SIEMENS VAI – SECONDARY METALLURGY MODERN LF-RH HIGH PRODUCTIVE PLANTS[1]

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Abstract
In the last years, the secondary metallurgy equipments within Siemens VAI had a remarkable and outstanding success. Various ladle furnaces and RH plants were successfully started up to secure and to stabilize the quality of produced steel. The Siemens VAI design allows the production of a wide range of steel grades within high productivity steel plants – either oxygen or electric. Important improvements on heating rate capacity, energy and electrode consumption through new technologies are still obtained on the ladle furnace process. The Siemens VAI RH technology was continuously improved including design parameters, as well as metallurgical process and models to meet today's requirements. Siemens VAI secondary metallurgy design concepts meet any layout special requirements thanks to the different solutions available and great experience gained by installing more than 200 units worldwide. This paper reports the latest successfully commissioned installations.
Key words: LMF, RH, Equipment, Design, Performances.

Resumo
Nos últimos anos, os equipamentos de metalurgia secundária dentro da Siemens VAI tiveram um sucesso notável e marcante. Vários Fornos Panela e Plantas de RH foram colocadas em operação com sucesso para garantir e estabilizar a qualidade do aço produzido. O projeto Siemens VAI permite a produção de uma enorme gama de graus de aço dentro de plantas de alta produtividade – tanto a oxigênio quanto elétricas. Importantes melhorias na capacidade da taxa de aquecimento, consumo de energia e eletrodos, ainda são obtidas no processo do Forno Panela através de novas tecnologias. A tecnologia em RH da Siemens VAI foi continuamente aperfeiçoada incluindo parâmetros de projeto, assim como processos e modelos metalúrgicos para atingir os requisitos atuais. O conceito de projeto da Metalurgia Secundária da Siemens VAI se adequa a qualquer demanda especial de layout graças às diferentes soluções disponíveis e a grande experiência ganha com a instalação de mais de 200 unidades no mundo. Este artigo relata as últimas instalações comissionadas com sucesso.
Palavras-chave: LMF; RH; Equipamento; Projeto; Performance.

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1 INTRODUCTION

In the last years, the secondary metallurgy equipments within Siemens VAI had a remarkable and outstanding success. Various ladle furnaces and RH plants were successfully started up to secure and to stabilize the quality of produced steel.
The Siemens VAI design allows the production of a wide range of steel grades within high productivity steel plants – either oxygen or electric steelmaking – where the tap to tap times are in the range of 25-35 minutes. The ladle furnace performance allows an incredible flexibility during different phases of the steel production e.g. it acts as a buffer for vacuum treatment and casting sequences; it can balance temperature differences, etc. The RH plants extend the product mix to high demanding quality steel by decarburizing and degassing in short cycle time.
Even if the ladle furnace process was introduced in the 1970's, important improvements on heating rate capacity, energy and electrode consumption through new technologies are still obtained, e.g. new roof design with copper cladded plates, powder injection lances for deep desulphurization, multi-wire feeding machine.
Siemens VAI RH technology was continuously improved including design parameters, snorkel dimensioning optimization and multi functions T-COB lance, as well as metallurgical process and models to meet today's requirements
Siemens VAI secondary metallurgy design concepts meet any layout special requirements thanks to the different solutions available and great experience gained by installing more than 200 units worldwide.
This paper will report the latest successfully commissioned installations.

2 SECONDARY METALLURGY FACILITIES

Higher steel production does not only mean quantity, but also quality. Therefore modern secondary metallurgy facilities, particularly LMF (ladle metallurgy furnace) and RH (Ruhrstal Heraeus) equipments are integrated in the steel production line. In addition, modern secondary metallurgy facilities provide an opportunity for steel plants to extend the product mix and to be more flexible in order to respond to the steel market situation.
The LMF has the main function of steel refining with chemical and temperature adjustment and the RH has excellent performances in terms of decarburization and degassing. Both provides short cycle time which results in a high number of heats treated per day, especially only RH has the competence to produce them.
Siemens VAI as a plant supplier improves continuously their technology including design parameter and layout as well as metallurgical process parameters and models to meet today's requirements.

3 HIGHLIGHTS OF LF PROCESS AND TECHNOLOGY

Depending on the production rate of the primary unit, a single or a twin LMF should be installed. Twin LMF means two separate stations with one common electrode swivelling gantry and transformer where the heating is possible in one station at a time but all the other operations are possible in parallel. The net treatment time is strongly reduced with this configuration.
The investment costs are limited considering the extreme flexibility supplied by this technical solution. The single station LMF has also the possibility to have a double ladle car, ladle turret and/or a trimming station on the same line.

