LD STEELMAKING AT VOESTALPINE STAHL GmbH, LINZ

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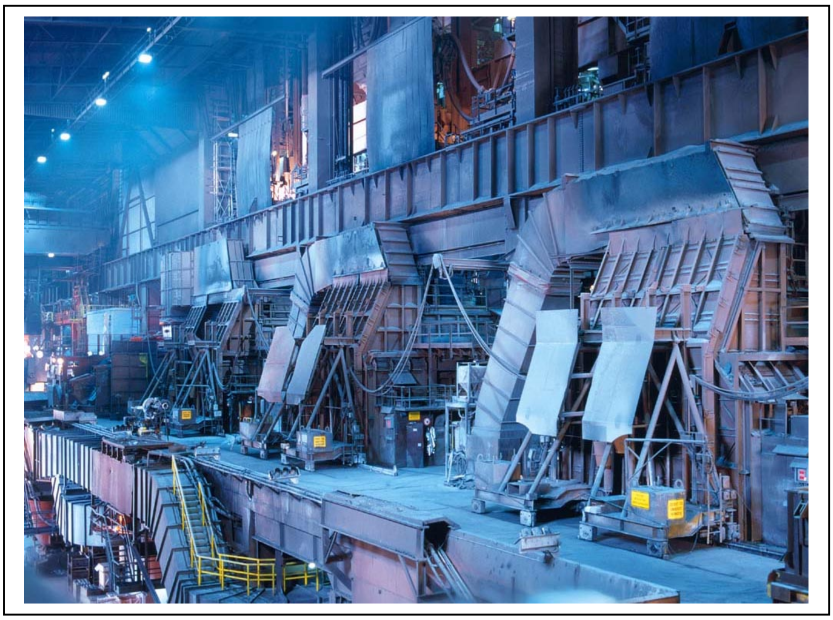
ABSTRACT/SUMMARY: The LD steelmaking plant #3 of voestalpine Stahl Linz with its three 150-ton converters is one of the most efficient and productive steelmaking plants in the world, where 4.4 million tons of slabs are produced with an average daily production of 80 heats. Over the past few years, the refractory lifetime of the converters was doubled, the three-converter operation was raised to more than 78 %. Because of lack of hot metal at the location, the specific scrap rate per Ton of good slab was increased up to 330 kg/t and the specific hot-metal rate was reduced to 776 kg/t. The Slag Splashing technology was implemented, hot-metal desulphurization was converted from torpedo ladle operation to co-injection in the charging ladle.

Keywords: converter, refractory, hot metal ratio, hot metal desulphurization, slag detection



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1 INTRODUCTION

During the past few years, the production volumes of the LD steelmaking plant (Fig. 1) were continuously increased in order to meet market requirements. Six years ago only 3.6 million tons of steel were produced from 23,986 heats, whereas today 4.4 million tons are produced from more than 28,250 heats (Fig. 2).

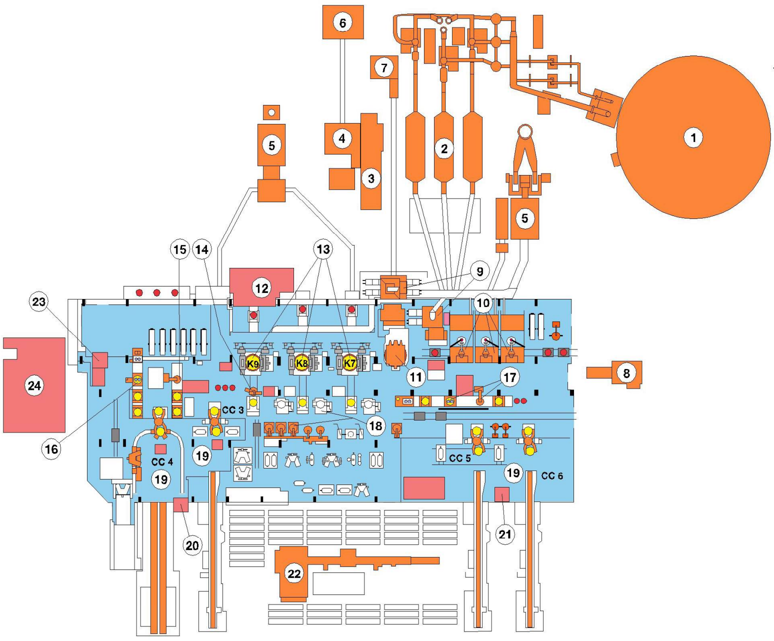


Fig. 1: Layout of the existing Steelmaking Plant LD3 of voestalpine Stahl GmbH, Linz.

This production increase was made possible by the startup of

- the second ladle furnace and the second RH plant in February 2000
- by exchanging the three converter vessels in 2001
- by installing 18 new teeming ladles in 2000 and 2001, as well as by
- converting the hot-metal desulfurization from the torpedo ladle on a calcium carbide basis to co-injection in the open charging ladle on a calcium carbide and magnesium basis in August 2001.

