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VACUUM TANK DEGASSING STATION WITH DRY MECHANICAL VACUUM PUMP FOR VD AND VOD TREATMENT AT KAMASTAL (PERM), RUSSIA[1]

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Abstract

The paper describes the Danieli first installation of a vacuum degassing system with dry mechanical vacuum pumps, which started-up in 2009. The Layout and main components of the degassing station are explained together with the characteristics of process control system which has been especially developed for this application. The metallurgical performances from the start-up, demonstrate the gases removal efficiency achievement, in the high demands quality grades.

Key words: Vacuum; Tank; Degassing; VOD.

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1 INTRODUCTION

The Kama Stahl Metallurgical Works Ltd. steelmaking facilities in Perm (Russia) have been modernized and expanded by the installation of a new Danieli degassing station, with a dry mechanical vacuum pump for a nominal 60 t heat size. With the new equipment the assortment of high-quality steel grades, cast in slabs and ingots, has been increased.
The product range includes products for applications in oil, transport, mining and nuclear industries covering alloyed steels (VD), Ultra Low Carbon grades (VD-OB) and stainless steel grades (VOD).
The successful start up of the degassing station took place in November 2009.

Figure 1. Vaccum tank degassing station.

2 MATERIAL AND METHODS

2.1 Layout and Main Components of the Degassing Station

Thanks to the compact layout together with the tank on a car, it was possible to retain with the degassing station inside the limited space of the auxiliary bay (Figure 2). The tank on the car guarantees a link between the degassing station and casting bay. This arrangement minimizes, in terms of space and time, any interference between the new degassing facility and the existing ladle transport system in the casting bay. The tank on the car occupies space in the casting bay only during the inserting and removing of the ladle from the tank.

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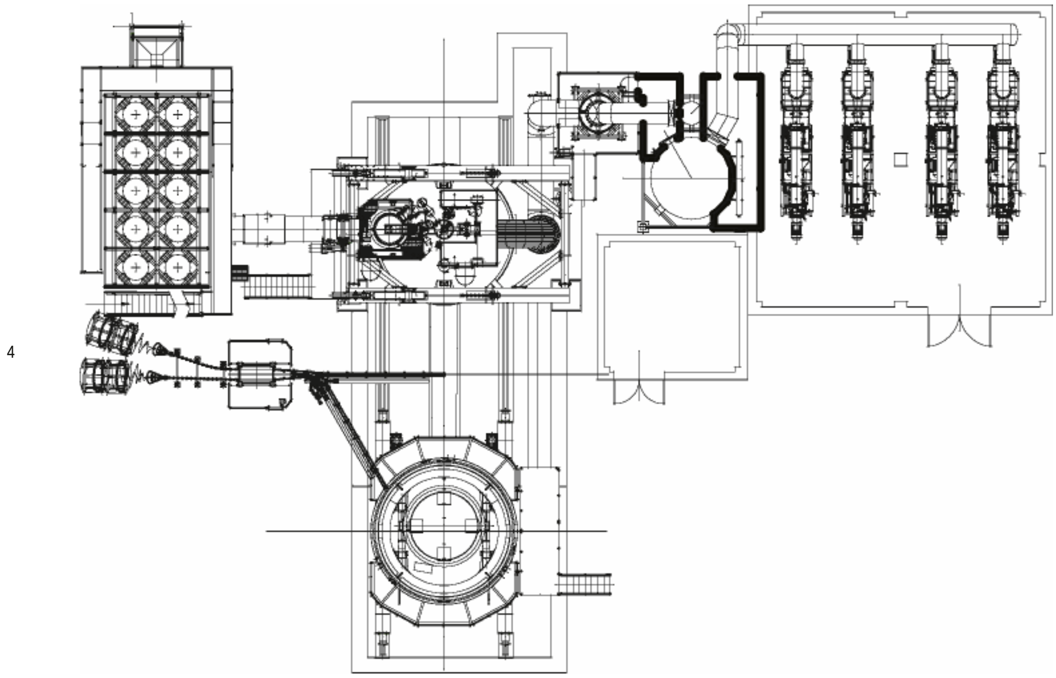

Figure 2. General Layout of the steel degassing system.