For both solutions, single or twin LMF, an extreme low reactance of the secondary circuit has been obtained resulting in a very high active power yield.
Typical performance figures of our furnaces are:

- Design heating rate up to 5 ℃/min
- Energy consumption < 0.45 kWh/ ℃, t
- Electrode consumption 8 g/kWh
- Argon consumption 0.1 Nm³/t
- Nitrogen pick up < 5 ppm
- Desulphurization rate > 66% with top slag and > 80% with powder injection
- Carbon pick up < 10 ppm
- Treatment cycle < 30 min

Wide ranges of steel grade can be produced at LMF. Considering the rapidly increasing demand of AHSS and HSLA steel the LMF equipment is the ideal solution to fulfil high level quality requirements. High quality can be achieved through a combination of stirring (bubbling or electromagnetic, both application are used in our plants) and sealed air system over the ladle while heating and chemical balance are performed.
The above mentioned LMFs where installed in high quality steel production plants and often part either of a LMF-RH route or of a LMF-VD. The combination with vacuum processes does not affect the primary melting unit productivity (BOF or EAF) because the LMF is a high performing energy source in the steel plant acting as buffer between the melting and the casting area.
Production of steel through a LMF-RH route requires performing the desulphurisation at LF, without severe restrictions for the BOF or EAF.

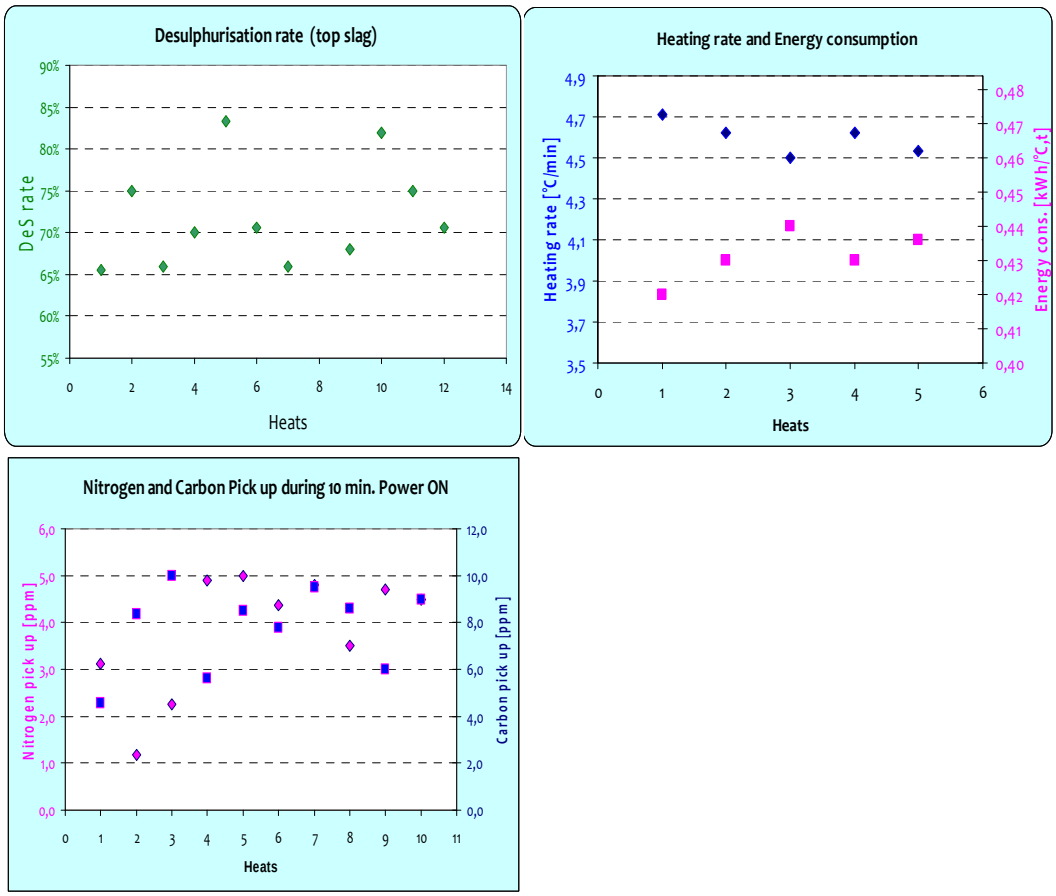

Figure 1. Handan Steel Company 270 t TWIN LMF (P.R. of China) Performance data (Nov. 2008).

