggest in the world. 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 since already 40 years ladle metallurgical units have been executed and the successful cooperation is continued also in the 21st century, especially in vacuum metallurgy. Four new RH units, embedded in different production lines and with different metallurgical tasks, are described as an example for this. The main technical and design parameters of these units are presented.
Key words: RH; Ladle metallurgy; Russia.

RUSSIA – REFINANDO, NÃO SOMENTE RECURSOS

Resumo
A Russia é o maior produtor de aço na Europa, e com aproximadamente 60 Milhões de toneladas de aço em 2009, se posiciona como o terceiro maior produtor mundial. Deste modo, a indústria siderúrgica naquele país enfrenta pressão no cumprimento de exigências de mercado por qualidade e economia da produção. Grandes investimentos em modernizações, em reformas de instalações existentes ou instalação de novas unidades para refino secundário, são conseqüência imediata neste cenário. A SMS Mevac já há 40 anos, implanta unidades de metalurgia de panela com muito sucesso em seus resultados, tendo um desenvolvimento notável especialmente nas tecnologias de metalurgia de vácuo. Quatro novas instalações RH em diferentes unidades produtivas e com diferentes funções metalúrgicas são descritas como exemplo. Os principais parâmetros técnicos e de projeto destas unidades são apresentados.
Palavras-chave: RH; Metalurgia de panela; Rússia.

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[2] *Metallurgical engineer of SMS MEVAC, SMS MEVAC GmbH, Essen, Germany*

1 INTRODUCTION

Since more than 60 years Russia and the former Soviet Union respectively is one of the biggest steel producers in the world. If we have a look to the last years, the steel production in Russia was about 72 Million tons in 2007 which means position No. 4 in the worldwide ranking behind China, Japan and USA. In 2009 the annual Russian steel production was still about 60 Million tons and that means being now the number three among the steel producing countries

The discovery of iron ore deposits in Russia already started in the 18th century. A great share of the iron ore was exported because the development of the Russian steel industry was started in the late 1920s and early 1930s and increased during the Second World War. From 1950 till 1970 the former Soviet Union was the No. 2 behind the USA and from 1970 until 1991 it was the country with the biggest raw steel output worldwide.

The big advantage of the Russian steel industry are the low production costs because, together with Australia, Russia is one of the two countries which can provide all raw materials for steel production independently from its own resources. Nevertheless the Russian steel production required a lot of investments especially because of the high material and energy consumption and to increase the product quality by erection of new equipment. Thus from 2005 on huge investment projects have been finalized at the main steel producers.

2 COOPERATION IN STEEL REFINING

Though in Western Europe, USA and Japan already in the 1950s and 1960s the demand for quality and economy in steel production becomes of continuously increasing importance and thus a lot of investment has been done in the field of ladle metallurgical processes, this development carefully started in Russia not before the 1970s. The first vacuum unit for steel refining of DH type was erected in 1972 by SMS MEVAC in Magnitogorsk at MMK which is today one of the biggest Russian steel producers. After a break of around ten years, but in parallel with further increasing demands for vacuum treated steel also in Russia, the cooperation in steel refining was continued by the installation of further 9 vacuum units, 3 Ladle Furnaces and several Ladle Treatment Stations between 1983 and 1997.

Since 2000 there was again a rapidly increasing worldwide demand for steel and especially vacuum treated steel grades like ULC steels, pipe grades, transformer plates and steels for the automotive industry. Also Russia reacted on this demand and the number of vacuum installations increased continuously (Figure 1). Until today the SMS group has erected, revamped or gained contracts for additional 10 vacuum units of different types as well as 7 Ladle Furnaces and several Ladle Treatment Stations. So since 1972 in total 36 ladle metallurgical units had been successfully executed in Russia leading to nearly 40 years cooperation on this field.

