OXYCUP® FURNACE OPERATION AT TISCO, CHINA [1]

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ABSTRACT

The OxyCup plant at TISCO, Taiyuan, China, started operation as scheduled in June 2011. The plant was designed to process 600,000 tpy of self-reducing brick produced from dust and sludge residues together with approximately 100,000 tpy of pit scrap and skull. The plant layout includes a brick fabrication with material handling, mixing tower and curing hall. Two types of brick are produced in two different lines with residues from carbon steel production as well as from stainless steel production. Two individual operating OxyCup shaft furnaces are used to reduce and melt the brick and skull to liquid hot metal for Carbon steel and a liquid iron/chromium/nickel alloy for stainless steel and slag according to the quality of the charge material respectively. The furnace top gases are de-dusted in a wet gas cleaning system and used for hot blast generation at the plant and electricity generation in a separate power plant on site. To increase the availability of the furnaces >8,000 hpy, a third furnace is installed to replace one of the other two in case of refractory repair and mechanical/electrical maintenance.

Key words: OxyCup, Hot Metal, Fines Recycling, Cupola Shaft Furnace

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2 INTRODUCTION

In June 2011 commissioning of the largest OxyCup plant worldwide started at TISCO, Taiyuan Iron & Steel Company, China. The plant is designed to process 600,000 tpy self-reducing bricks made from steelmaking residues together with about 100,000 tpy of lumpy pit scrap and skull. The total input materials are split and supplied equally to two shaft furnace lines of identical melting capacity. A third shaft is available as a back-up in case of maintenance issues. This constellation guarantees an availability of the plant of >8,000 hpy.

Beside the dust and sludge from conventional carbon steel making similar residues from stainless steel making are processed. Because the conversion of stainless steel residues never before was applied in the OxyCup process, intensive laboratory and field trials were carried out during the design phase of the plant. The recovery rates of chromium and nickel from the residues had to be demonstrated successfully.

Since the target given by customer was to ramp-up the production quickly to the rated level, intensive training of the Chinese operation personal was required. The training covered material handling, brick-making and furnace operation in theory and practice.

3 PROCESS FUNDAMENTALS

The key success factor of the process is the so called Carbon-brick, which is a formed, pressed into keys mixture of iron base residues and carbon base materials, Figure 1. The cold binder is cement. The oxide/carbon ratio is adjusted to a level that allows direct reduction to take place inside of the brick.

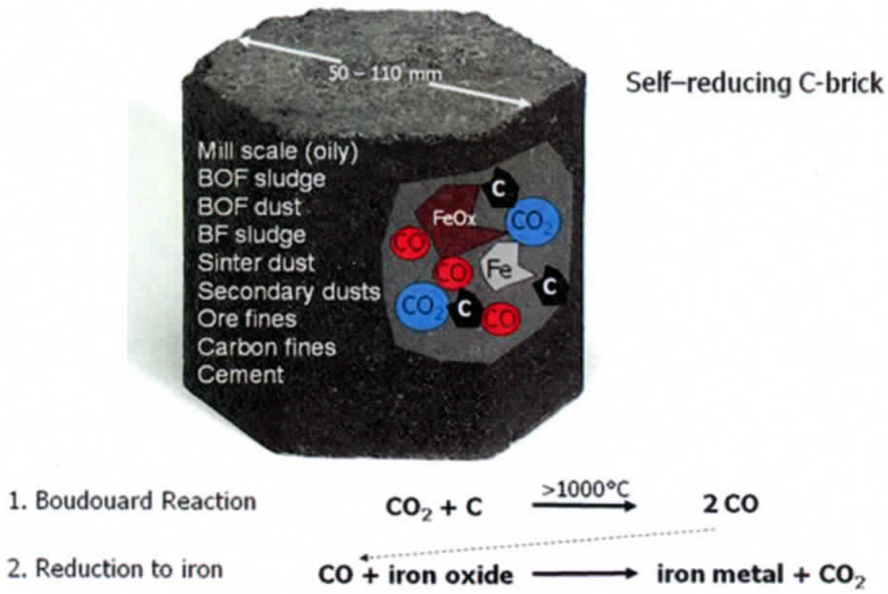


Figure 1. Self-reducing C-brick. Materials indicated can include Carbon steel residues and stainless steel residues as well.

Due to direct contact in the brick the reduction of iron oxides and of chromium and nickel oxides as well can be completed within a very short time of 20 minutes only in case there is sufficient temperature level achieved in the furnace. Laboratory tests proved that even heating up in inert gas atmosphere results in almost 100% of metallization when a level of more than 1,400 °C is obtained. However, very intensive mixing of the materials is the key success factor to distribute both the carbon for reduction and the cement binder perfectly into the residues. The cement addition required is about 12% in order to achieve a cold strength of more than 5 N/mm^2. Depending on certain components in the residues like zinc or alkalis the cement amount or grade has to be adopted accordingly The carbon addition, as a general rule, must follow the stoichiometric demand for direct reduction..

The direct reduction inside the brick is completed before melting at approximately 1450 °C. Liquid metal and slag are leaving the furnace continuously over a siphon type iron and slag separator. Because of the non-iron components in the residues and the cement binder of the bricks the slag volume is in the range of 300 kg/t hot metal and higher. The composition of the slag can be adapted to the desired composition levels by charging adjusted amounts of fluxes into the furnace. Beside the C-brick also scrap and skull is be charged into the furnace. The industrial experience of the process covers scrap ratios from 20% in minimum up to 100% in case high hot metal productivity is required.

