OPERATIONAL RESULTS OF LATEST VACUUM PLANT START-UPS[1]

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Abstract

As the request for quality steel and stainless steel is rising throughout the industry and as the added values through vacuum treated steels is increased, the number of installed and contracted vacuum plants for the improvement of the steel quality is getting higher and higher. Nowadays, vacuum treatment facilities are not only to be installed in integrated and stainless steel plants, but also approx. half of the so-called minimills are built worldwide with mostly tank degassers. In this paper, we would like to take a look on the design as well the operational results of our latest commissioned vacuum plants like the VTD's at SSAB/US and Uralstal/Russia, the VOD's at Dongbei Steel/China and TISCO/China, whereas the Tisco plant is the biggest VOD worldwide, and also the RH's at CSA/Brasil and Tisco/China. An outlook will be given on the future of the vacuum treatment philosophy which is arising of the market trends.

Key words: Vacuum technology; VTD; VOD; RH; Quality; Productivity.

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1 INTRODUCTION

As the request for quality and stainless steels is rising throughout the industry and as the added value through vacuum treated steels is increased, the number of installed and contracted vacuum plants for the improvement of the steel quality is getting higher and higher. Nowadays, vacuum treatment facilities are not only to be installed in integrated and stainless steel plants, but approx. half of the so-called mini-mills are built worldwide with mostly tank degassers.
In this paper, we would like to take a look on the design as well the operational results of our latest commissioned vacuum plants like the VTD at SSAB/ US and Tisco/ China, whereas the Tisco plant is the biggest VOD worldwide, and also the RH at CSA/ Brazil and Zhangjiagang/ China.
An outlook will be given on the future of the vacuum treatment philosophy as a result of the current market trends.

2 HIGHLIGHTS OF THE VACUUM PROCESS TECHNOLOGY

Increasing demands for improved quality and increased productivity require new investments and applications in the field of secondary metallurgy as well as in the primary melting unit. Purpose of this paper is to concentrate on vacuum technology applied to secondary metallurgy plants. Environmental demands, new market trends and steel quality requirements called for a new definition of vacuum plants product portfolio. Meaningful investments in research and development have been necessary to satisfy steelmakers´ requirements.
The new operational results of our improved vacuum plants are available and decisive to define the future market trends.
Steelmakers were faced with a crucial decision, whether to combine vacuum tank degasser and recirculation degasser or rather opt for a single unit installation. A detailed analysis of primary process routes for steel making and productivity requirements led to the design of tailor-made solutions. The increased environmental demands required different solutions especially in terms of creating vacuum: the basic vacuum technology remained unchanged, but plant designers had to focus on improving consumption and off gas treatment data.

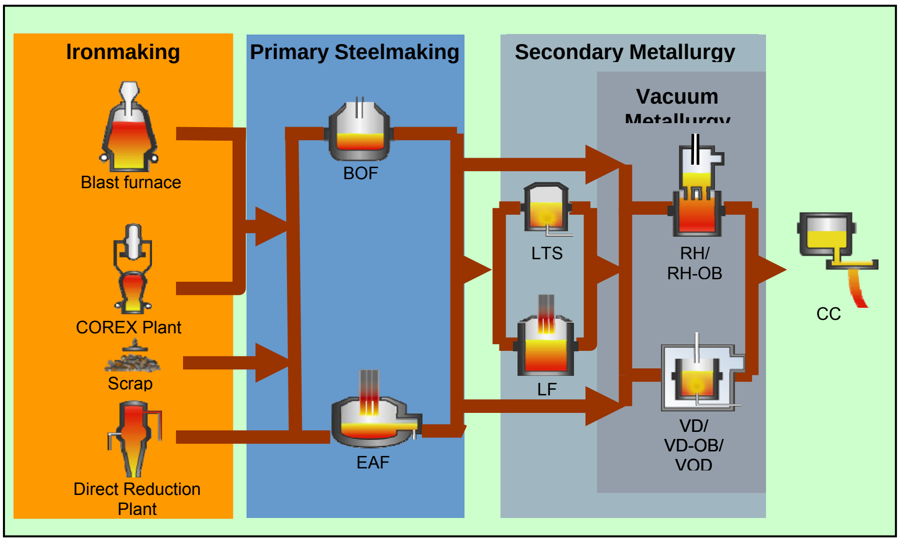

Figure 1. Steel-making cycle.

3 HIGHLIGHTS OF VACUUM TANK PROCESS AND TECHNOLOGY RESULTS

Vacuum tank degassing applies to different process route applications and an extreme wide range of product qualities, such as stainless steel or high quality carbon steel. The latest start-up results are essential for future product development in terms of environmental friendly solutions and steel quality achievements. This paper will take into consideration the start-up of the SSAB plant located in Alabama (USA).

The plant produces high quality plates and, due to the introduction of dedicated solutions, the plant configuration was extremely challenging for the engineering crew.