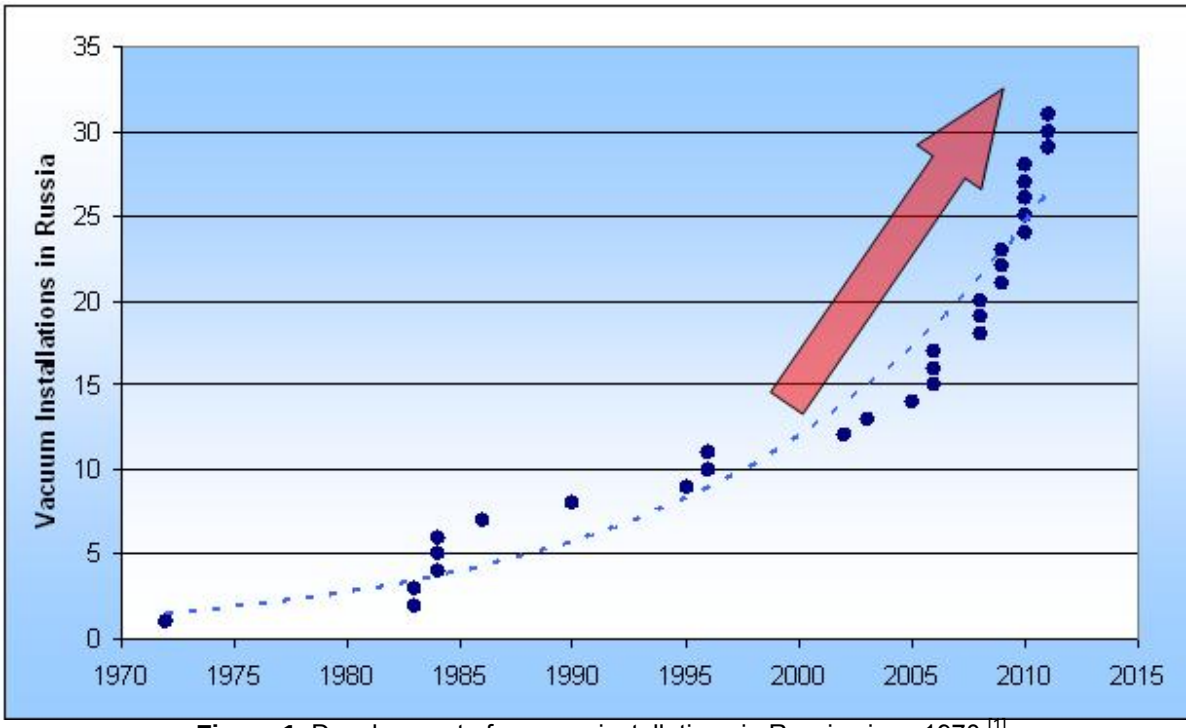

Figure 1. Development of vacuum installations in Russia since 1970.[1]

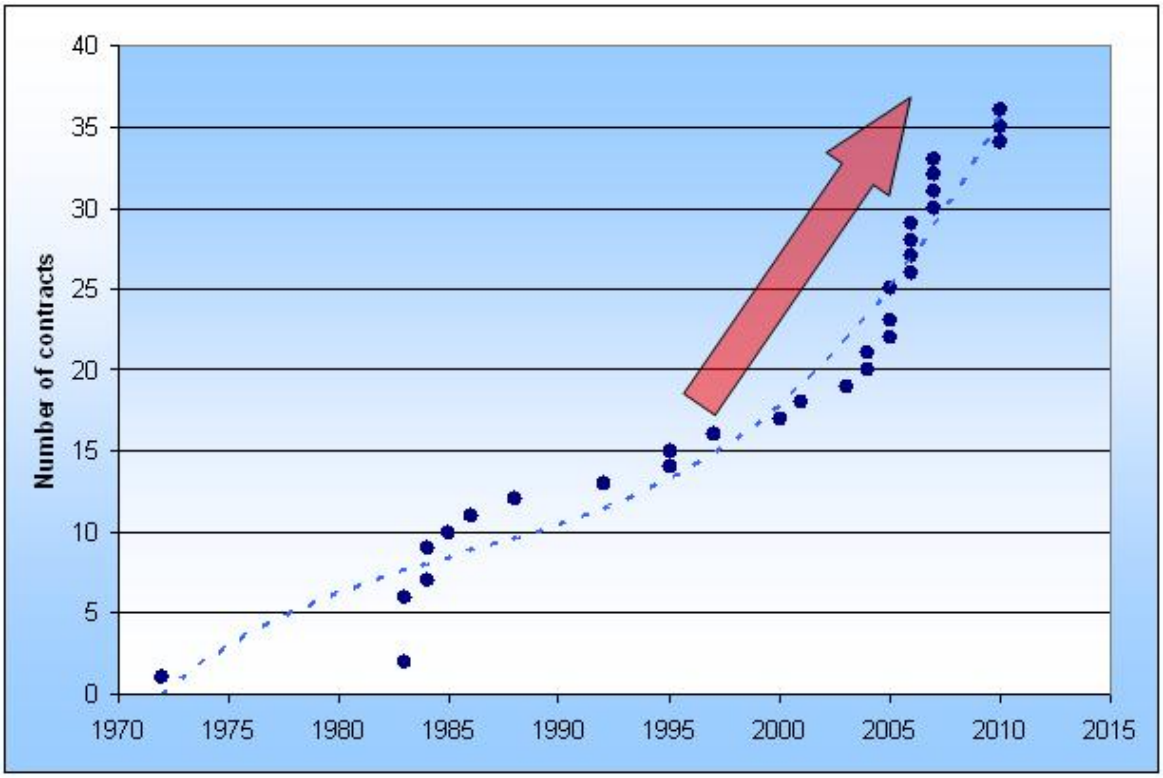

Figure 2. Development of SMS MEVAC's contracts for ladle refining in Russia since 1970.