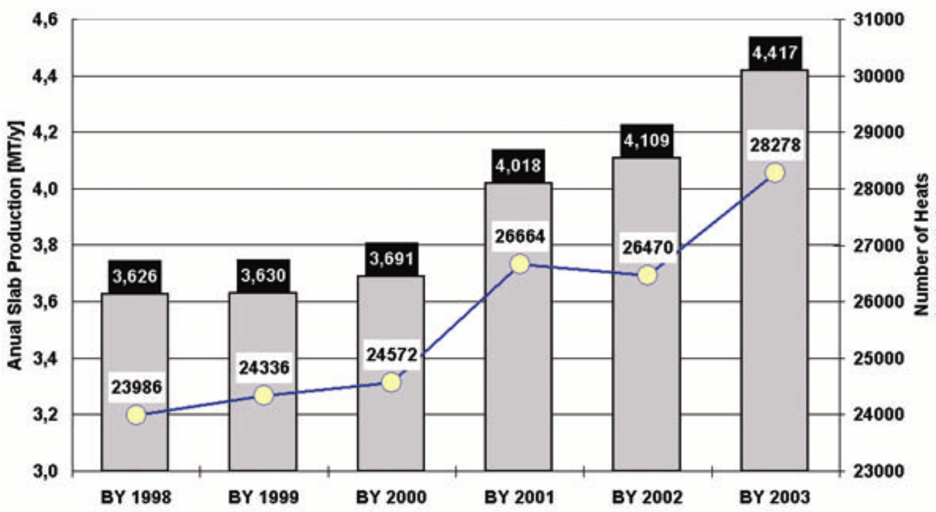


Fig. 2: Production at LD3, 1998–2003

2. HOT METAL SUPPLY AND HOT METAL DESULPHURIZATION

The steelplant is supplied with 10,000 t of hot metal per day from three blast furnaces. Of this, 5,500 t per day come from the big blast furnace A which has a diameter of 10.5 m and around 2,300 t per day from the two smaller blast furnaces which have a diameter of 8 m each. The hot metal is delivered by means of torpedo cars. There are usually eleven torpedo cars being used, which have an average filling volume of 280 t. The hot metal is transferred from the torpedo cars into the charging ladles at the two reladling stations. Following this the hot metal is desulphurized down to the required sulphur content in the 2 treatment stands of the new hot metal desulphurization plant. The average sulphur content in the hot metal prior to treatment is about 0.059%. Fig. 3 shows the frequency distribution of the sulphur content in hot metal in 2003.

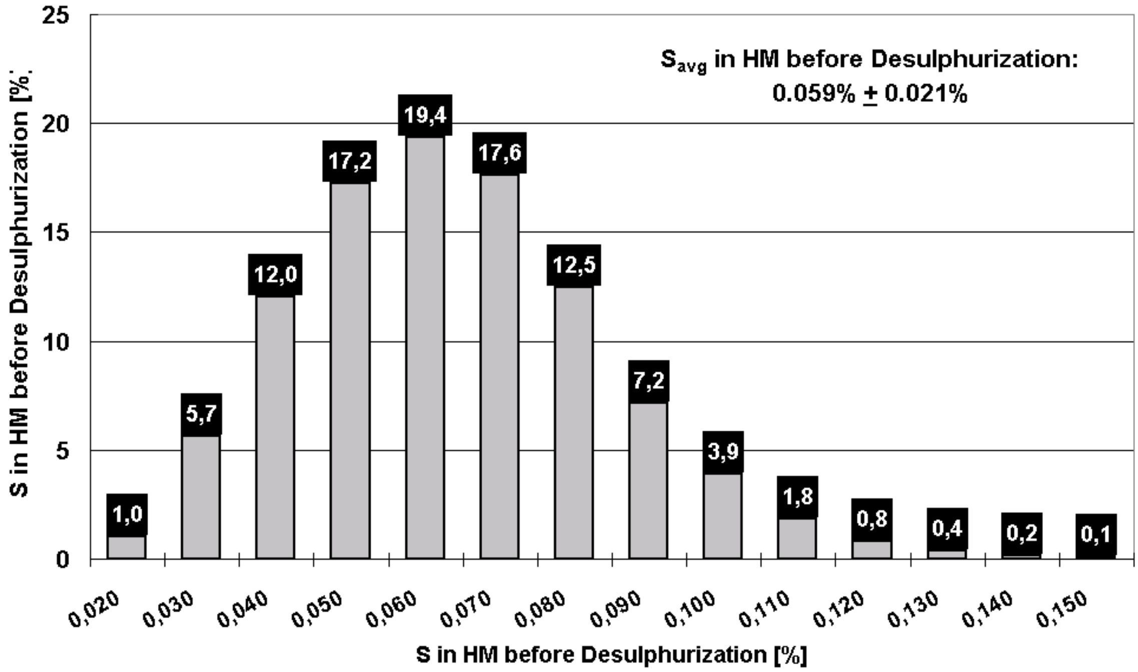


Fig. 3: Frequency distribution of the sulphur content in hot metal prior desulphurization in 2003.

Different desulphurization processes are used depending on the sulphur content of the hot metal prior to treatment and the sulphur content which is required by the LD-process and the treatment time available, by changing the ratio of CaC2 to Magnesium. The coinjection process with a 5:1 ratio of CaC2 – magnesium was the most used process in 2003 with 43.4%. Fig. 4 shows the distribution of the processes used during the last year. Beside the three coinjection processes approximately 19 % of all treatments are carried out with monoinjection on a CaC2 basis.

There are approximately 80 treatments per day carried out on the new desulphurization plant, with treatment times of 20 min (Table 1)—9 min for injection and 5 min for deslagging. The lifetime of the injection lance is approximately 1200 min, corresponding to roughly 130 heats. The hot metal losses are approximately 5.5 kg/t.

After deslagging the hot metal is charged in one of the 3 LD- Converters. In case of delays the desulphurized hot metal is poored into the 2000 t hot metal mixer, which is used as a buffer. Last year about 4,6 % of the hot metal charged into the LD-vessels came from the hot metal mixer.