Plant configuration:

- twin tank solution (tank moving with fixed covers);
- Ladle size 185 shT;
- vacuum pump consisting of a combination of steam ejectors and watering pumps with a suction capacity of 500 kg/h at 0.67 mbar;
- steam supply via an electric steam generator (boiler);
- dust filter in line with < 10 mg/m3 filtering capacity;
- treatment time for pipe grades < 35 minutes.

As is the case in many VTD plants, the equipment is not in continuous operation, but rather order based. Standby costs affect the steel making cost. Due to this reason, an electric boiler solution was adopted in combination with the steam ejector to reach a stand-by to hot phase time of less than 20 minutes. The steam ejector pump was a combination of watering pumps and classic steam ejectors. The vacuum pump capacity is strictly correlated to the environmental requirements: the process dust formation is isolated at the tank exit before entering the vacuum pump. That allows avoiding the use of any special filter material at the water treatment plant of vacuum pump. The project developed for SSAB Alabama consists of a full package: technological equipment, water treatment and steam supply. Figure 2 presents the vacuum plant performance.

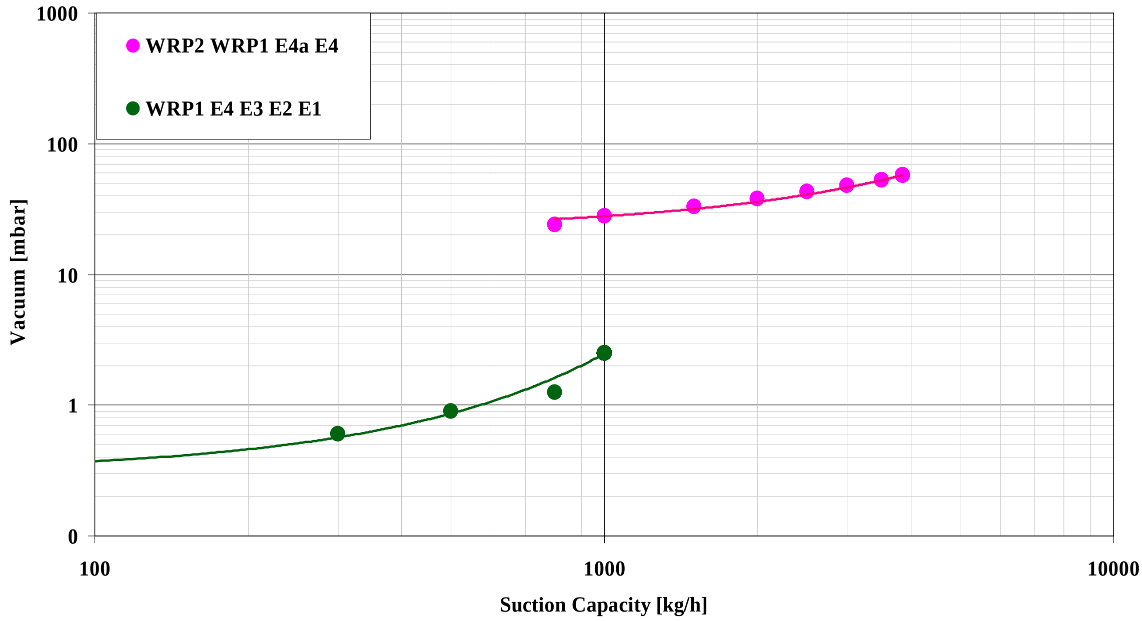

Figure 2. 180t VTD vacuum pump performance.

The filtering capacity related to the off gas volume generated during the process is a key issue for the vacuum plant design. The extreme low density of the off gas during the vacuum treatment, expected around 1.0 g/m³, results in a volumetric process flow of more than 500,000 m³/h. Considering the process off gas conditions and the filtering requirements, a double filter has been installed resulting in lower filter pressure losses. The final pressure in the vacuum tank has been ensured and is far below 1mbar during the vacuum process. Last but not least the pump down from atmospheric pressure to 1 mbar is reached in 5 minutes. In the following, a schematic view of the tank-filter-vacuum pump line shows the pressure characteristics during the deepest vacuum stage.