Figure 2 gives an overview of all ladle refining units supplied by SMS group in Russia. Currently around 30 units for steel refining under vacuum are operating in Russia and the tendency is still increasing because the share of vacuum treated steel will be enhanced in Russia as well as everywhere in liquid steel production.

3 SMS MEVAC'S NEW RH UNITS IN RUSSIA

To have a more detailed view to SMS MEVAC's RH technology, four different RH units which have been erected between 2007 and 2011 will be presented to you with their individual design and production conditions. The RH units are located at NTMK in Nizhniy Tagil, at OEMK in Stary Oskol, at MMK in Magnitogorsk and at NLMK in Novo Lipetsk (Table 1).

Table 1. New RH units in Russia supplied by SMS MEVAC

CONTRACT	CUSTOMER	TYPE	HEAT SIZE	MELTING PROCESS
2005	NTMK (Nizhniy Tagil)	RH – Duplex	160 T	BOF
2006	OEMK (Stary Oskol)	RH – Single	160 T	EAF
2007	NLMK (Novo Lipetsk)	RH – Duplex	320 T	BOF
2007	MMK (Magnitogorsk)	RH – Duplex	370 T	BOF

Some common items of these four projects can be regarded at in advance. All of the a. m. customers have already many years of experience in the field of RH (most of them also in DH) technology i.e. the new RH units are the second or third RH unit in the respective plant.

Also one design item is common with all of these units. The immersion of the snorkels into the steel works with vessel lifting by means of 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 which have been supplied by SMS MEVAC. The advantage towards the conventional ladle lifting with a bottom ram cylinder is that there is no sensitive hydraulic equipment below the steel ladle which could 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.

Three of the four RH units are so called Duplex vessel units. A Duplex vessel unit has two treatment positions served by two ladle transfer cars, but sharing a common alloy addition system and a common vacuum pump system. The major advantage of this design is that ladle handling time is effectively eliminated from the treatment cycle. When one vacuum treatment is finished by breaking the vacuum, the vacuum pump system is connected to the other station by means of a movable bend.

3.1 The Duplex Vessel RH unit at NTMK

Located in the Central Ural, 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]

4 x BOF	3 x LF	1 x Single RH	1 x Bloom CCM (4 strands)
		1 x Duplex RH	1 x Slab/Bloom CCM (2/4 strands)
			1 x Beam Blank CCM (2 strands)
			1 x Slab CCM (1 strand)

Containing both long and flat products, the key products are rail steel,[3] semi-finished products for pipe steels[4] and steels for the railway industry e.g. for train wheels and tires. Because of the huge deposit of Vanadium enriched ores close to Nizhniy Tagil an additional product is Vanadium enriched slag, forming 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 5,000,000 tons per year. The older RH unit was already commissioned in 1996; the new RH unit was commissioned in 2007. This unit is designed for a maximum annual capacity of 1,500,000 tons per year i.e. an additional share of vacuum treated steel of 30% for NTMK. The share of vacuum treated steel at NTMK is actually around 45%.

Concept

Based on more than 15 years of experience with batch type degassers also the new one is a RH type. Though pipe steel grades, which are a key product at NTMK, are commonly produced via process routes with tank degassers, NTMK prefers the LF-RH process 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 the degassing treatment of rail steels and other semi-killed steel grades is advantageous in RH because of the huge reaction chamber, which must not be paid by reduction of productivity like by a big freeboard in tank degassers.

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 per day, the other reason are the bad experiences with the first RH degasser regarding refractory life which can block the vacuum degasser, if only one treatment position is available. To match these demands, the concept of a Duplex Vessel RH degasser was implemented for NTMK. In Figure 3 you can see the principle picture of the new RH unit at NTMK. As this RH unit should also offer the possibility to treat ULC steel grades, both vessels were equipped with SMS MEVAC's multifunctional TOP lances which either can blow oxygen for adjusting the carbon-oxygen relation for decarburization treatments or keep the vessel on temperature by its burner function.