4 LMF EQUIPMENT

LMFs can be equipped with a wide range of auxiliary equipment.

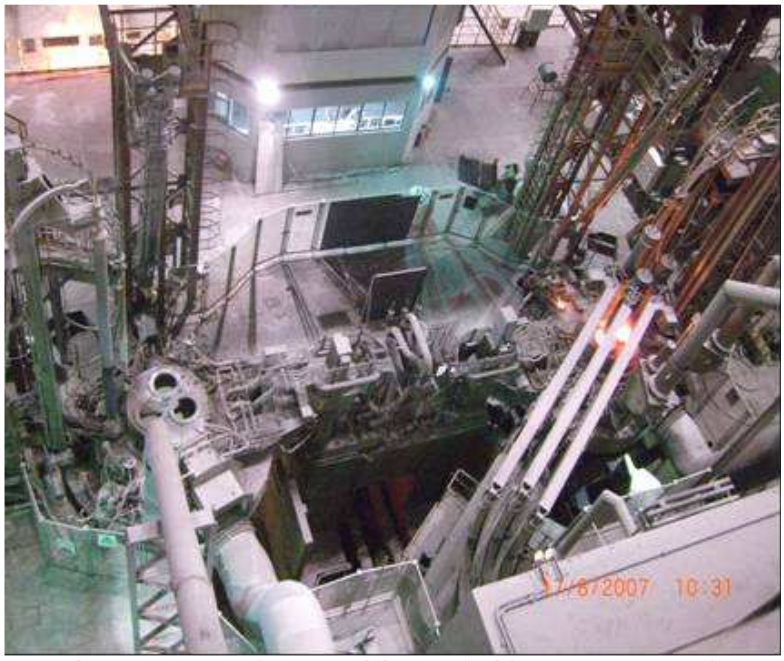

Figure 2. Maanshan Steel (P.R. of China- August 2007).

For this reason the LMF has been equipped with:

- Powder injection lances for deep desulphurization
  When deep desulphurization is required and treatment time is shorter, then a deep powder blowing equipment is the right system to satisfy both metallurgical and productivity requirements. Sulphur content lower than 10 ppm can be reached in 10 min treatment.
- Multi-wire feeding machine
  Fine chemical analysis tuning is necessary, then a wire feeder is the right equipment for the secondary metallurgy. Our design enables to simultaneously feed more wires which results in time saving, especially in big ladle size where the amount of wire to be injected is quite significant. The feeding operation is fully automated.
- CCTV for stirring control
  This auxiliary equipment has been introduced recently at the LMF and gives the operators the complete control of the metal/slag reactions status. The inspection door can be maintained closed during the whole treatment avoiding air infiltration inside the tight roof. The reaction to any abnormal situation can be very fast if the eyes of the operators are constantly on the bath surface where the treatment success plays the major role.
- CCTV camera for LMF area control
  Safety logistic control is fundamental in a modern steel plant. The CCTV system, appropriately positioned, is a must to control traffic in a high productivity plant. In case a breakout occurs, the camera system gives an immediate warning to the operators.

- Emergency stirring lance
  Fundamental for secondary metallurgy is the metal and metal/slag mixing. Any risk of process stop is avoided with this lance and it also helps to increase the process kinetics if used together with the normal mixing system.
- Automatic Temperature, Oxygen & Sampling lance
  In order for our temperature and chemical analyses to be in line with our goals, the sampling procedure and practice must be reliable and repeatable; the automatic system cancels the risk of human errors. The automatic system also allows increasing the automation level of the LMF station.
- Automatic stirring coupling
  Safety and fast connection is the success of this system!
- Jib cranes over the LMF station
  Electrode and lances replacement independently of the meltshop crane is a must in high productivity meltshops.
- Complete centralized station control via Level 1
  Siemens VAI Level 1 philosophy, design and structure allow the complete control of the machine and its auxiliary equipment.
- Electrode regulation system
  The Siemens VAI experience in electrode regulation is worldwide known.
- State of the Art Level 2 system
  In this case the ladle furnace potential is incredibly enhanced in terms of productivity, metallurgical results and process control. The high automation level reduces the number of operators and gives the plant managers the possibility to control all the process phases in detail through the Level 1 and Level 2 databases.