2.2 Dry Mechanical Vacuum Pump

A dry mechanical vacuum pump with four parallel skids (Figure 3) is installed to create the necessary vacuum for the different types of treatment. The installation, commissioning and integration of the vacuum pump have been done in excellent co-operation with Edwards. Kama Stahl is the first plant operating a VOD degassing station for the stainless steel production, using multiple dry mechanical pump modules for this range of heat size. The number of parallel skids, and therefore the suction capacity, has been defined based on the heat size and the treatment / process conditions. The product mix includes the production of stainless steel and ULC grades for a 55 t heat size. The treatment for the production of these grades requires a higher suction capacity than for a standard VD process. This situation forced the installation of four skids, which corresponds to about 90 kg/h of dry air at 0.7 mbar.

Figure 3. Four parallel vacuum pump skids in the pump room at KamaStal.

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Each skid consists of three pumps in series (three stages). The high vacuum booster (HV), the high compression booster (SN) and the primary dry screw pump (IDX). Between the SN pump and the IDX pump an intermediate heat exchanger (Figure 4) was installed, for the VOD process only.

Figure 4. Skid configuration of the vacuum pump. (a) Heat exchanger; (b) HV pump; (c) SN pump; and (d) IDX pump.

The well studied quantity and position of the sensors allows detailed online monitoring of the vacuum system and supports, together with the recorded trend files, well-focused maintenance activities (Figure 5).

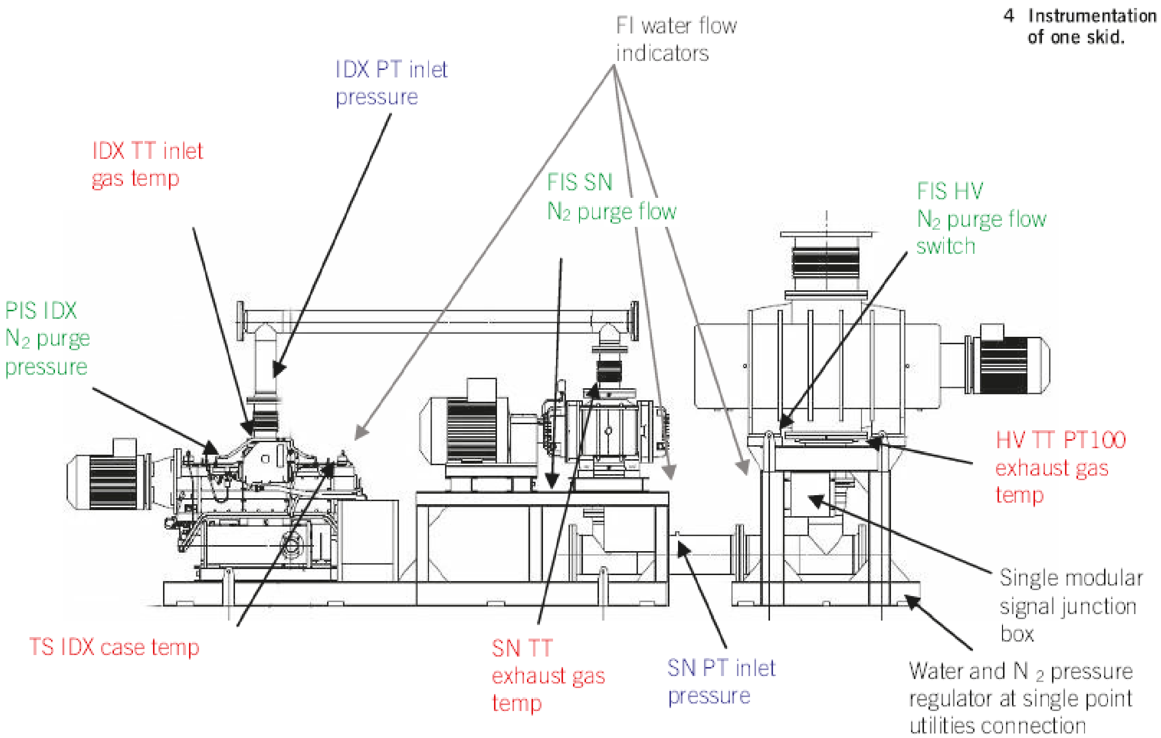

Figure 5. Instrumentation of one skid.