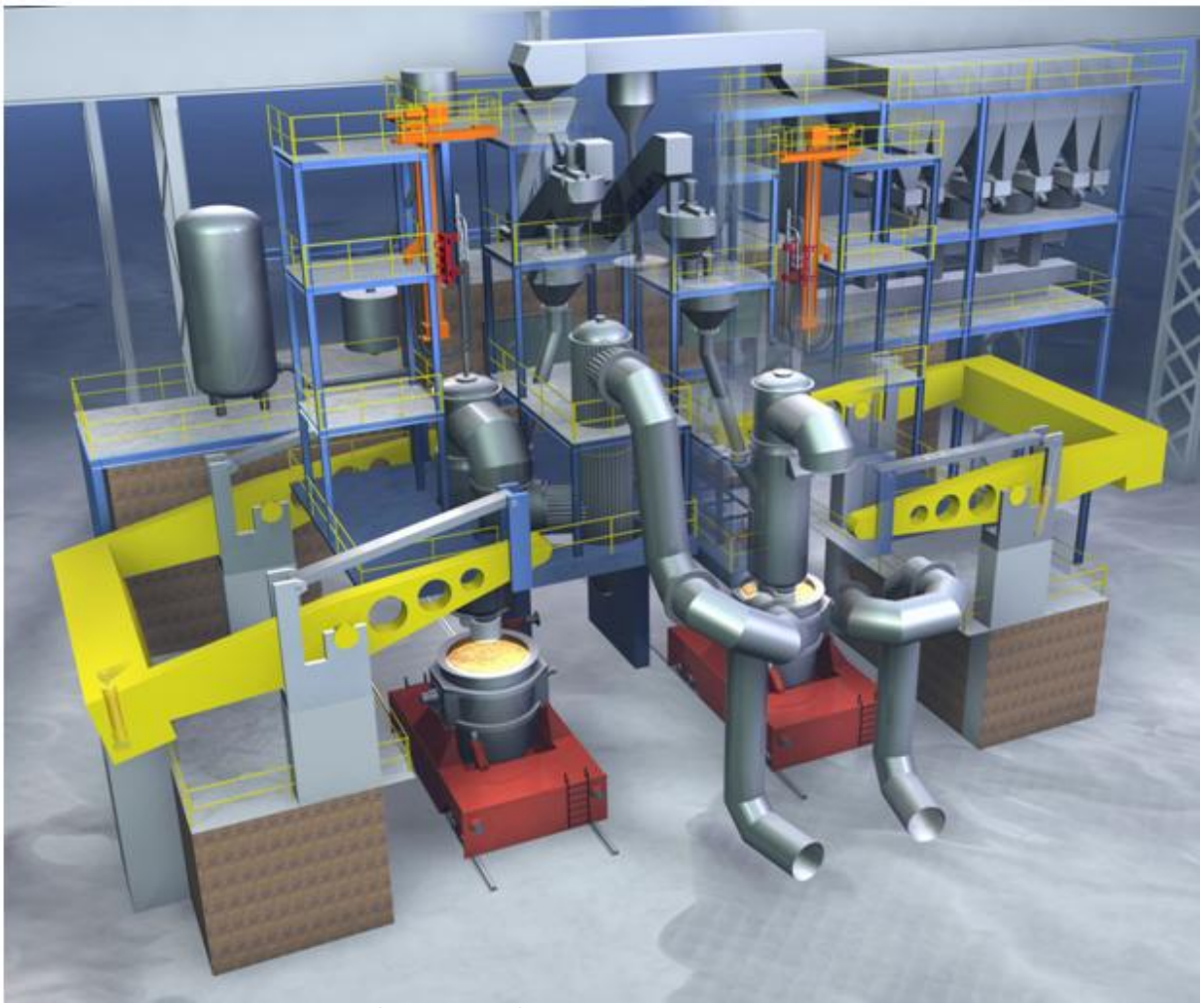

Figure 3. Schematic of the Duplex Vessel RH unit at NTMK.

Main technical data

Vessel
Inner snorkel diameter of refractory: 550 mm

Vacuum pump system
Type: 3 stage steam ejector system with 4 water ring pumps
Deep vacuum: 550 kg/h at 0.67 mbar

TOP lance
Maximum oxygen blowing capacity: 1500 Nm³/h

Metallurgy
Hydrogen content after degassing: ≤ 1 ppm
Treatment capacity: ≥ 9 heats within 8 h

3.2 The Single Vessel RH unit 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 and close to the Ukrainian border. OEMK is an electric steel plant and a 100% subsidiary of the METALLOINVEST holding. Instead of scrap the raw material for electric arc furnace charging are metalized pellets out of iron ore concentrate and oxidized pellets respectively, generated by the MIDREX reduction process. It is the biggest production complex in Europe based on that type. The production line consists of the following processing units:[5]

4 x EAF	3 x Single LF	3 x Single RH	4 x Billet CCM (6 strands) 1 x Bloom CCM (4 strands)

Containing only long products, the key products are bearing steel, semi-finished products for pipe steels, wire rods, 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 3,000,000 tons per year. The older RH units have been erected by SMS MEVAC in 2003 and 2004. They are the former DH units supplied by SMS MEVAC in 1984 which had been revamped to RH process by stepwise modification of vessels, vessel heating systems and vacuum pump systems. The new RH unit was commissioned in 2008. This unit is designed for a maximum annual capacity of 1,100,000 tons per year i.e. an additional share of vacuum treated steel of more than 30%.