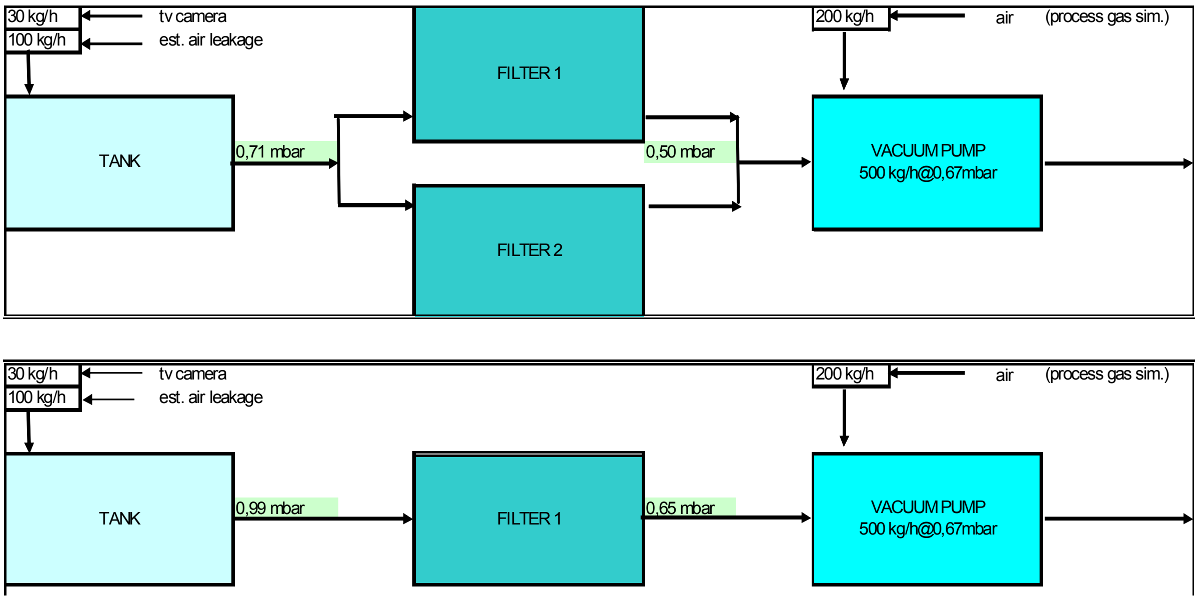

Figure 3. 180t VTD filter unit characteristics.

The metallurgical performances are the result of both the plant configuration and mechanical design as well as of proper process operations. The melt shop proves extremely efficient in reaching a high quality level already via EAF-LF route, while the VTD gives additional support to amplify the product ranges and thus satisfy any market requirements for plate production.

During the commissioning phase the process parameters definition have been tuned and defined in order to reach the following results:

- final hydrogen level in tundish < 1.6 ppm after 20 minutes of vacuum;
- final nitrogen level < 40 ppm after 20 minutes of vacuum (70 < Nitrogen initial < 80 ppm);
- sulphur after VTD < 10 ppm;
- tank vacuum pressure during the treatment < 0.5 mbar.

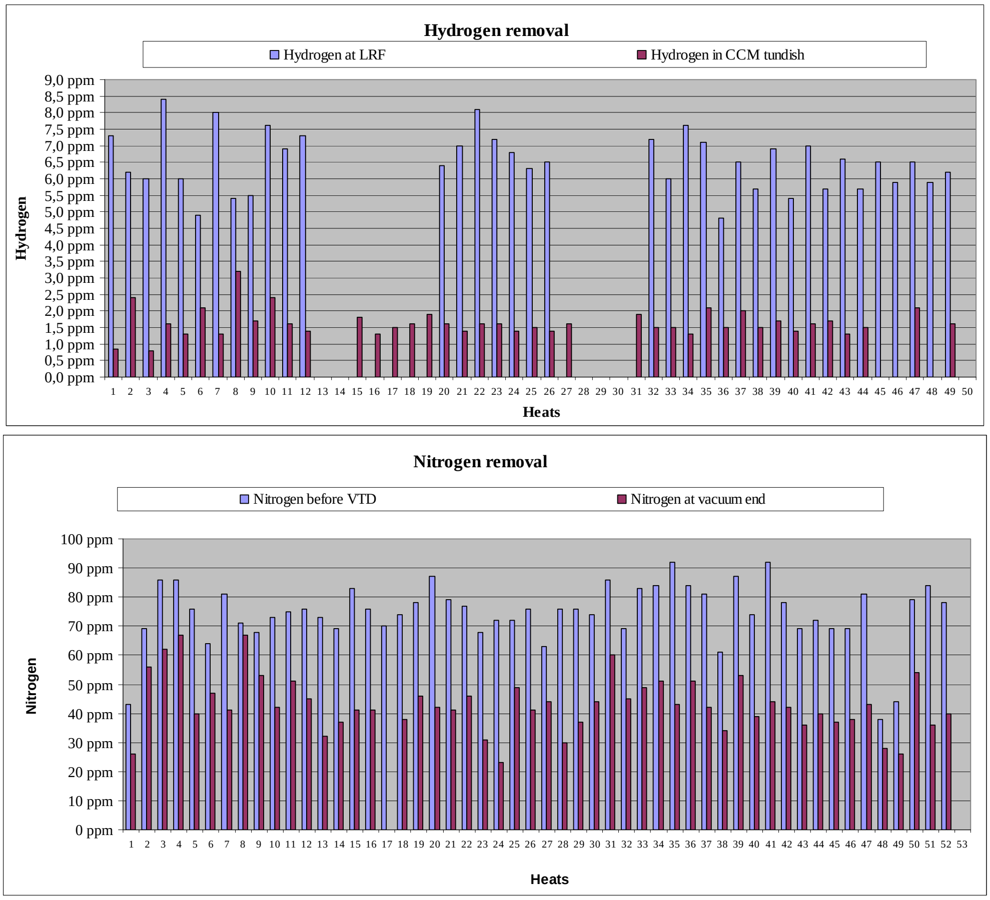

Figure 4. Hydrogen and nitrogen results during the first test phase.