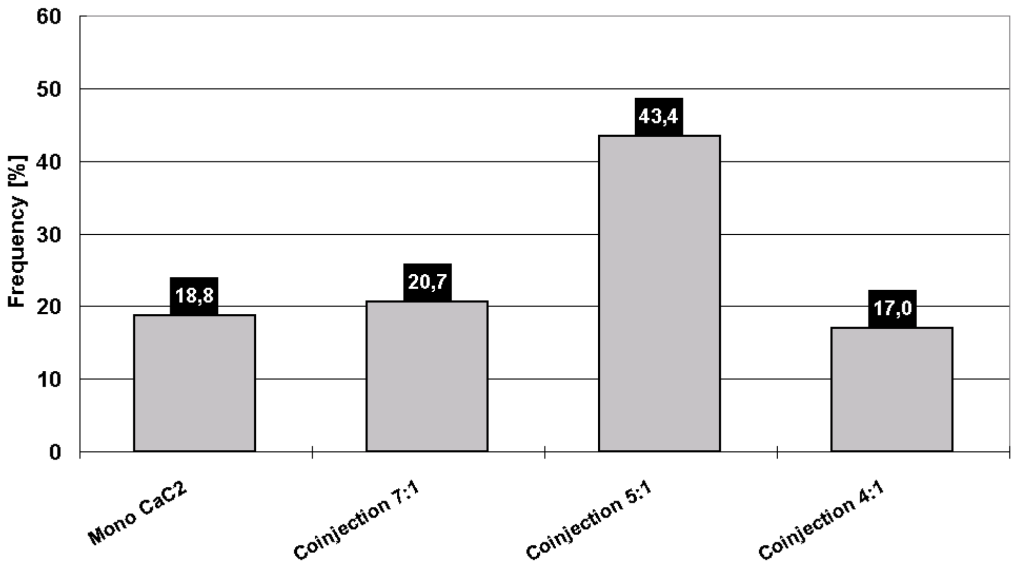


Fig. 4: Frequency of desulphurization processes used in 2003

The average hot metal analysis charged into the LD-vessels has 4,47 % C, 0,68 % Si, 0,68 % Mn, 0,072 % P, 0,005 % S, whereby the analyses from the three blast furnaces vary considerably. The average charging temperature is about 1,337°C.

Table 1: Operating Results of the New Co-injection Plant

Treatment time	20 min
Injection time	9 min
Deslagging time	5 min
Hot-metal quantity	125t
CaC_2	2.5 kg/t
Mg	0.4 kg/t
Lance lifetime	1,200 min
Fe losses	5.5 kg/t
S_A	0.059%
S_F	0.0049%
Hot-metal temperature prior to treatment	1,349°C
Hot-metal temperature after treatment	1,337°C

3. TECHNICAL DATA OF THE LD-CONERTERS

The three LD - Converter vessels were exchanged in the BY 2001 and BY 2002 during full-load operation within the shortest possible period of time. The revamping times, from tapping the last heat until start of blowing the heat at the new vessel, ranged from 28 days at converter #7 to 22 days at converter #9.
The new LD-vessels have a working volume of 115 m^3 (Tab. 2) The average amount of liquid steel which is tapped is about 160 t. Each converter has twelve bottom stirring elements, each of which has its own valve stand. The oxygen lance has a six hole lance tip with an angle of 15°.

The blowing rates vary between 530 and 590 m3/min depending on the refractory lifetime of the converter. This corresponds to a specific blowing rate of 0.22 – 0.25 m3 / t min.
Each converter is further equipped with a sublance which is however not used for the inblow measurement. The carbon content at the end of blowing is determined by an offgas model.
At the end of blowing the following measurements can be carried out by the sublance:

- Temperature
- Temperature with sample
- Temperture with oxygen activity
- or Temperature with sample and oxygen activity.

An Infrared slag detection system in combination with a pneumatic slag hammer is used for the purpose of carry over slag detection and prevention.

Table 2: Technical Data and Dates of Converter Vessel and Teeming Ladle Exchange

Number of Vessels	3
Type	LD-S
Working volume [m^3]	115
Steel tap weight [t_{liquid}]	160
Spec. working volume [m^3/t]	0.71
Number of Bottom Stirring Elements	12
Lance	6 hole / 15°
Blowing Rate [m^3/min]	530 - 590
Sublance	T, TS, TO, TSO
Slag Retaining System	Pneumatic Hammer
Slag Detection	IRIS (Infra Red System)

4. PRODUCTIVITY AND PROCESS TIMES

Fig. 5 shows the monthly development of the LD process times. The sum of the process times is between 29.1 and 31 min. Approximately 5 min are needed for scrap and hot metal charging. The average monthly blowing time is 14.7 min. The remaining time of the liquid steel in the converter between end of blowing till start of tapping is 5.5 min on an average, and the tapping time is between 4.5 and 4.7 min. In the current business year on an average 80 heats are being produced.
The actual tap to tap times vary between 34.4 min in a three vessel operation and 30.3 min in a two vessel operation. Due to the increase of the refractory lifetimes of the LD - Converters a three vessel operation could be raised up to 78.8 % in the actual business year.
On January the 20th 2004, 96 heats per day were produced in a three vessel operation for the first time. The record for a two vessel operation is 92 heats per day and for only one vessel 51 heats.The maximun monthly production of liquid steel in the steelplant was reached in October 2003 with 400,500 t. This corresponds to 2547 heats per month or an average of 82.16 heats per day.