Concept

The decision for Single Vessel RH unit was made for several reasons. At first, the maximum daily capacity for this RH unit was required to be only around 20 heats per day. To match this demand, the concept of a Single Vessel RH degasser was deemed to be sufficient for OEMK. At second, the customer has also more than twenty years of successful experience with batch type degassers and the process line as well as ladle and refractory management were aligned to that. At third, the alternative concept of a tank degasser would have had no real advantage because the main task for vacuum treatment at OEMK is the removal of hydrogen and they already achieved excellent results with their batch type degassers.

Achieving extremely low sulphur and nitrogen contents starting from high initial values as in other EAF plants is also not required at OEMK because the metalized pellets they use for charging are quite clean. Each RH unit is working in line with a Ladle Furnace in front and a Ladle Treatment Station for stirring and wire feeding behind the RH treatment position. All positions can easily be reached by a ladle transfer car.

In figure 4 you can see the principle picture 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 scheduled for degassing treatments, it is only equipped with an atmospheric burner lance to heat up the vessel or keep it on the required temperature.

Vessel exchange 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 foreseen.

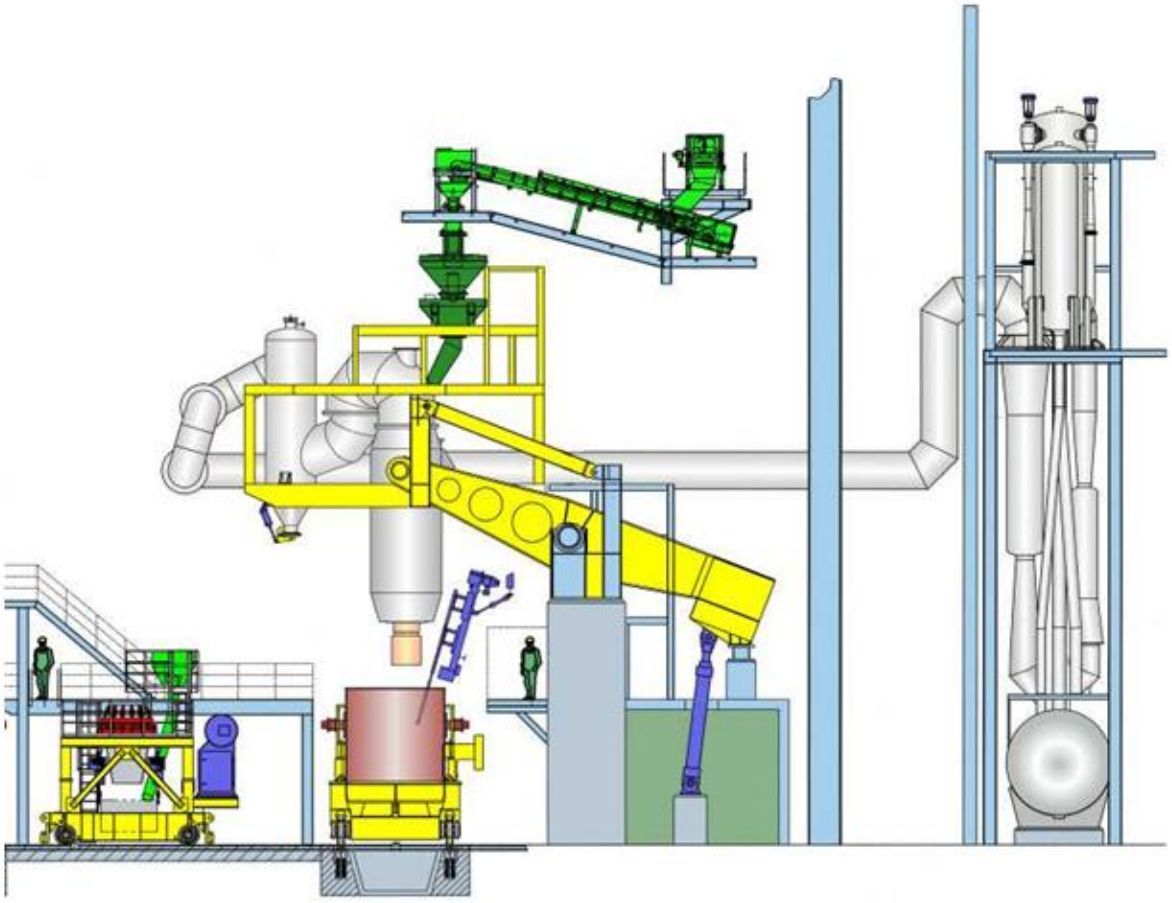

Figure 4. Schematic of a Single Vessel RH unit with Rocker Arm.