Besides SSAB Alabama, the Siemens VAI team was called upon to design a tailor-made solution for Tisco (Taiyuan, China), where the 180t VOD installed is the biggest VOD worldwide to date. Plant performances have to match the high productivity rate of an integrated stainless steel line designed by Siemens VAI, with the melt shop consisting of two BOF, two EAF, two AOD and two twin LMF. The new demands of low carbon ferritic stainless steel grades required the installation of the new VOD. The process time of the VOD has to match the CCM demands. Following the performance test parameters:

- treatment cycle for low carbon ferritic grades < 73 minutes;
- final carbon + nitrogen < 130 ppm;
- hitting carbon via off gas analysis system and process models +/- 20 ppm.

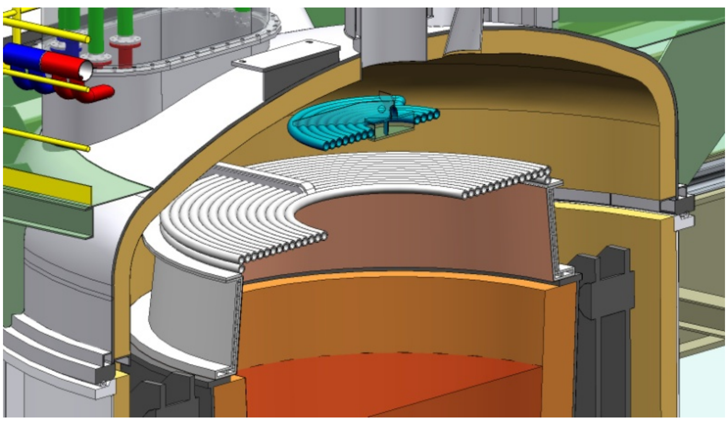

Figure 5. Copper cladded ladle roof for Tisco VOD 180t.

The VOD plant required a complete review of the standard VOD engineering solution:

- in order to reduce the skull formation under high oxygen blowing rate a new ladle cover has been designed;
- a new oxygen lance solution based on common experience from RCB EAF technology and LD converter technology has been installed;
- the existing melt shop ladle design has been modified in order to extend the steel bath surface area without requiring any adaptation of the existing melt shop units;
- a process model with integrated off gas analyzer has been developed based on previous project experiences. The off gas is analyzed with the following Siemens instruments: Oxymat for oxygen and Ultramat for carbon monoxide and carbon dioxide measurement. The off gas flow measurement is based on ultrasound measurement.

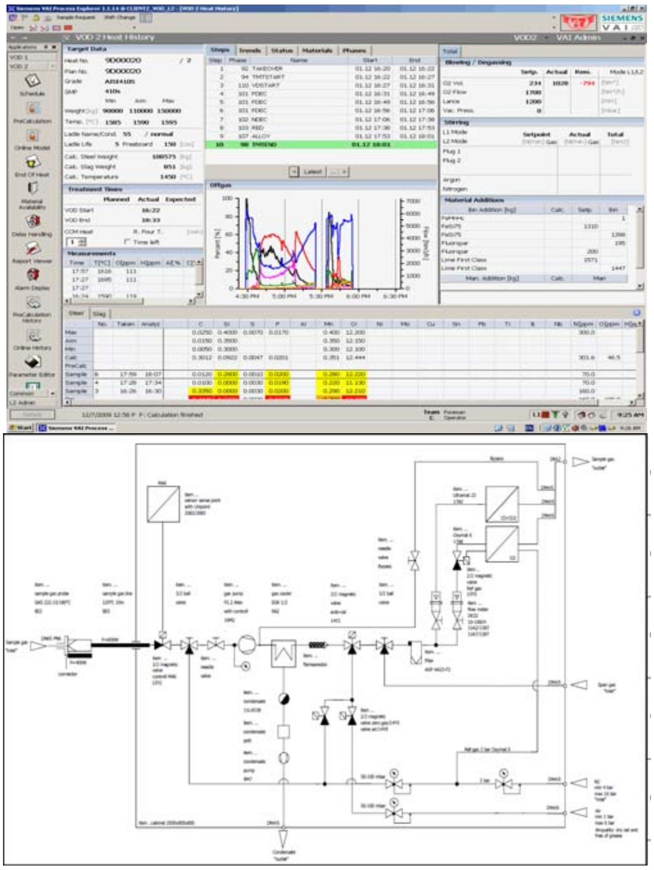

Figure 6. Process control based on an off gas analyzer.

Such new solutions are further improvements of previously developed solutions which were successfully implemented for different applications. For example, the ladle roof is based on the ladle furnace copper cladded roof used in Voest Alpine Stahl Linz where the high risk skull formation for a typical pipe to pipe design roof is minimized, due to a freeboard of 300 mm.