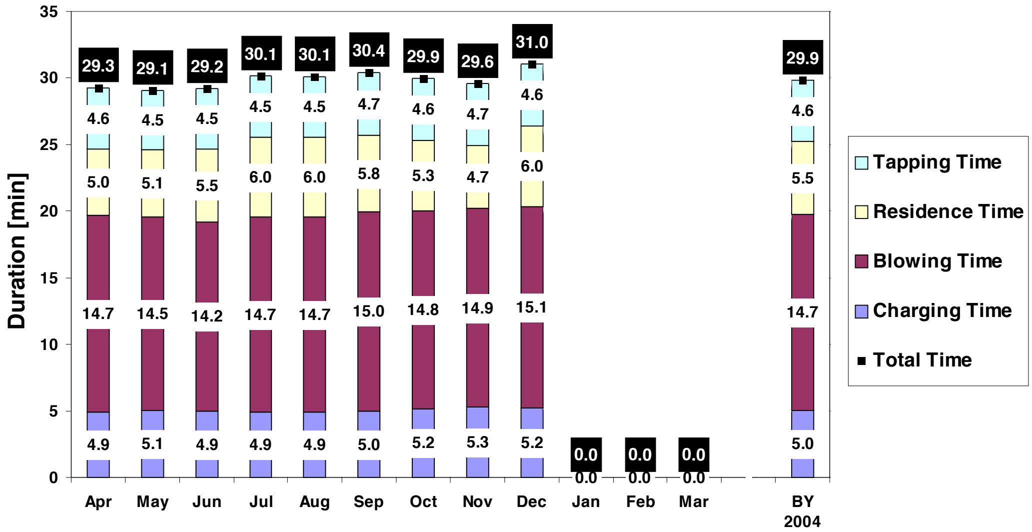


Fig. 5: Development of the process times at voestalpine Stahl GmbH, Linz

5. CARBON CONTENT AT END OF BLOWING

The determination of the carbon content at the end of blowing is detected by an offgas model. Fig. 6 shows the distribution of the targeted carbon content in 2003. Originally only three different types of targeted carbon content namely 0.025%, 0.03% and 0.04% were installed. About 80% of the heats produced have an aim of 0.03%. Since October 2003 trials with 0.05% and 0.06% are have been carried out.

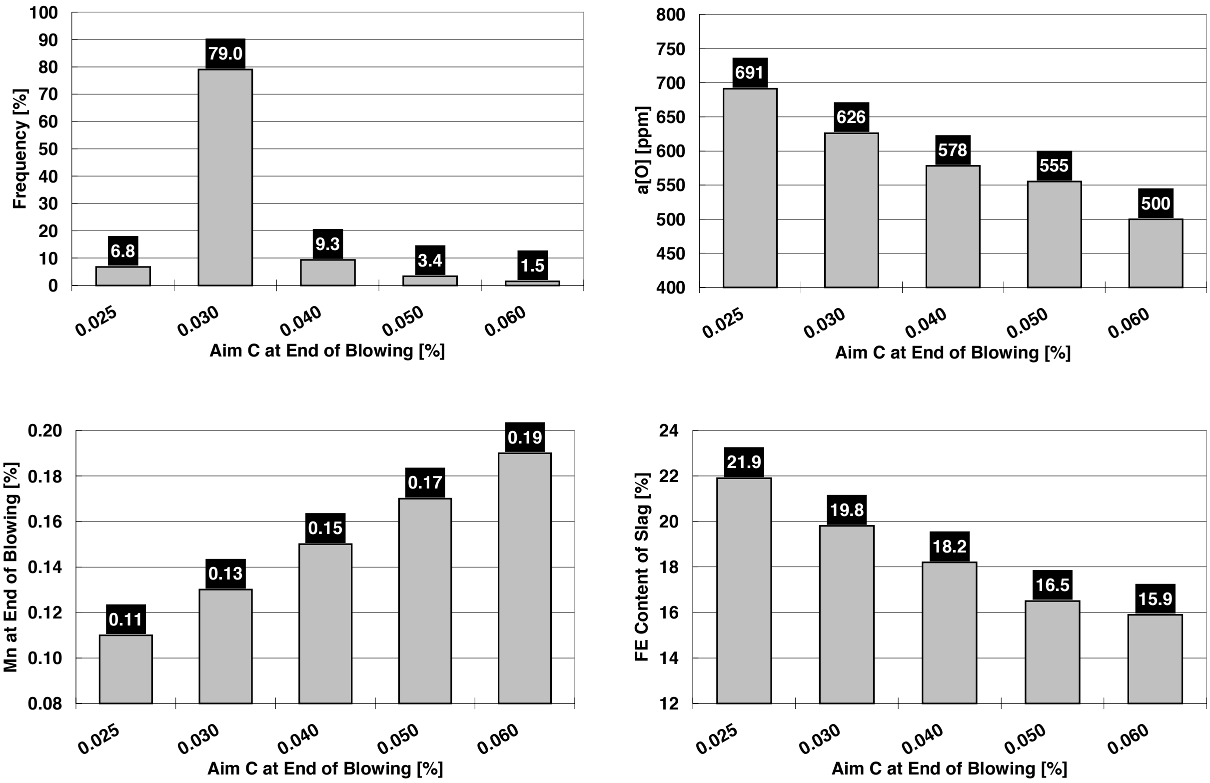


Fig 6: Distribution of aim carbon content, oxygen activity, Mn in steel and Fe content in slag at the end of blowing

Up to now about 3.4% with target 0.05% carbon and 1.5 % with 0.06 % carbon of the production have been produced. The benefits of tapping with higher carbon levels can be summarized as follows:

- Lower oxygen activity
- Higher Mn content
- Lower Fe content in slag

Within the next few months the ratio of higher carbon contents will be increased, to gain the all the benefits such as a higher yield, reduced FeMn and Al consumption as well as the positive impact on the refractory lifetime and steel quality.

6. INCREASE OF TAPPING DIAMETER AND CARRY OVER SLAG

In 2001 all three converters were equipped with the infrared slag detection system IRIS. This system replaced the EMLI system. The replacement was due to its lower maintenance effort and higher reliability.