Main technical data

Vessel
Inner snorkel diameter of refractory: 460 mm

Vacuum pump system
Type: 4 stage steam ejector system
Deep vacuum: 500 kg/h at 0.67 mbar

Metallurgy
Hydrogen content after degassing: ≤ 1 ppm

3.3 The Duplex Vessel RH unit at MMK

Being situated at the city of Magnitogorsk in the southern part of the Ural Mountains close to the "Magnetic Mountain" a big iron ore deposit which gave the name for the city, MMK is an integrated steel plant and, with 9.6 Million tons of crude steel in 2009, the biggest steel producer in Russia. The company was found in 1929 and the first tap was in 1932. The production line in the BOF plant consists of the following processing units:

3 x BOF	2 x Twin LF	1 x Single RH	4 x Slab CCM (1 strand)
	1 x Single LF	1 x Duplex RH	

Containing both flat (~85-90%) and long products (~10-15%), the key flat 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 14,000,000 tons of crude steel per year. The Single RH unit was already commissioned 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 to be treated in RH unit No. 2 are mainly plates for pipelines to feed the new plate mill which started operation end of 2009. In figure 5 you can see the principle picture of the new RH unit. As this RH unit should 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 are working directly in line with the Twin Ladle Furnace positioned in front of RH (see figure 6) and a Ladle Treatment Station (LTS) on each line positioned behind. Both lines are served each by two ladle transfer cars, but with the possibility that each car can reach every position on the respective line to exclude intermediate crane handling.

The idea for the ladle refining of steel grades for pipelines was to perform heating, pre-alloying and desulphurization steps incl. powder injection, if required, at the Ladle Furnace, transfer the ladle to RH for degassing and final alloying and after that to the LTS for Ca treatment. In case very low final sulphur contents must be achieved starting from high initial values, a deslagging station is available close to the LF.

This process line is not the common concept, if the main steel grades to be treated are line-pipe grades or other heavy plates. Mostly these grades are 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 a sufficient bath stirring and metal slag reaction requires at least three porous plugs. At MMK there are already two slide gates at the ladle and therefore only two quadrants are available for porous plugs.

Nevertheless all kind of pipe grades can also be produced with this process line without having the disadvantages of a Tank Degasser like 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.