The VOD process produces a considerable amount of dust that affects the pump performances. The heat load during the VOD process has also to be reduced before entering the dust filters and the vacuum pump. The suction line consists of water cooled ducts, dust catcher, cooler and filters. One of the major challenges for Tisco was the installation of the twin VOD unit in a tight envelope.

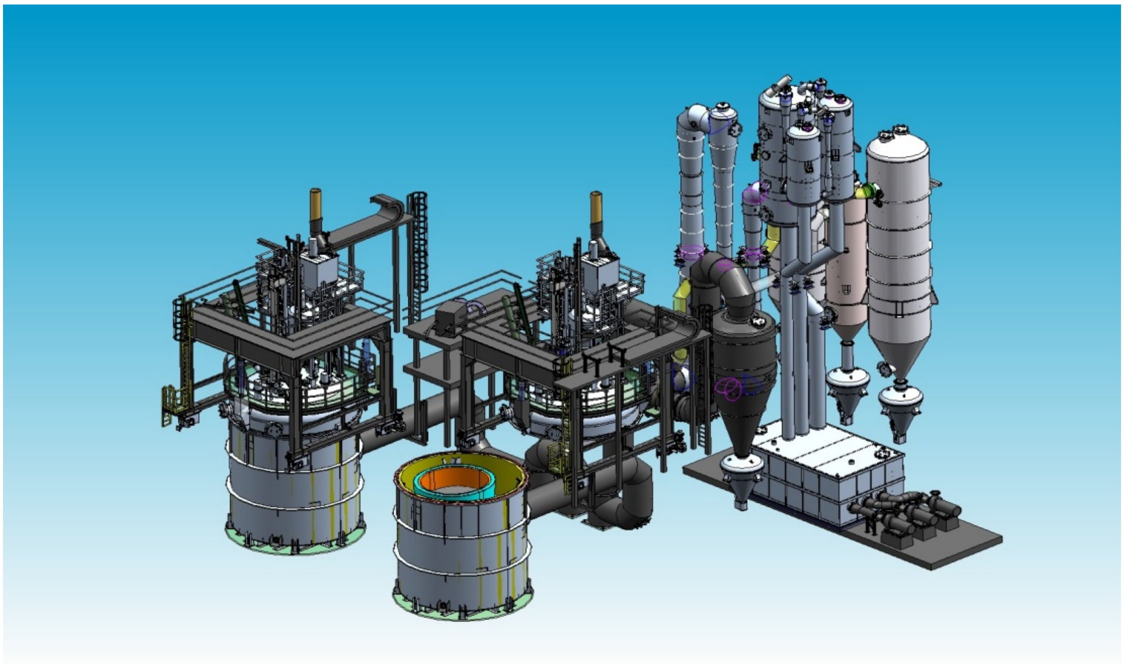

Figure 7. Tisco 180t VOD 3D Model.

4. HIGHLIGHTS OF RH PROCESS AND TECHNOLOGY RESULTS

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 (15ppm carbon is state of art design), Interstitial Free grades (no slag reaction during treatment remove the risk of Si pick up) are produced and RH plants have been successfully applied for production of pipe steel in combination with a ladle furnace and powder injection for deep desulphurization. Final nitrogen levels lower than 30 ppm and hydrogen lower than 1.2 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 during the past years in combination with LMF. The latest start up results from CSA integrated mill shop in Rio de Janeiro, Brazil will be also described.

At Zhangjiagang Hongfa (ZHF) steel plant, two single 180 t RH has been installed after previous RH installation; the plant consists of two vessel transfer cars, pre heating burners, S-COB lance and snorkel maintenance car. A steam vacuum pump is installed. The plant performances have been measured during spring 2010.

The metallurgical process is carried out in the RH vessel with the following characteristics:

- vessel diameter 2,800 mm;
- vessel height approx. 8,000 mm;
- snorkel inner diameter approx. 600 mm;
- circulation rate max 180 t/min;
- the S-COB burner reached a maximum power input of 2.5 MW during the vessel pre-heating and has an oxygen blowing capacity of 2,000 Nm3/h.

The plant is designed for a capacity of 3,000,000 t/year. The treatment time for the production of Ultra Low carbon grades, high Silicon grades and low Hydrogen and

Nitrogen grades is in the range of 27-40 minutes. A final inclusion removal phase is done at the ladle pick up position giving the possibility to integrate this activity with the snorkel spraying (typically every 4-6 heats).
Under vacuum additions are possible with a process vessel connection to the alloy bunker systems with the possibility of direct charging to the vessel for materials like Aluminium and scrap.

Figure 8. ZHF two180t RH start up (December 2009) plant overview.

The vacuum pump performances are deeply investigated during the commissioning phase in order to guarantee the maximum suction capacity during the pump down period and the oxygen blowing phase.
The vacuum pump design has considered the following process phases:

- light treatment;
- hydrogen removal;
- natural decarburization (without oxygen blowing);
- forced decarburization (with oxygen blowing);
- chemical heating.