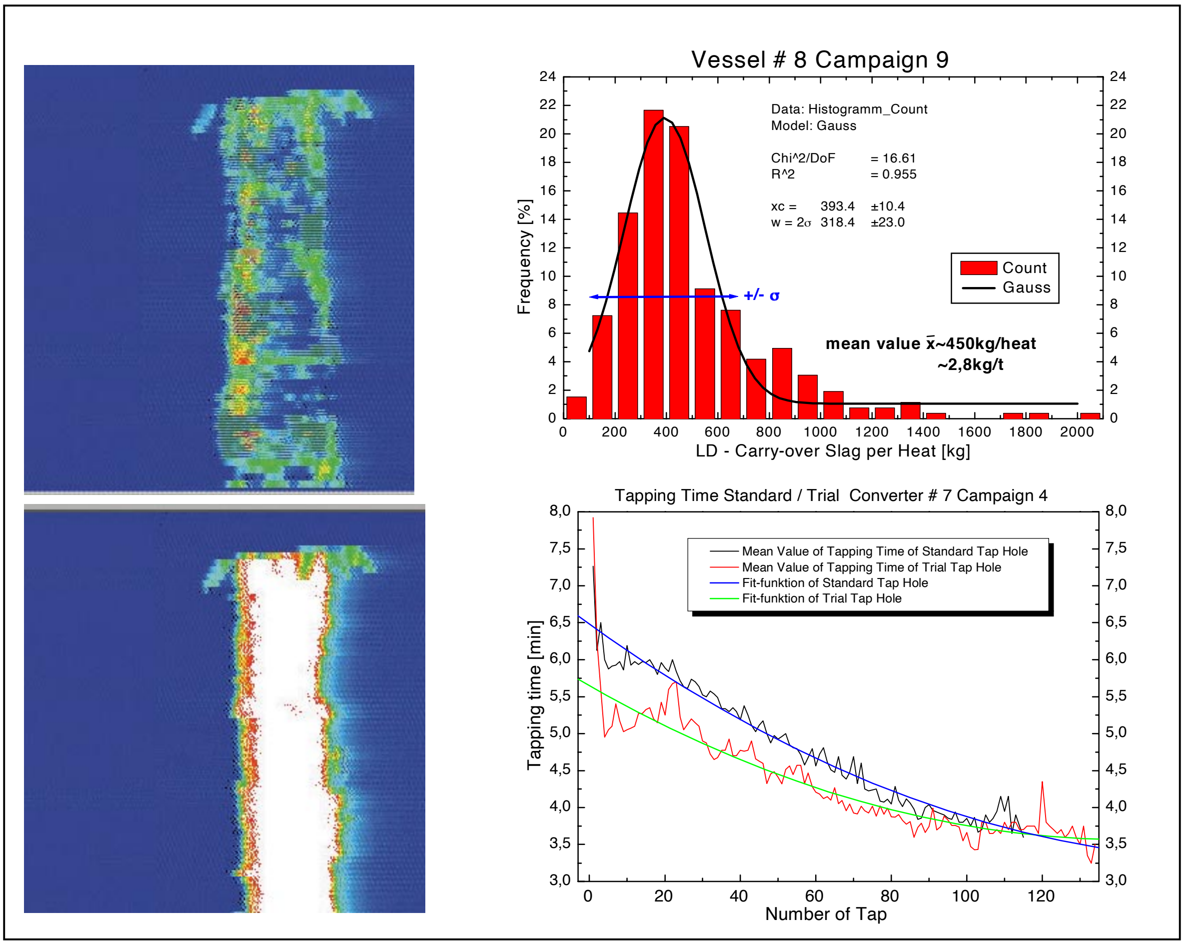


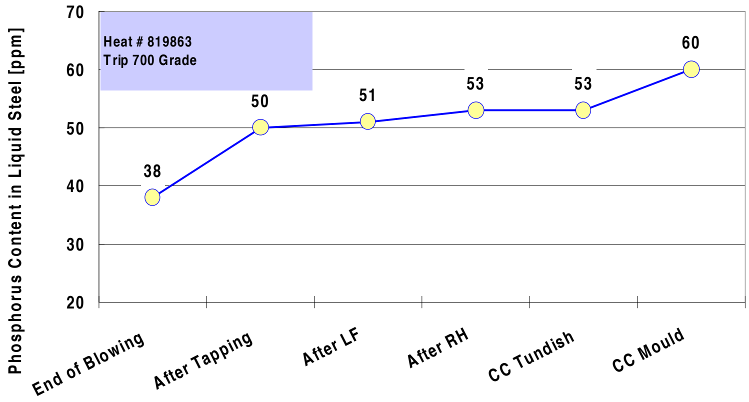
Fig 7: Increase of tap hole diameter and amount of converter carry over slag

The average amount of carry over slag from the converter to the refining ladle is 450 kg per tap which corresponds to a specific slag amount of 2.8 kg/t. In more than 46% of all heats the carry over slag is less than 400 kg.

The calculation of the LD - carry-over slag is performed by means of a multiple regression. Therefore the analysis of steel and slag before tapping and after tapping as well as the amount and analyses of all tapping and ladle additions, such as lime, raw magnesite and ferro alloys have to be balanced. Therefore the weight of the liquid steel tapped has to be registered. The calculation then is the least square fit of all the oxides in the slag based on the aluminium burn-out and the rephosphorization.

An additional benefit of the pneumatic slag stopper is the fact that it can be used to reduce the early slag flow by tilting the converter for tapping with the closed hammer. This is performed during the production of high quality steel grades where only small rephosphorization rates are allowed.

Fig. 8. shows the development of the Phosphorus content in the steel from the end of bowing to the final sample of a Trip 700 steel grade with high Al content. The phosphorus in the steel sample increased from 38 ppm at the end of blow up to 50 ppm in the first ladle sample. During the ladle furnace and vacuum treatment another 3 ppm Phosphorus pick up could be observed. So the total Phosphorus pick up for this heat from the end of blowing to the end of the secondary metallurgical treatment was about 15 ppm. The refining slag was completely reduced so that the P2O5 was only 0,001% An additional Phosphorus pick up of 7 ppm was observed from the tundish to the mould.(Fig. 8).