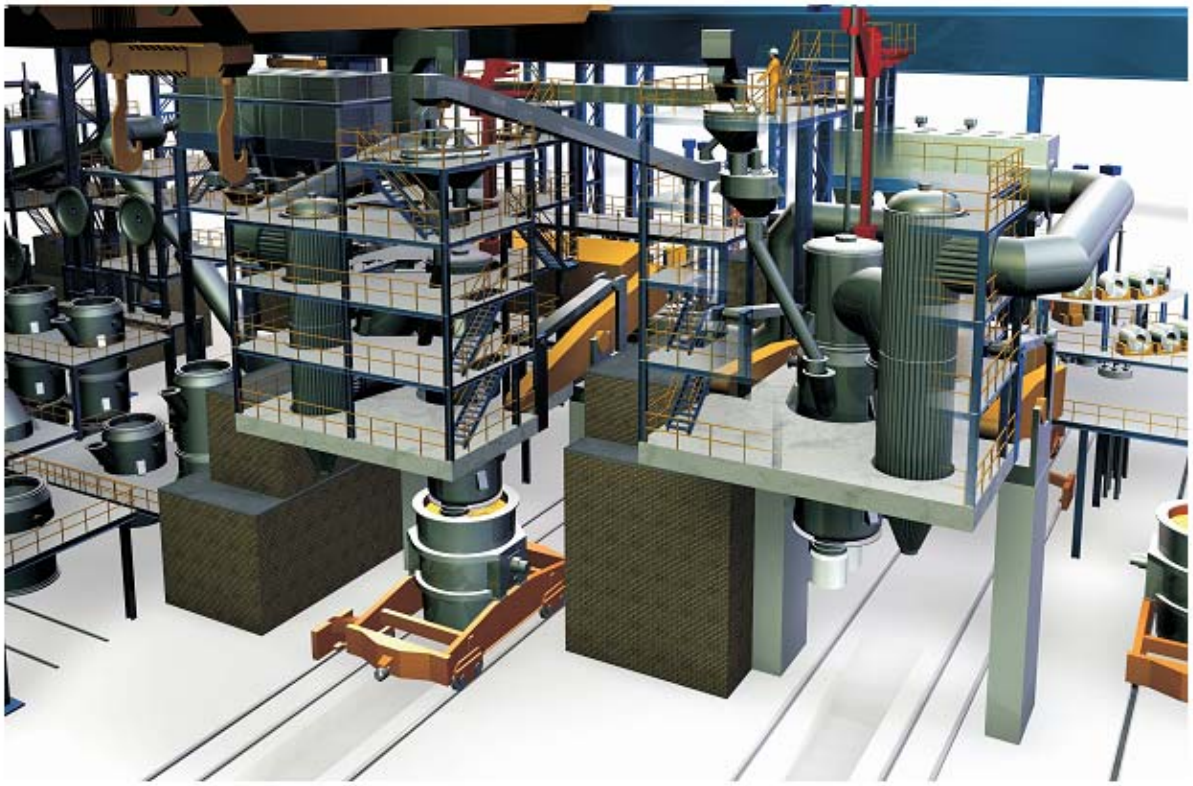

Figure 5. Schematic of the Duplex Vessel RH unit at MMK.

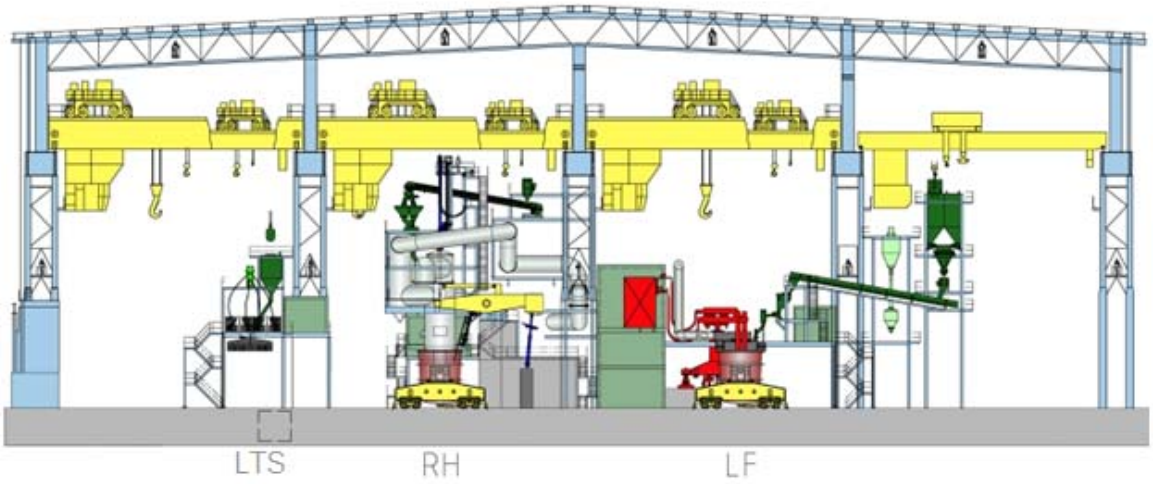

Figure 6. Schematic of the arrangement of Twin L and Duplex RH unit at MMK.

Main technical data

Vessel
Inner snorkel diameter of refractory: 750 mm

Vacuum pump system
Type: 3 stage steam ejector system with 4 water ring pumps
Deep vacuum: 1200 kg/h at 0.67 mbar

TOP lance
Maximum oxygen blowing capacity: 3800 Nm³/h

Metallurgy
Hydrogen content after degassing: ≤ 1.5 ppm
Nitrogen content after degassing: ≤ 50 ppm
Carbon content after decarburization: ≤ 20 ppm

3.4 The Duplex Vessel RH unit at NLMK

With a share of around 15% of the Russian steel production, 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 found in 1931 and the first tap was in 1934. The production lines in the two BOF shops consist of the following processing units:

3 x BOF (180 T)	3 x Single LF	1 x Single RH	2 x Slab CCM (2 Strands)
3 x BOF (320 T)	2 x Single LF	1 x Duplex RH	3 x Slab CCM (2 Strands)

NLMK's key flat products are hot and cold rolled coils and especially grain oriented and non oriented sheets for electrical application 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 9,400,000 tons of crude steel per year. The first 180 t RH unit was already supplied by SMS MEVAC in 1985; this RH unit was revamped in 2005 and the new RH unit No. 2 from SMS MEVAC will be commissioned in 2011. This RH unit is designed for a minimum annual capacity of 4,300,000 tons per year.