A step-less vacuum control system adjusts the various process requirements with a special task of energy saving. Dust collection is part of the vacuum pump.
Extremely low pressure (0.3 mbar) has been reached in order to reduce the pressure equilibrium level of the gases present in the steel to speed up the process and to obtain very low level of hydrogen and nitrogen.

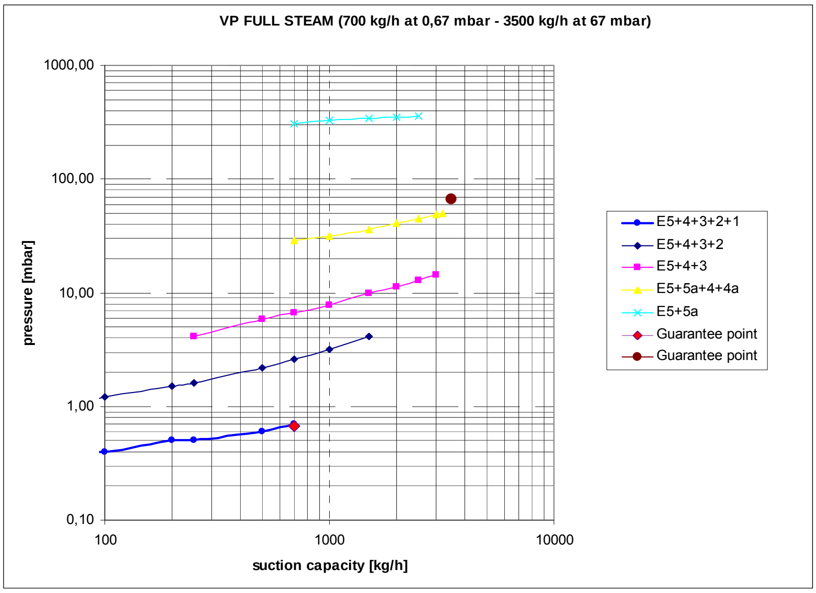

Figure 9. ZHF two 180t RH-OB pump performance data.

One of the main goals for the RH-OB is the reduction of carbon; fast treatment and reliable results are the main requirements especially for high production rate melt shop. Carbon lower than 15 ppm and close to 10 ppm are nowadays obtained. The typical practice applied for the decarburization process is a combination of natural decarburization in vacuum conditions, due to the oxygen amount present in the steel at process start, and the forced decarburization, due to the oxygen blowing. The oxygen stream penetrates the steel surface at supersonic speed, splashing occurs during this phase. The vessel geometry and the de-skulling possibility, through the use of the S-COB lance, are the measures taken to avoid any production delay.

The average ladle arrival condition for the production of ultra carbon low carbon grades are here listed:

- initial carbon < 350 ppm;
- start [O] > 600 ppm;
- sulphur and phosphorous depending on final analyses;
- Si < 50 ppm;
- start temperature > 1,580°C.

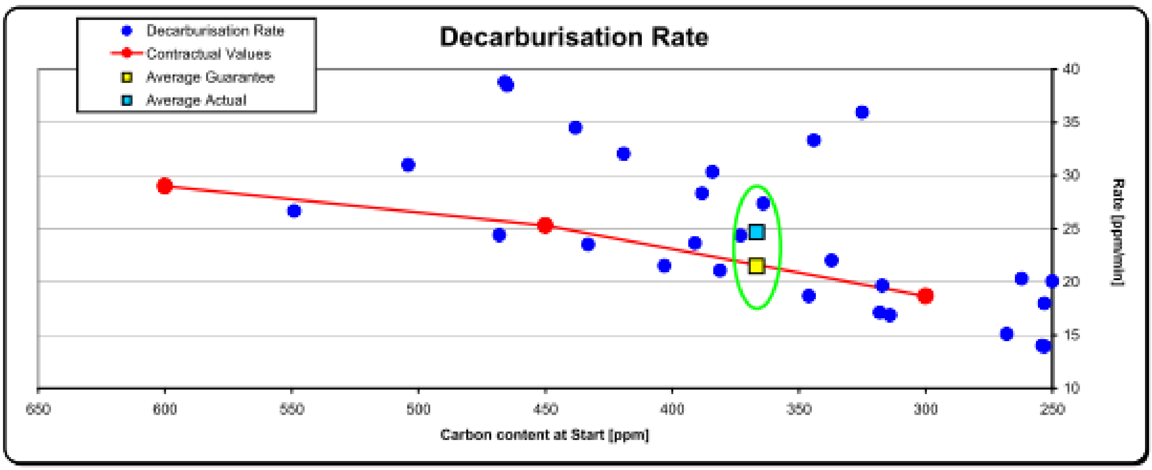

Figure 10. ZHF decarburization rate.

In terms of steel cleanness and rate of inclusions, additional tests and measurements are performed at secondary metallurgy stations in order to improve the final quality. A total oxygen content < 15 ppm and inclusion content < 20 μm are typical request from customers.