Slag Analysis [%]	FE	MN	CaO	SiO2	P2O5	Al2O3
End of Blowing	26.6	4.19	42.1	10.4	1.12	1.0
After LF	0.12	0.02	45.89	0.14	0.001	44.1

Fig 8: Development of P in liquid steel and P_2O_5 in slag for Trip 700 grade

7. DEVELOPMENT OF REFRACTORY LIFETIME AND AVAILABILITY

In order to be able to implement the required production volumes, great efforts are being made to increase the availability of the three converters. This can only be achieved by increasing the refractory lifetimes and, thus, reducing the number of relining operations, which last roughly four to five days from the last tap until start of blowing the first heat at the relined vessel.
The refractory lifetime, which had been approximately 1,000 to 1,200 heats for years, was increased to 1900 heats per converter vessel during last three business years (Fig. 9). A record lifetime of 2504 heats was reached at converter #8 in January 2004.

As the lifetime increased, the number of relining operations decreased from between 22 to 24 annually to 14 in the current business year. Specific refractory costs were thus reduced by 20% in the last two business years. The target converter refractory lifetime in the years to come is more than 3,000 heats in order to reduce the number of relining operations to 9 per business year.

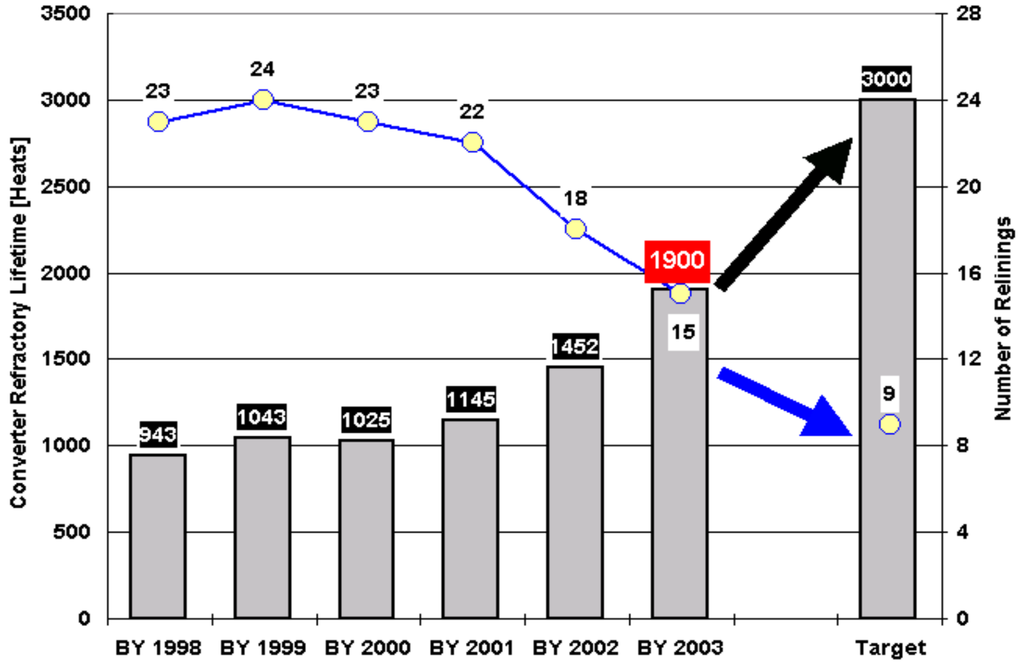


Fig. 9: Converter Refractory Lifetime and Number of Relining Operations, 1998–2003

Apart from vessel exchange, which served to eliminate vessel deformations and, thus, ensured a more uniform stress distribution in the brickwork, the following measures and process changes were carried out in order to increase the refractory lifetime:

- Improved relining systems and use of higher-quality materials
- Introduction of slag-splashing technology
- Controlled reduction of the tapping temperature
- Change of slag practice

Slag-splashing technology was introduced in the period from May to June 2001. At the same time a laser measuring instrument was installed in order to measure the refractory wear. Slag splashing is not yet being fully utilized at the moment. For lack of hot metal at the location of Linz and owing to a temperature loss of approximately 25 °C resulting from the slag-splashing process, corresponding to a hot-metal rate of 15 kg/t, only approximately 9.5% of the heats are currently splashed. At the moment, efforts are being made to automate the slag-splashing process and to increase its frequency.

8. INCREASE OF THE SPECIFIC SCRAP RATE

The lack of hot metal at the location of Linz called for the reduction of the specific hot-metal rate and increase of the scrap rate. The specific hot-metal rate has been reduced from 833 kg in 1998 to currently 776 kg per ton of good slab, while the specific scrap rate has been increased from 251 to 331 kg per ton good slab (Fig. 10). The reduction of the specific hot metal rate could be achieved by the following measures:

- Reduction of tapping temperature
- Reduction of cooling agents

- Removal of non metallic cooling agents
- Use of pig iron
- Increased FeSi consumption