5 POWDER INJECTION SYSTEM FOR LMF

Several plant installations were requested to SIEMENS VAI in order to reach low sulphur content after LMF treatment in a reliable and faster way. Reduced treatment time and more efficient chemical interaction between elements are the main characteristics of this solution. Reduced slag building material consumption and energy requirements were noted especially when an RH process follows the LMF process and a typical refining slag for top slag desulphurisation of 10-12 kg/t is not required. Time for desulphurisation is also reduced thanks to direct contact between desulphurizing agents and sulphur in steel, as compared with the interaction on ladle top required by top slag desulphurization. A wide variety of desulphurizing materials can be used depending on the local market availability. Main materials tested in our installation are lime and calcium-silicon powder.
The mechanical installation was also well adapted to the LMF layout with a dedicated opening in the roof and even with combined function emergency stirring or powder injection.

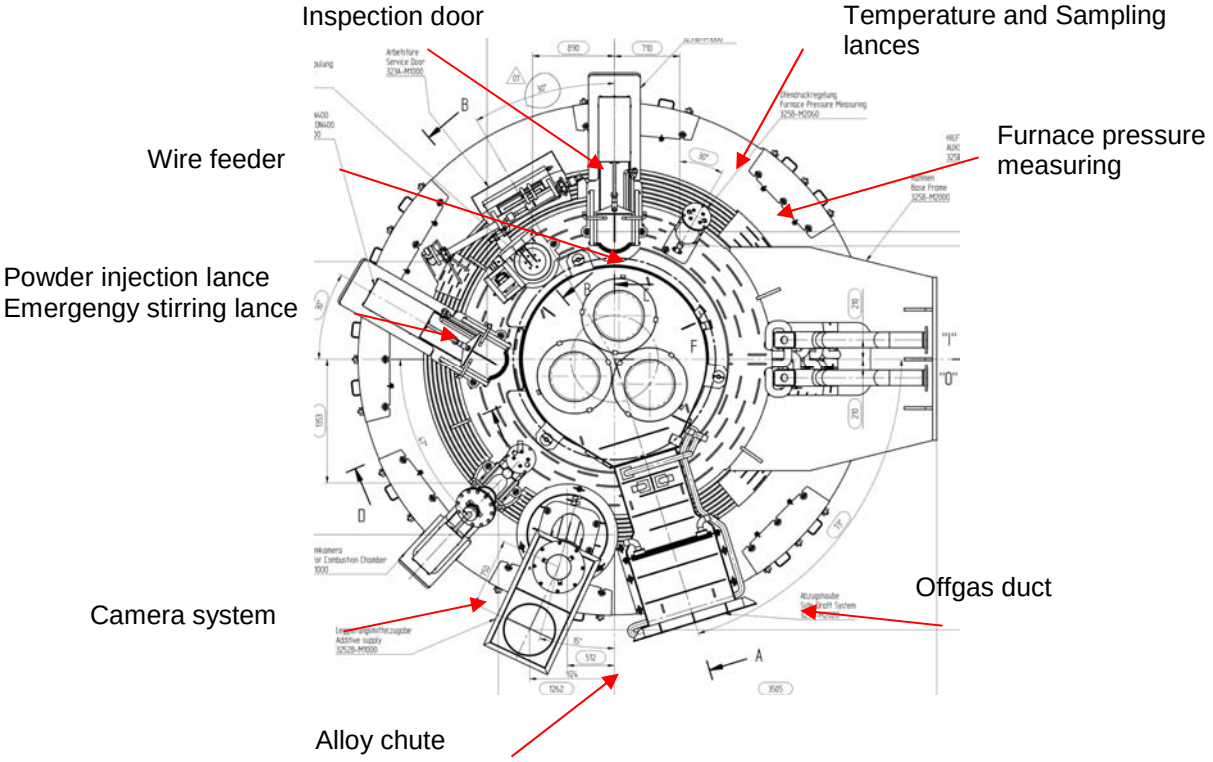

Figure 3. Typical LMF roof layout.

The lance manipulator is fixed on the working platform for easy maintenance access and it does not interfere with the other auxiliary equipment installed. Multi lances storage and fully automated lance change were part of our projects.

Figure 4. Handan Steel (P.R. of China- August 2007).