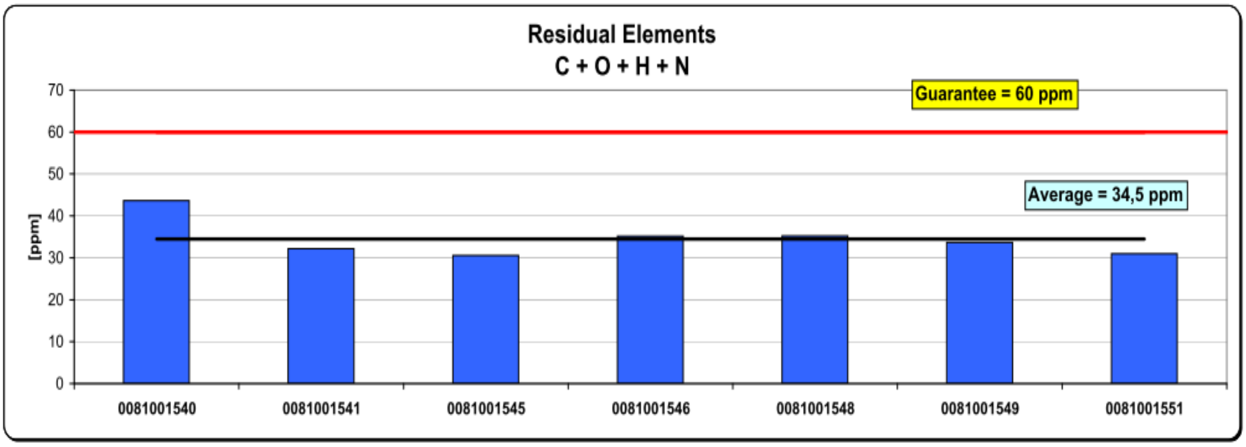

Figure 11. ZHF residual elements content.

One of our latest RH plant start-up is described in order to show the metallurgical performances of Siemens VAI plant design. ThyssenKrupp CSA in Brazil is a new steel making line installed by Siemens VAI in Rio de Janeiro (Brazil). The steel plant consists of one BOF, one AHF (Aluminum Heating Facility), one RH and one slab caster. ULC grades are part of the production, start-up of the 330t line was successfully done at the end of 2010 and during the first quarter of 2011, the performance tests have been completed for the RH and AHF. Special requirements were the high productive line and high quality; a production of 5,000,000 t/y is expected and a test of more than 50 heats per day for several days already demonstrated the capability during the performance period.
The RH-OB consists of the following main parts:

- RH vessel 3,600mm, split vessel solution for reduced maintenance cost;
- highly advance heat insulation for the RH vessel;
- snorkel inner diameter 750 mm;
- circulation rate 230 t/min;
- vessel height 8,750 mm;
- S-COB lance for decarburization, chemical heating, vessel heating and vessel de-skulling. Heat capacity 3.5 MW.

The RH-OB is equipped with a full steam pump capable of a suction capacity of 1,000 kg/h @ 0.67mbar and 6,000 kg/h @ 67mbar. The pump configuration is a typical 5 stages pump with intermediate condensers. The off gas is cooled after exiting the vessel in a combined cooler/dust separator. An Off gas analysis is performed in order to control the process reactions.

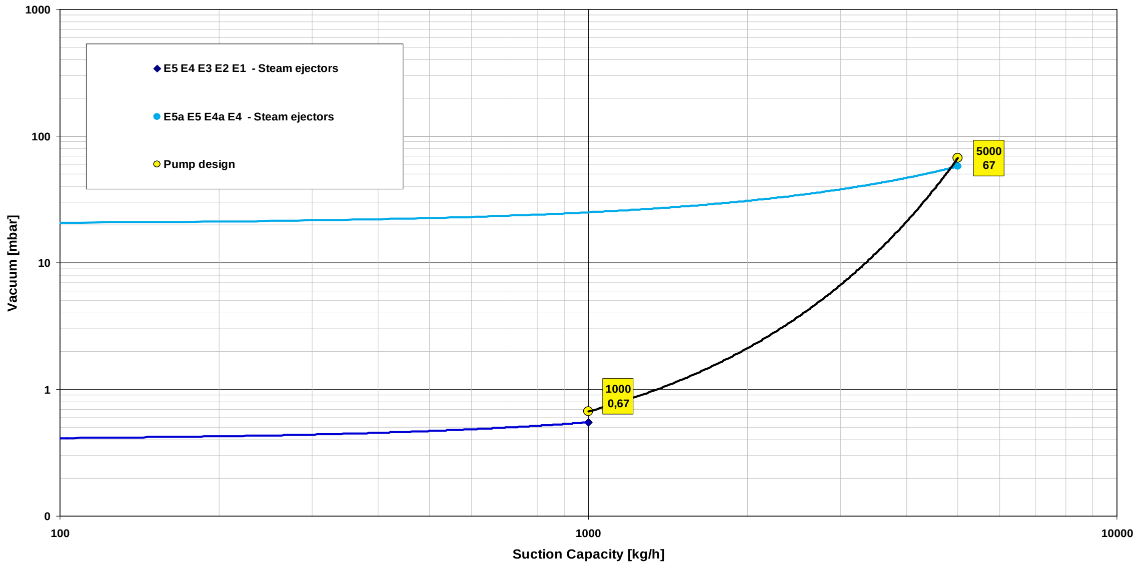

Figure 12. CSA 330t RH-OB vacuum pump performance data.