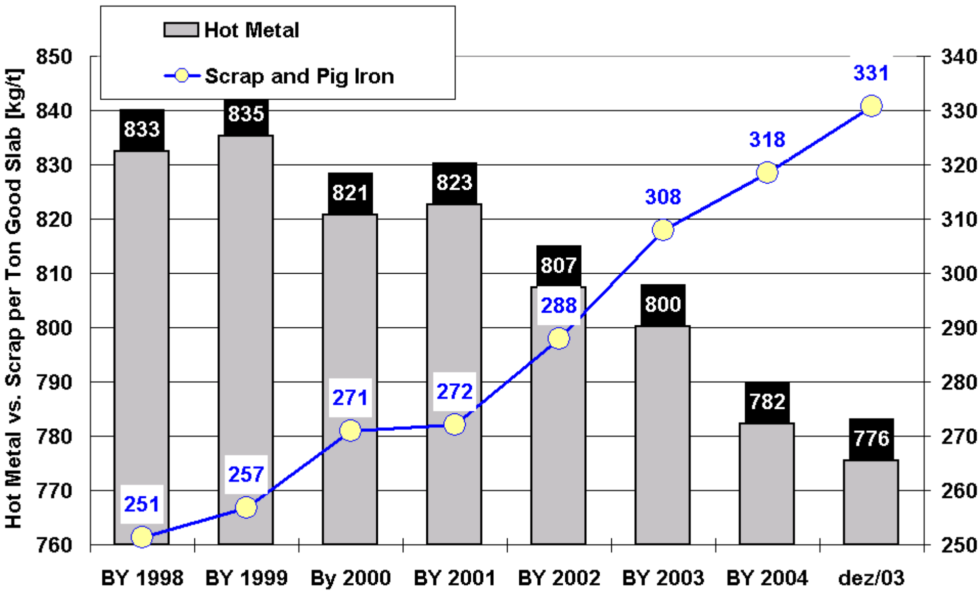


Fig. 10: Development of the specific hot metal consumption 1998 – Dec. 2003

The startup of the second ladle furnace in February 2000 allowed for a specific reduction of the mean blowing-end and tapping temperatures. The converter tapping temperature was reduced by 20°C over the past two years from 1,670°C to 1,650°C (Fig. 11), while at the same time the number of heats with tapping temperatures above 1,700°C was reduced from 18.6% to 6.3%.

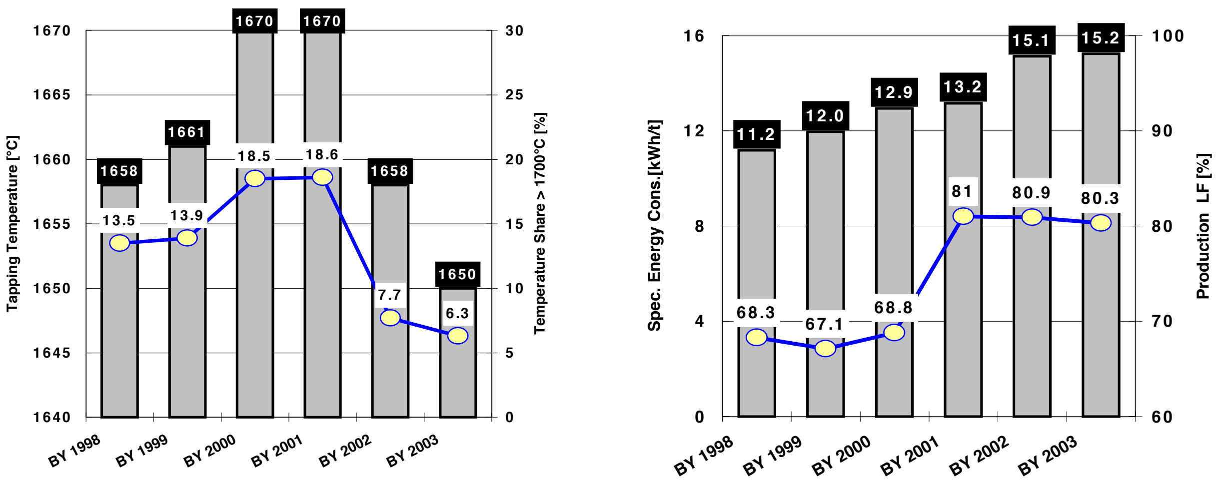


Fig. 11: Development of the Tapping Temperature and of the Electric Energy Consumption at the Ladle Furnaces

With the start up of the second ladle furnace the production via ladle furnace could be increased from approximately 68% up to 80%. The reduction of the tapping temperature did not appear to its full extent in the specific energy consumption of the ladle furnaces. Primarily the temperature reduction by 8 °C from the business year 2002 to the business year 2003 did not show up in the ladle furnaces.

The specific coolant consumption—LD slag and dust briquettes—has been considerably reduced. The amount of dust briquettes was reduced from 19.6 kg/t down to 2 kg/t (Table 3). The non metallic cooling agent LD slag was replaced by metallic cooling agents. At the same time the consumption of FeSi, which is used in the converter for heating purposes in order to equilibrate the energy balance, has been increased by 1.56 kg/t. With these measures the liquid steel output could be increased by 7.5 % with the same hot metal amount compared with 1998.

Table 3: Comparison of Specific Scrap and Hot-Metal Rates per ton good slab in 1998 and Dec 2003

	BY 1998	Dec. 2003
Hot metal [kg/t]	833	776
Pig iron [kg/t]	-	19,4
Scrap [kg/t]	251	311.6
Hot-metal Charging temperature [°C]	1,356	1337
Si in hot metal [%]	0.68	0.8
Dust briquettes [kg/t]	19,6	2
Slag [kg/t]	3,95	-
FeSi [kg/t]	0.44	2

Due to the increased Si input the specific slag amounts of the converter was increased, which is a disadvantage of that kind of process operation. The metallic yield as well as the basicity decreased, since the maximum amount of lime charged into the converter is 12,000kg. Fig. 12 shows the shift in basicity in converter # 8 as an example.
In the year 2001 during the first campaign on the new converter vessels the average basicity of slag at the end of blowing was 3.2. However during the last campaign number 15, a basicity of only 3.0 could be achieved, since the actual Si input needed more than the allowed 12,000 kg to reach the target basicity of 3.2.
The big slag amounts had some positive impacts on the converter metallurgy. Due to higher slag amounts and lower tapping temperatures the dephosphorization was improved (Fig. 12). The average Phosphorus content could be reduced from 0.0091 % down to 0.0065 %.