Table 1. Following typical performance results.

	deS rate	Start S value	End S value	SiCa powder consumption
Group 1.	>80%	100-80 ppm	<20-16 ppm	3.44 kg/t
Group 2.	<80%	50-40 ppm	< 10-8 ppm	3.13 kg/t

6 LMF SPECIAL DESIGN

Research and development is a ceaseless process in our company. A water cooled roof made in copper, a new innovative solution, was implemented and installed in VOESTALPINE STAHL-LINZ. The advantages of the utilization of copper material for cooling purposes are well known. Yet another important aspect must be considered: skull formation over the roof is an unpleasant situation during strong operations at the ladle furnace. Several steel plants work under severe stirring conditions due to tight treatment time and very low sulphur demand; in this case reduced stirring flow is not acceptable. With the copper solution the skull formation is completely removed.

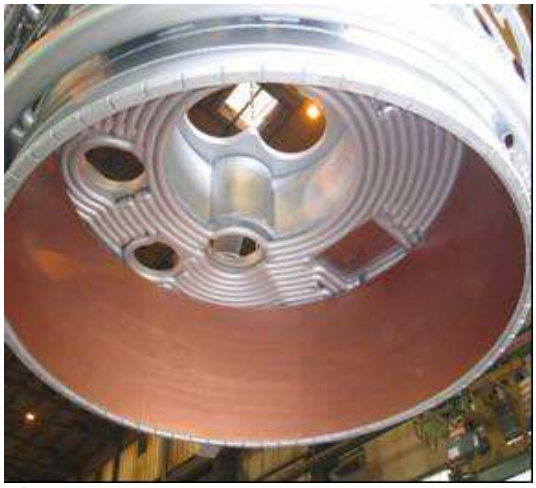

Figure 5. LMF copper roof.

Figure 6. LMF copper roof.

Figure 5 shows the LMF roof in SIEMENS VAI workshop during the delivering stage. Figure 4 shows the roof status after several months of operation.

7 HIGHLIGHTS OF RH PROCESS AND TECHNOLOGY

RH is a vacuum recirculation process which means that the steel is circulated through up-leg snorkel and back through down-leg snorkel. The circulation rate is an important key to secure optimum condition for metallurgical processes. The contribution of Siemens VAI to improve this condition is highly demonstrated by our plant performances.

Ultra low carbon grades (15 ppm carbon is state of art design), Interstitial Free grades (no slag reaction during treatment remove the risk of Si pick up) are produced and in combination with a ladle furnace and powder injection for deep desulphurisation, RH plants have been successfully applied for production of pipe steel. Final nitrogen content lower than 40 ppm and hydrogen lower than 1,5 ppm are also reached.

Several plants have been successfully started up in the latest years, five RH plants have been successfully started up in China the past two years and Bhilai Steel Plant in India recently.

At Zhangjiagang Hongfa (ZHF) steel plant an 180t RH has been installed after previous RH installation, the plant consists of two vessels transfers' cars, pre heating burners, T-COB lance, and snorkel maintenance car. A full system vacuum pump is installed.

Figure 7. RH Plant at ZHF.

At Nanjing NISCO a 150t twin installation RH was successfully started up. The installation is a consequence on increasing its production of high quality steel grades for demanding product application. The RH commenced operations in early 2007. During the hot commissioning period API (American Petroleum Institute) steel grades and carbon structural steel were produced.

Figure 8. Twin Stand RH Plant at Nanjing ISCO.

At Taiyuan ISCO a new 180t RH T-COB plant was installed for the production of pipe steel, IF steel and automotive steel grades.

Figure 9. Twin RH T-COB Plant at Taiyuan ISCO.

At Maanshan ISCO a twin RH T-COB Plant with a size of 300t was installed for a production of 3.400.000 t/a
At Jinan ISCO a 150t RH twin degasser was installed at Steel making plant no.3. This extension of the process route enables the customer to produce up to 1.800.000 t/a of high quality steel grades like Silicon Steel DW230, Pipe Steel X80, ULC IF Steel and Low Carbon Steel SPHE

Figure 10. 150t Twin RH Plant at Jinan Iron & Steel.