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2.3 Main Equipment Components

- Vacuum tank on car (tank diameter 5.2 m) > tank cover with pinhole camera, oxygen blowing lance and vacuum batch hopper;
- raw material handling system with 10 bins > wire feeder system with 4 lines;
- suction line with cyclone, main shut off valve, gas cooler and textile filter;
- separate nitrogen flooding for bag filter and vacuum tank;
- four-skid dry mechanical vacuum pump with intermediate heat exchanger and individual skid valves (suction capacity approx. 90 kg/h at 0.7 mbar).

The pumping speed of each single pump is controlled via VFD. This regulation guarantees, apart from the others, the maximal possible pump speed without overcoming the maximum allowable current. Different “pump step configurations” can be chosen via HMI to eventually slow down the pump speed in case of strong slag foaming. Additionally, to the “pump step selection” Danieli integrated successfully a full PID control loop acting on the booster global frequency, including skid selection to achieve active and accurate pressure regulation throughout the VOD process over a wide range of suction capacity.

Kama Stahl is the first plant in the world to use this complex control for a steel degassing system using dry mechanical vacuum pumps.

Figure 6 illustrates the vacuum target pressure and the regulated vacuum pressure during a VOD process.

The requested lower pressure for the main blowing with respect to the initial blowing can be achieved only with the shown ramp (gradient) in the graph. The maximal possible ramp is driven by the actual maximum possible suction capacity and the actual gas evaluation.

The maximal possible suction capacity is commanded by the maximum possible pump speed, which is limited by the maximum allowable current via VFD. Therefore, it is not possible to achieve immediately the requested, much lower vacuum pressure.

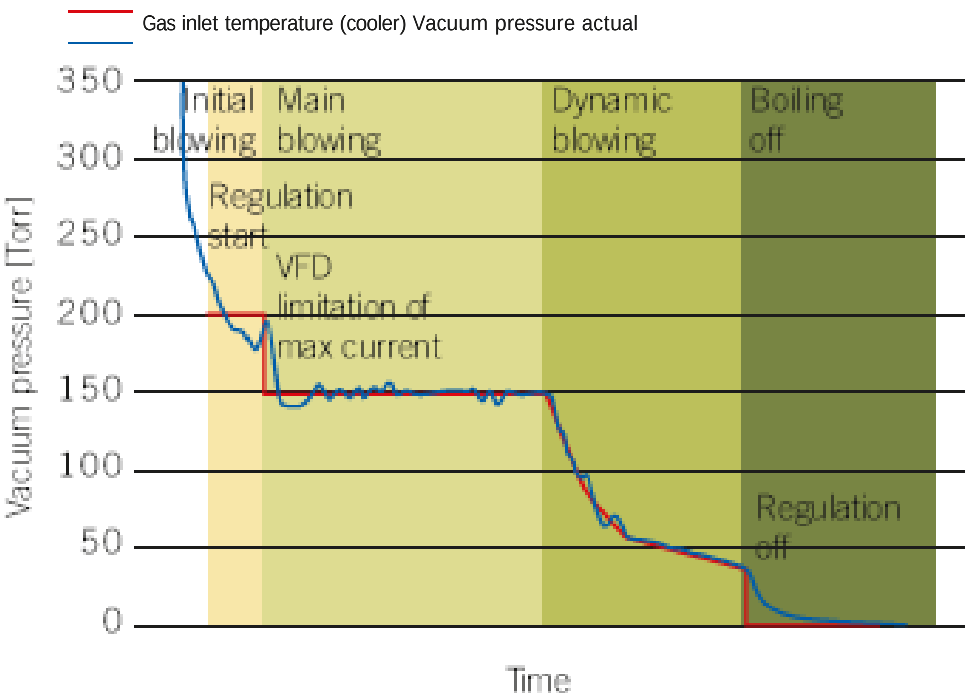

Figure 6. Full automatic pressure regulation during VOD process.

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2.4 Suction Line

The dry mechanical vacuum pumps require a cleaning of the process gas. A certain amount of dust can be tolerated but this amount is less than the quantity arriving from the steel degassing process.
In the suction line's integrated filter guarantees the required dust separation from the process gas.
The filter has its own automatic cleaning system, which is activated after each treatment cycle in order to keep the filter bags as clean as possible.
The cleaning is done by many short injections of nitrogen. Based on the fact that the filter bags have to be protected against gas temperatures rising too high, which happens during the VOD process, a gas cooler is installed directly prior to the filter. At Kamastal an additional cyclone has been installed with a cooling effect for a pre-filtration in order to reduce the dust flow to
the gas cooler. This reduces the frequency of cleaning intervals of the cooler.
Figures 7 and 8 shows the temperature pattern of the gas temperature at the cooler inlet for a VOD and a VD treatment.
The two graphs (Figures 7 and 8) show that the additional gas cooler in front of the filter is needed only for the VOD process, while the VD process will not create gas temperature problems for the bags of the textile filter.