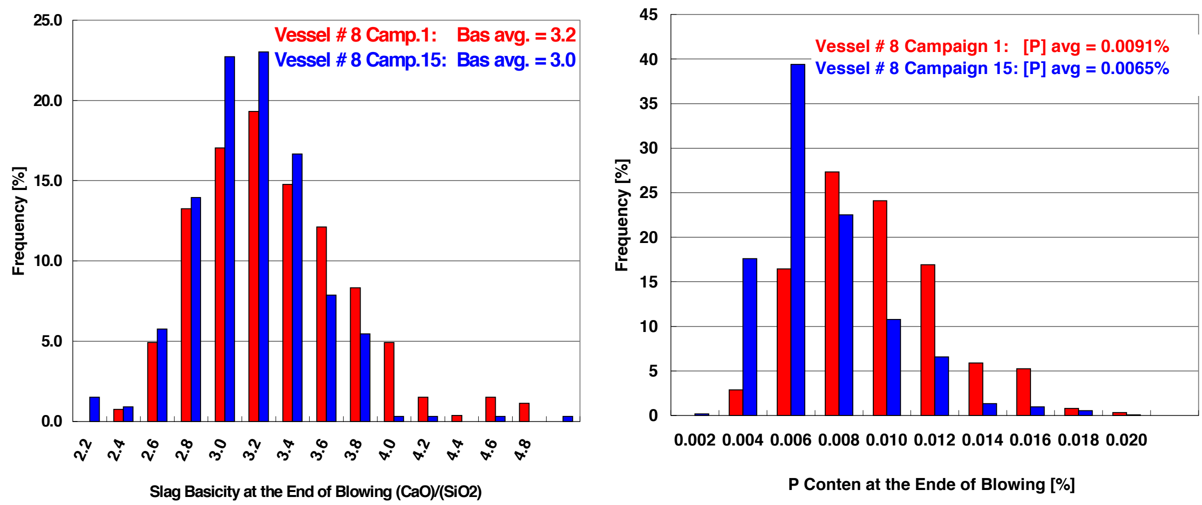


Fig. 12: Basicity CaO/SiO2 and P at end of blowing at converter # 8

9. OUTLOOK

The goal of the years to come is to ensure a production volume of 4.7 million tons of liquid steel. In order to achieve this goal, a new continuous casting machine as well as an additional hot-metal desulfurization station in the steelmaking plant are to be installed. This poses a special challenge to converter operation because 84 heats per day will have to be produced with the existing three converters. During the relining of the blast furnace A from July to October 2004, additional effort will be necessary to reduce the hot metal ratio. High flexibility with respect to the scrap and hot metal ratio will be necessary for the LD – steel maker to fulfill the requirements of steel quality and the availability of raw materials. Hot metal ratios of between 740 and 840 kg/t and scrap ratios of up to 380 kg/t will have to be achieved in the Linz steel plant.

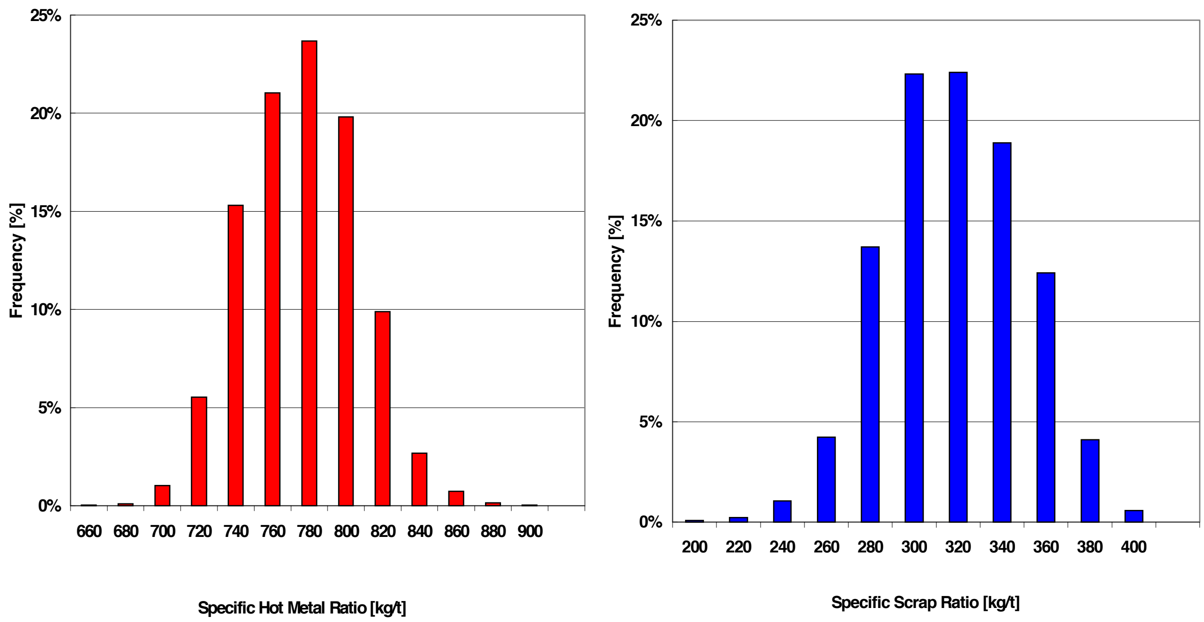


Fig. 13: Distribution of Hot metal and Scrap ratio in 2003

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