Following product mix is produced at CSA RH:

- tin plates;
- interstitial free grades;
- mild steel for cold rolling and forming;
- non-alloyed structural steel;
- micro alloyed pipe steel.

The most significant process performance is the final carbon level reached at the end of the RH process. An average Carbon content of < 13 ppm average has been obtained; several heats during the performance test also reached a carbon level < 10 ppm.

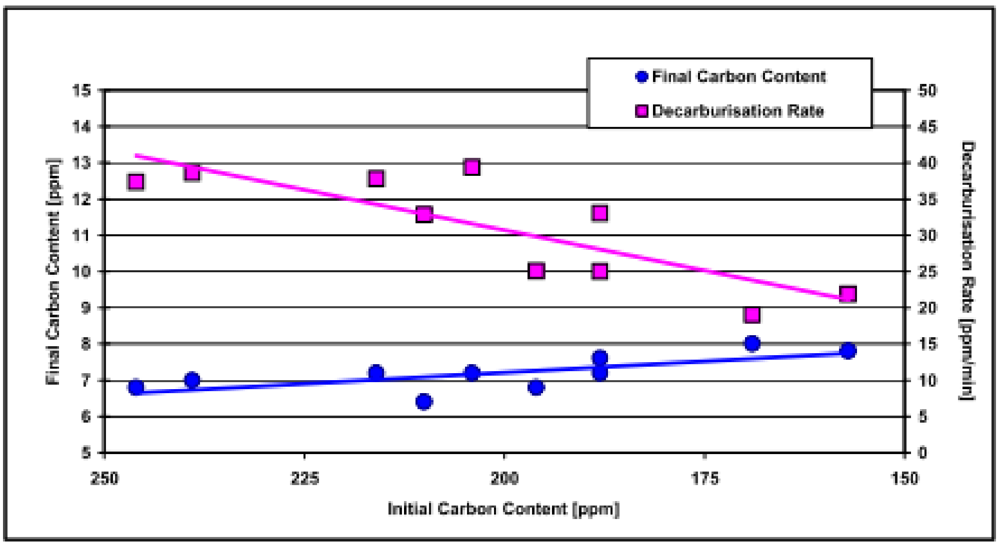

Figure 13. CSA 330t RH-OB decarburization results.

Table 1. CSA 330t RH-OB main performance test results

Contractual Guarantees Status			CSA 330t RH-OB	
			Contractual	Test results
Decarburisation	C_{end}	[ppm]	<15	11,7
	C_{init}	[ppm]	300	221
	Time	[min]	15	18,4
Treatment Cycles		[Group]	ULC	IF
		[min]	35	34,7
Chemical Heating		[°C/min]	3,5	7,6
Skull Removal		[t/h]	4	4,9
Temperature accuracy		[°C]	±5	4,5

5 HIGHLIGHTS OF RH

5.1 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 offers an easy access for refractory lining and repairing. With the aim of minimizing refractory consumption and 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.

5.2 S-COB Lance

In modern RH, a water cooled S-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 nozzle. To ensure that the system is tight during vacuum treatment, an inflatable sealing is installed in the stuffing box (Siemens VAI patent).
A brand new development is the replacement of the maintenance intensive ignition burner with an electrical ignition system - a spark generator - which is capable to ignite the main burner without ignition flame (patent pending).

5.3 Alloy Addition System

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

5.4 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 the benefit that the RH vessel platform can be well accessed and vessel exchanges 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.

5.5 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 mini-mills. Siemens VAI has 4 of such installations in contractual phase – 2 for VD, 1 for VOD and 1 for RH.

5.6 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 and 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 helps to check the oxygen jet stream. Alternatively, the camera can be installed in the S-COB lance, expecting benefit on observation of the refractory surface, particularly at the lower part of the vessel, where the wearing is higher than in other parts.

6 CONCLUSION

Siemens VAI is committed to offering High-End solutions to meet the request for increased productivity, quality and efficiency.
VTD and RH plants are designed according to the latest requirements and are the object of R&D programs aimed at guaranteeing continues improvements. Process parameters and plant commissioning data are reviewed and studied continuously. After sales support and close contact to the steelmakers provides additional information for product development.
Plant performances are no longer stand alone requirements; vacuum plants solutions are increasingly demanding as know how resources for green solutions become available. The ecological foot print is now one of the main focuses during the project phase.
Actual vacuum plant start-up results show extreme high quality achievements in terms of cleanliness and residual elements content.
Continuous tests and focus on research and development of all steel making related processes and equipment parts guarantee that Siemens VAI is offering the State of Art Technology.