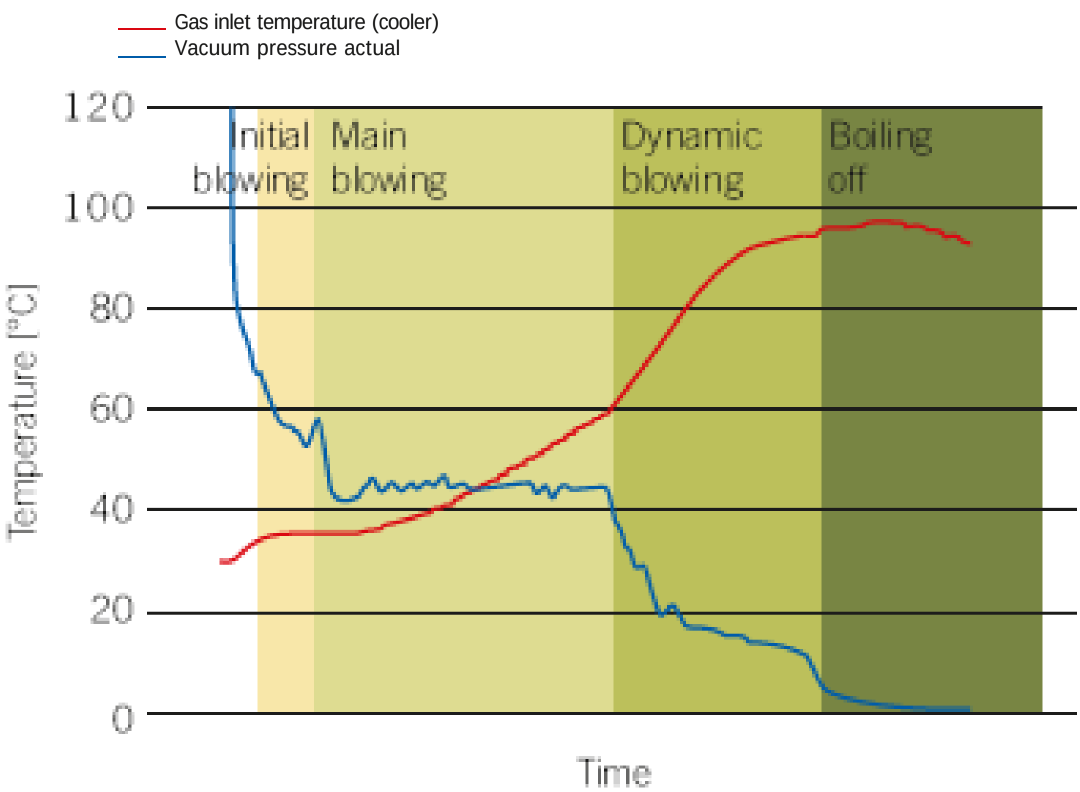

Figure 7. Pattern of process gas temperature at inlet of gas cooler during VOD process.