Following three charts showing the metallurgical results obtained in the abovementioned plants in terms of hydrogen removal and decarburization capacities:

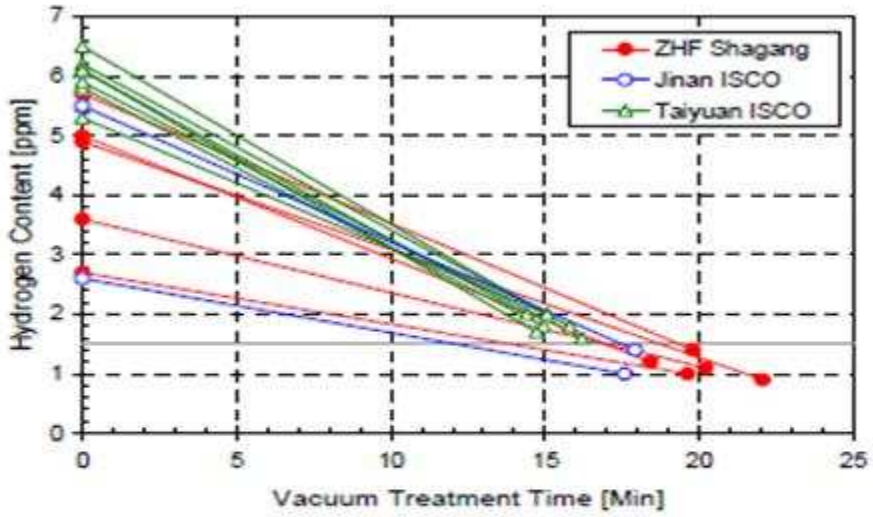

Figure 11. Hydrogen Removal Performance. Degassing time is counted as vacuum pump start.

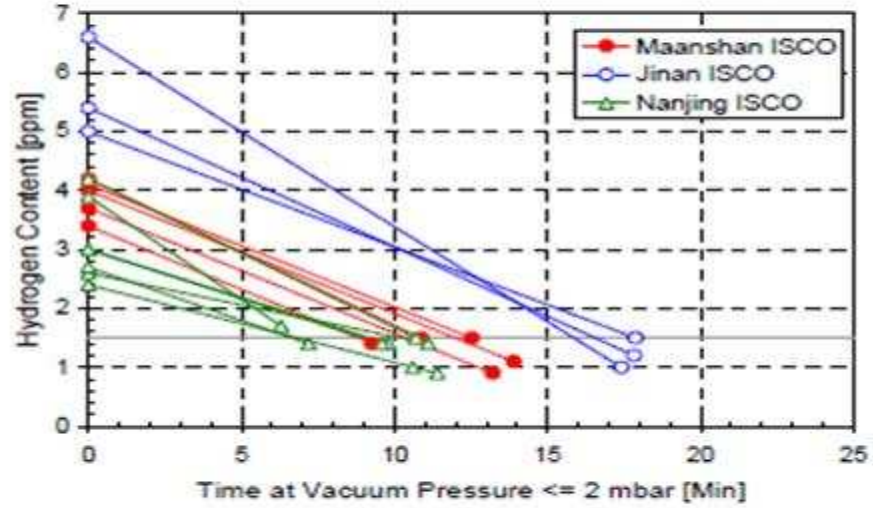

Figure 12. Hydrogen Removal Performance. Degassing time is counted at vacuum pressure ≤ 2mbar.

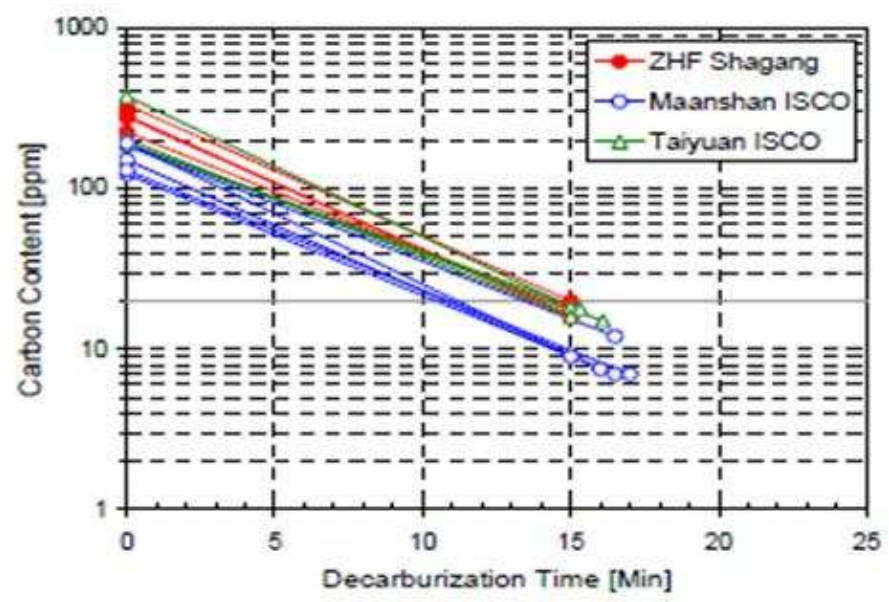

Figure 13. Carbon Removal Performance of heats.