Concept

The steel grades to be treated in RH unit No. 2 are mainly LC and ULC 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 on the one hand ultra-low carbon contents can be achieved in shortest treatment times, on the other hand huge amounts of alloys can be added precisely and in a controlled manner in RH via a

vacuum lock with a vibratury feeder. As the maximum daily capacity for this RH unit is required to be at least 39 heats per day, the decision was for a Duplex vessel system, similar to that at MMK, to match this demand. In figure 7 you can see the principle picture 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 are working each directly in line with a Ladle Treatment Station (LTS) positioned in front of RH. After RH treatment the ladles will be transferred by crane to one of the three continuous slab casting machines. Both lines are served each by one ladle transfer car.

The LF units are located in the BOF bay for ladle refining of other steel grades like for pipelines and shipbuilding and after that the ladle will be transferred to RH for degassing and final alloying, if required. Finally at the LTS Ca treatment and addition of insulation material will be done. Light treatment and decarburization grades will be usually supplied directly to RH.

Figure 7. Schematic of the Duplex Vessel RH unit at NLMK.

Main technical data

Vessel
Inner snorkel diameter of refractory: 750 mm

Vacuum pump system
Type: 3 stage steam ejector system with 4 water ring pumps
Deep vacuum: 1150 kg/h at 0.67 mbar

TOP lance
Maximum oxygen blowing capacity: 3200 Nm³/h

Metallurgy
Hydrogen content after degassing: ≤ 1 ppm
Carbon content after decarburization: ≤ 15 ppm

4 SUM UP AND COMPARISON

This chapter shall sum up and compare the different solutions for the versatile metallurgical and process demands at the four above mentioned Russian steel plants. The following Table 2 shows both data of the different plants as well as design and metallurgical data of the respective RH plants.

Table 2. Comparison of new RH units in Russia supplied by SMS MEVAC

	NTMK	OEMK	MMK	NLMK
Melting unit	BOF	EAF	BOF	BOF
Heat size	160 T	160 T	370 T	320 T
Total number of RH units	2	3	2	2
Type of new RH units	Duplex	Single	Duplex	Duplex
Main metallurgical target	Degassing	Degassing	Degassing	Decarburization
Required no. of daily heats	27	20	17	39
Required annual capacity of new RH unit	1,500,000 t	1,100,000 t	2,000,000 t	4,300,000 t
Principle of Snorkel immersion	Vessel Rocker Arm	Vessel Rocker Arm	Vessel Rocker Arm	Vessel Rocker Arm
Vessel type	Block type, welded snorkels	Block type, welded snorkels	Split type, welded snorkels	Block type, welded snorkels
Inner diameter of snorkels	550 mm	460 mm	750 mm	750 mm
Vacuum pump system	3 Stage SE[1)] + 4 WRP[2)]	4 Stage SE	3 Stage SE[1)] + 4 WRP[2)]	3 Stage SE[1)] + 4 WRP[2)]
Type of lance	Multifunctional TOP lance	Atmospheric Burner lance	Multifunctional TOP lance	Multifunctional TOP lance

1) SE = Steam ejector system; 2) WRP = Water ring pumps

It is obvious that all BOF plants have Duplex Vessel RH units whereas 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. The BOF tap-to-tap times can easily be followed by a Duplex unit but the EAF tap-to-tap times only require a Single unit.

Regarding the metallurgical targets definitely each type of RH unit can fulfill both Degassing i. e. removals 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 as 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 type of vessel is usually block type with welded snorkels, only at MMK a split type vessel with separated upper and lower vessel was supplied acc. to customer's request, but also here 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 customer's ladle refractory dimensions. Therefore also vessels or snorkels for the same ladle content can have differing dimensions. Regarding the vessel height the requested metallurgical tasks play the important part. 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 by 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 WRP whereas EAF plants normally have a lack of steam and prefer a combination of steam ejectors and water ring pumps with reduced steam consumption. When we look at table 2 we find a situation in reverse. The reason for a steam ejector system without WRP at OEMK is that at the plant already since many years operates two vacuum units and have just extended the existing steam to compensate the steam demand of the new RH unit. At the three BOF plants the steam generated by the BOF shop is either not available in stabile conditions over the hole time, not sufficient to feed both the existing and the new vacuum unit or is needed for other purposes like district heating or similar. At MMK a steam boiler had to be installed to have at least enough steam for the combined vacuum pump system.

5 CONCLUSION

Though several components of an RH unit are meanwhile standardized, the complete RH unit as such with regard to its main sections is still a tailor-made piece of equipment, designed acc. to the individual demands of each customer for production capacity, metallurgical performance and individual media conditions.

Russia has started to modernize and extend its existing steelmaking technology, not only in ladle metallurgy and not only with regard to RH technology but also for other

ladle metallurgical units. PNTZ at Perwouralsk with a new tank degasser, OMZ in St. Petersburg with new LF and VOD units and others are examples for this. This development should be continued in the future and hopefully so will do our cooperation and partnership in the field of ladle metallurgy.

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