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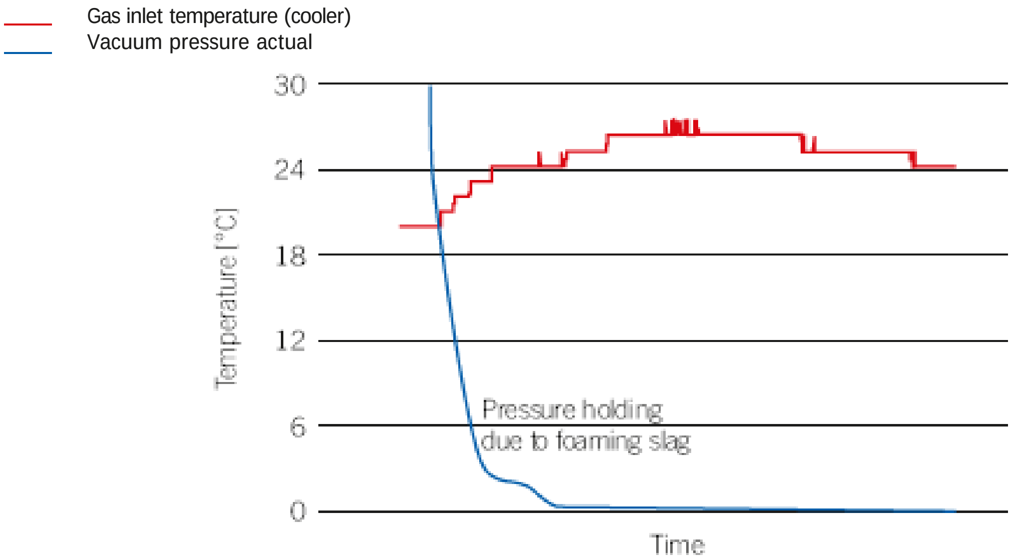

Figure 8. Pattern of process gas temperature at inlet of gas cooler during VD process.

2.5 Automation and HMI System

The new Steel Degassing Plant is equipped with a detailed and complex automation Level 1 and Level 2 system, which guarantee fast and easy guiding of the equipment and meet the high demands for steel quality for the wide ranging product mix. As an example, for the VOD process all process data are calculated by the Level 2 (e.g., oxygen blowing parameters, vacuum pressure settings, reduction and alloying material additions, etc.) and then sent to the HMI for equipment guiding.
Shown here is an example (suction line with pump configuration) of one of the principal HMI pages (Figure 9). Simply by clicking on the illustration of any single process equipment it will be open a window with more detailed information (Figure 10).

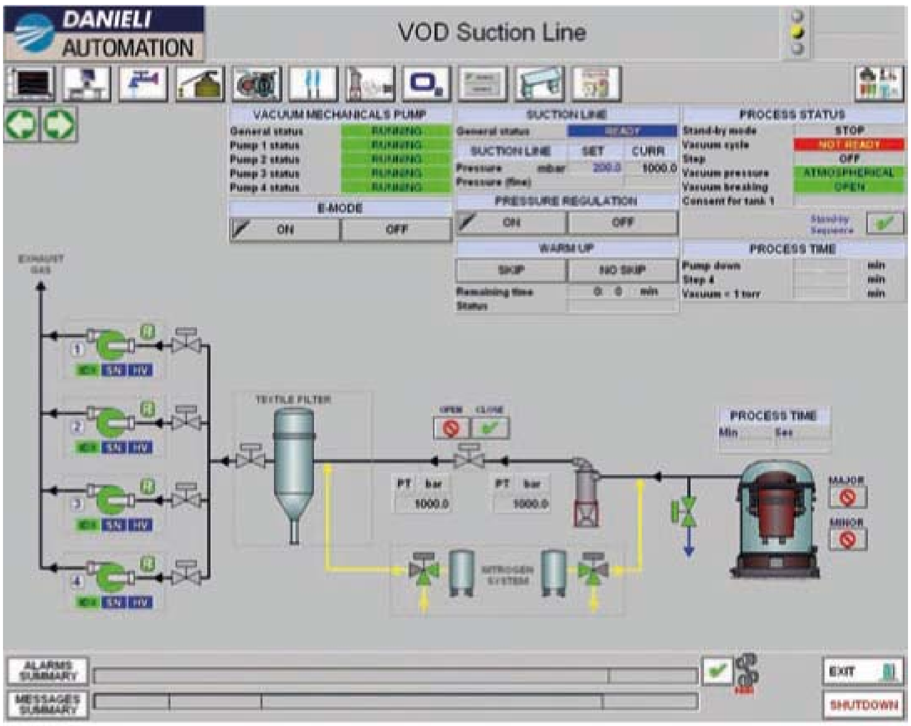

Figure 9. HMI page “VOD Suction Line.