In Bhilai steel plant successfully results were obtained in terms of guarantees:

Table 2. Guarantee results at Bhilai steel plant.

PG Parameter	PG Value	Test Value
Final Hydrogen in Rail Steel Grades	1,3 ppm	0,9 ppm
Final Hydrogen content in slab grade	2,0 ppm	1,3 ppm
Capacity per day	24 heats	25 heats
Vacuum level to achieved within 3 min	0,5 torr/0,67mbar	Achieved
Treatment time to achieve 1,3 ppm hydrogen	23 min	15 min 10 sec
Pollution control		
- Work zone dust content (mg/Nm3)	2	1,29
- Noise level (dBA)l	85	<85

8 RH EQUIPMENT

RH vessel

The vessel has to be designed to cover all metallurgical process phases during RH treatment. The vessel can be designed as split type or as mono-block. The split type vessel is divided into two pieces which offer an easy access fro refractory lining and repairing. With the target to minimize refractory consumption and to reduce the total operating cost, a concept for using water cooling panels for upper part of the RH vessel and hot off-take has been patented by Siemens VAI.

T-COB Lance

In modern RH a water cooled T-COB lance is installed on the hot off take. The lance also replaces side burners, which are conventionally used for vessel heating and offers additional function for oxygen blowing for aimed decarburization, chemical heating and skull removal. The lance tip is designed as Laval jet nozzle. To ensure that the system is tight during vacuum treatment, an inflatable sealing is installed in the stuffing box (Siemens VAI patent).

Alloy addition system

The vacuum tight addition system is integrated in the RH plant with the purpose to allow the alloy additions into melt during vacuum treatment. High yields of especially for carbon and other high oxygen affinity alloying elements can be achieved.

Ladle lifting system

For snorkel immersion, ladle and ladle transfer car are lifted and lowered by means of hydraulic cylinder. Ladle lifting by hydraulic offers benefit that the RH vessel platform can be well accessed and vessel exchanged can be performed easily. The alternative snorkel immersion system are ladle lifting by winch, vessel lowering by winch and ladle swivelling as well as lifting by ladle turret. In the latter system no ladle transfer car is required.

Vacuum pump

“Own design” combined with metallurgical process know-how and “one hand supplier philosophy” drives Siemens VAI to deliver a strong vacuum pump tailored to process requirements. Generally two types of vacuum pumps are offered: full steam ejector,

usually preferred in steelmaking shop where steam can be produced within the plant (integrated steelmaking) and hybrid pump. The second solution is a combination of steam ejectors and water ring pumps very often installed in electric steelmaking shops. As a trend for the future, the installation of mechanical dry vacuum pump can be reported, particularly in electric steel making shops and minimills.

Furnace camera

By the installation of furnace camera on RH hot off take the conditions inside the vessel can be exactly observed. During vessel heating, the camera is used to examine refractory material, burner flame appearance. During the process the camera monitors the steel level, the steel splashing during main decarburization phase and the splashing during the oxygen blowing as well as to check the oxygen jet stream. Alternative the camera can be installed in the T-COB lance, expecting benefit on observation of the refractory surface, particularly at the lower part of the vessel, where the wearing higher than other parts.

9 CONCLUSION

Siemens VAI Metals Technologies is glad in offering a High-End solution to meet the request for increased productivity, quality and efficiency in Ladle Metallurgy Furnace:
With the design of the secondary metallurgy stations using in-house technologies such as electrode conductive arms, roof manufacturing and worldwide experience acquired during hundreds of start up and commissioning projects Siemens VAI offer support and assistance to design the best solution for any steel plant requirements, which meets the steelmakers demand for increased productivity and low conversion costs.
Continuous tests and focus on research and development of all steel making related process and equipment part ensure that Siemens VAI is offering the State of Art Technology