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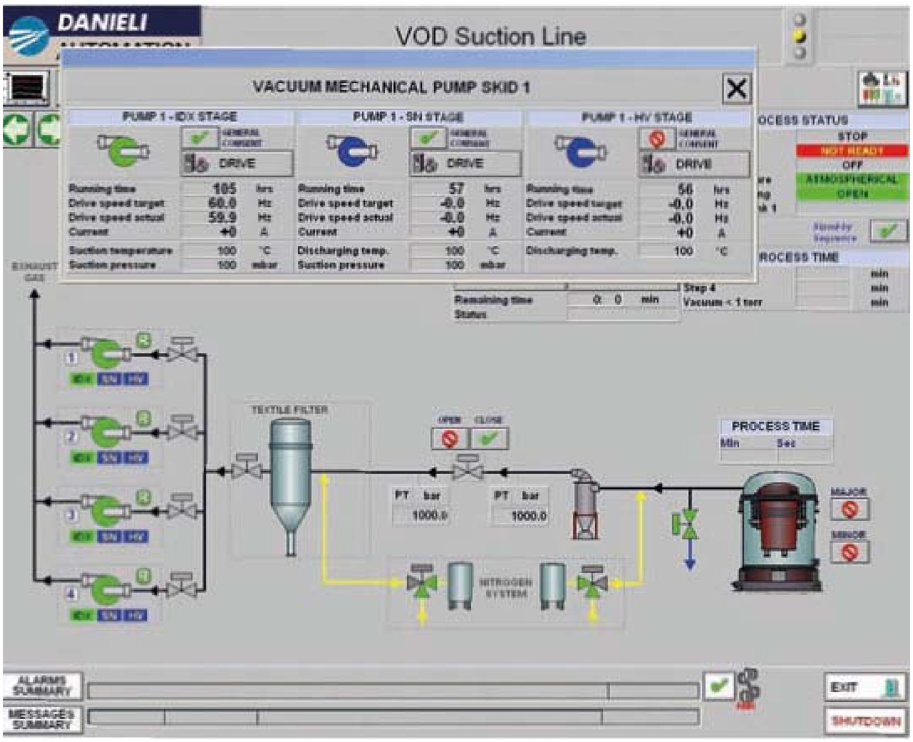

Figure 10. HMI page "VOD Suction Line" with detail window mechanical pump skid 1.

3 PERFORMANCE RESULTS AND DISCUSSION

The metallurgical performance guarantees for degassing already have been achieved already from the start-up.

Figure 11 shows the nitrogen content and the nitrogen removal over the initial nitrogen content for low-alloyed Al-killed steel grades. The targeted nitrogen reduction of 35% or greater was achieved, and it has been maintained in all performance heats.

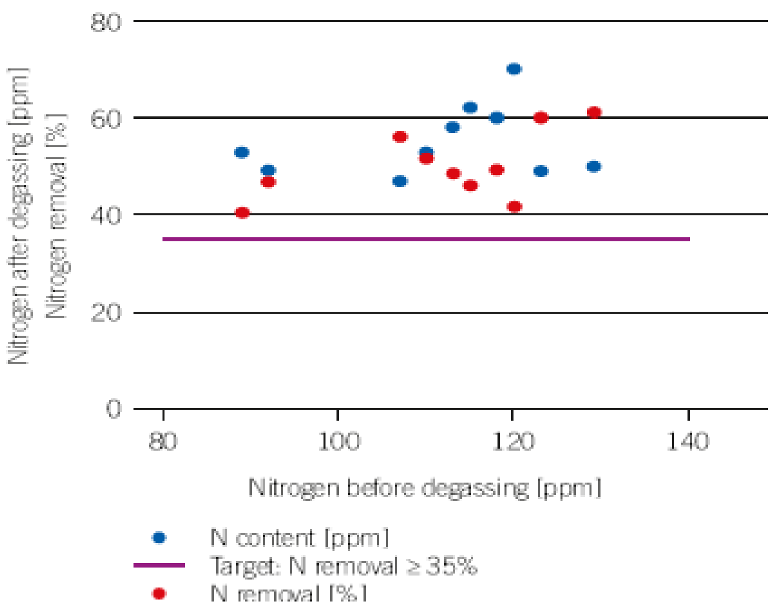

Figure 11. Nitrogen removal of VD performance heats.

Figure 12 shows the hydrogen content over the initial hydrogen content for low-alloyed Al-killed steel grades.

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The high demands on the quality of the performance grades made it necessary to achieve a target of maximum allowable hydrogen after degassing of maximum 1 ppm or less. The target has been matched during all the performance heats.

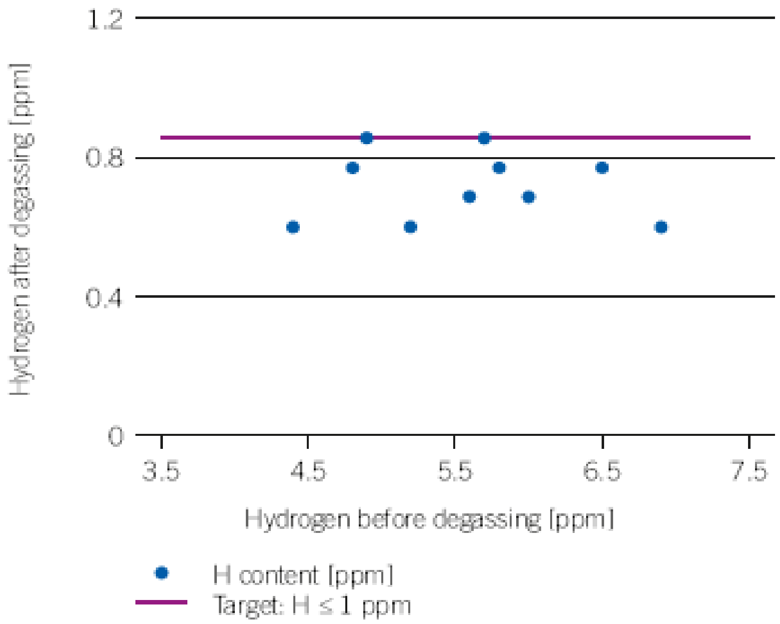

Figure 12. Hydrogen removal of VD performance heats.

Figure 13 shows the carbon content after De-C over the initial carbon content.
The target maximum carbon content after De-C was to not exceed 0.02%. The target has been matched by all the performance heats.
Thanks to well chosen equipment components, the precise installation of the equipment, and good maintenance it was possible to keep the leakage rate of the vacuum system at a low level of less than 15 kg/h from the first heat on.

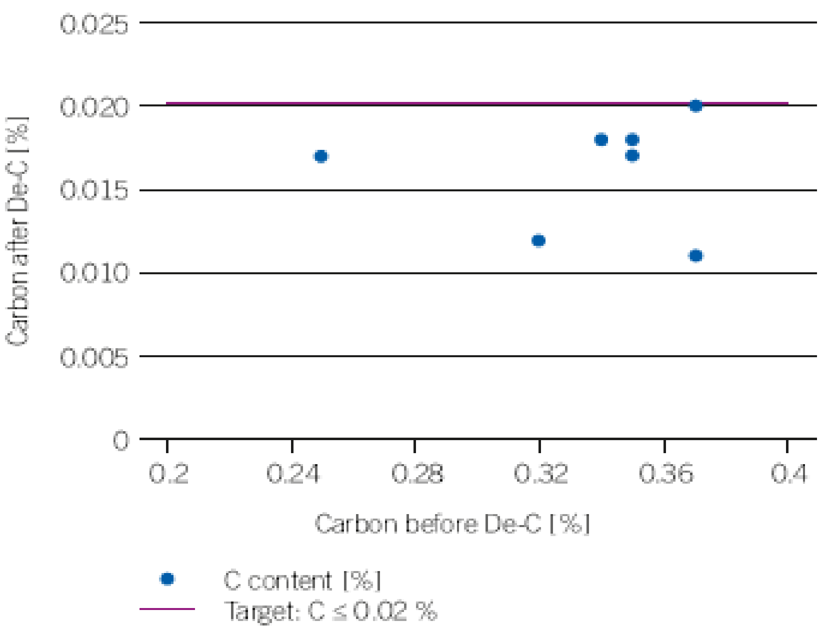

Figure 13. De-C results of VD performance heats.

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4 CONCLUSION

The first Danieli steel degassing station with dry mechanical vacuum pump has shown very good performance results from the first heat. The well designed equipment together with the detailed automation system and the good maintenance activity make the system operate very well. The generally lower suction capacity of the dry mechanical vacuum pump, compared to degassing stations with a similar heat size but with steam ejector vacuum systems, demonstrated the ability to meet the same high demand for steel quality. Also, the pressure regulation capability of the dry mechanical vacuum pumps has been used efficiently, which is used at Kama Stal for the vacuum decarburization.