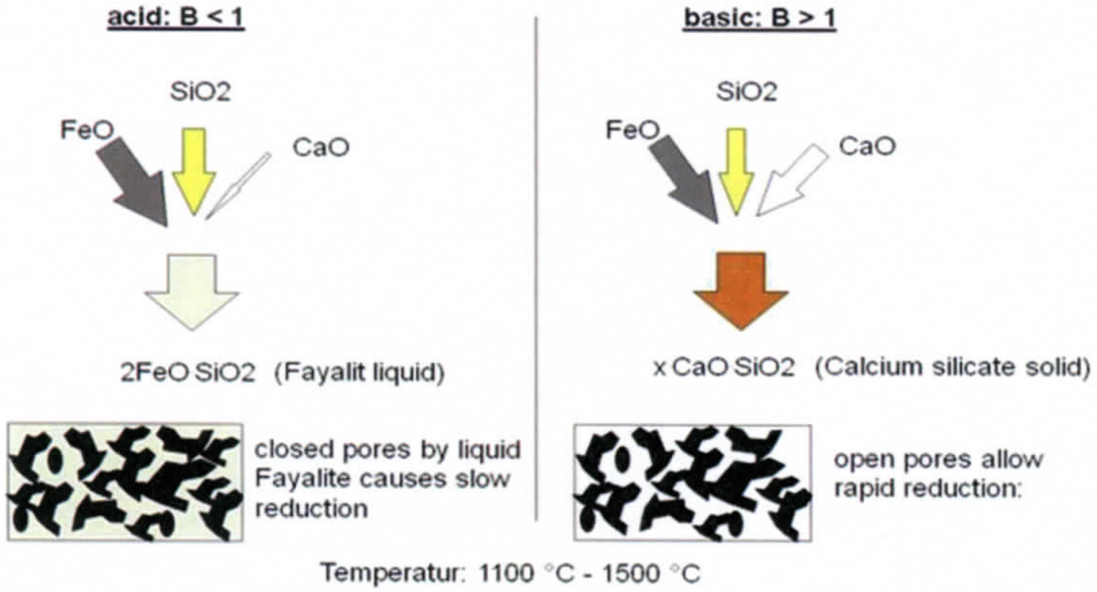


Figure 2. Basicity of C-brick should be larger than one to allow fast reduction.

For the composition of the C-bricks it is important that the basicity of the brick (CaO /SiO_2) is always larger than one to avoid Fayalite formation. Low melting Fayalite would close the pores and block the gas exchange within the open pores of the C-brick. The fundamentals are concluded in **Figure 2**.

4 LAYOUT AND EQUIPMENT OF TISCO'S OXYCUP PLANT

The plant complex installed at TISCO covers an area of 240 x 70 m^2. The main components are the Brick making and the OxyCup melting area, including all necessary utilities as shown in **Figure 3**.

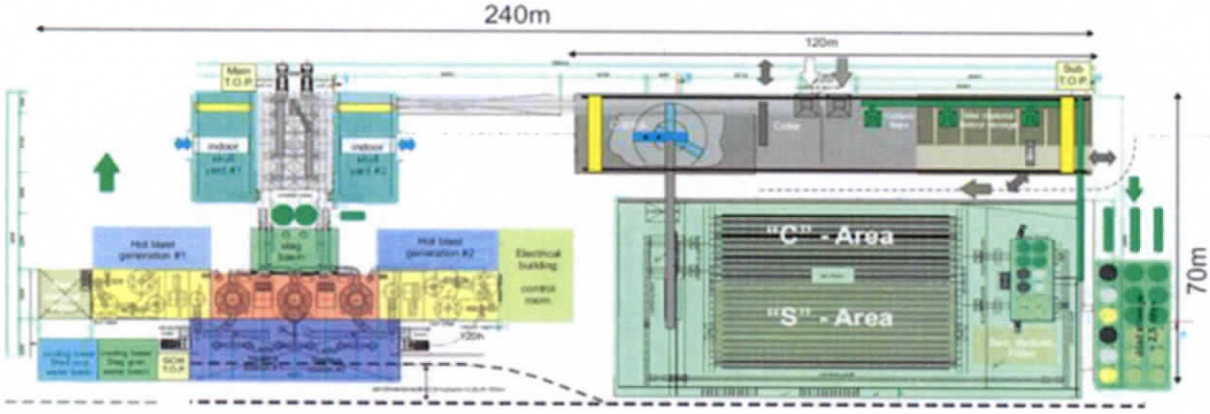


Figure 3. Layout and dimensions of TISCO's OxyCup plant
("C"-area = Carbon steel brick storage area, "S"-area = Stainless steel brick storage area.

4.1 The brick making plant

The brick-making plant is designed to produce brick by using fines from both carbon and stainless steel production. The plant is divided into three main sections:

- The material handling, including the dumping bins for wet materials and carbon fines, silos for dry fines, and silos for cement.
- The brick making equipment with material dosing, mixer and vibrating brick press and
- The curing hall with manipulators and high racks carrying the pallets with the bricks during hardening.

The materials are delivered to the plant by truck and are dumped and moved with the manually operated wet material handling crane into storage hoppers. Dry fines and cement – suitable for pneumatic transport – are blown into silos in the upper mixing tower. The wet components are pre-weight and transported into a final weighing bin that also receives and weighs the pre-selected amounts of dry fines, cement, carbon and water. This material mix is directly given into an intensive mixer that produces an equalized distribution of all materials in the batch.

A bucket transfers the material mix directly to the intermediate storage bin on top of the vibrating brick press. For emergency cases a material outlet exit is installed in the circuit. The vibrating brick press components are a metallic frame with hexagonal keys placed on a wooden pallet that are filled with the material mixture from above. After filling the keys metallic stamps are pressed into the keys in order to densify the material properly. The material compressing is supported by horizontal and vertical vibration given to the key frame. After vibration stamps and frame are lifted up leaving the green bricks on the wooden pallet. Overflow material is collected in the whole area and transported to a separate box, **Figure 4**.

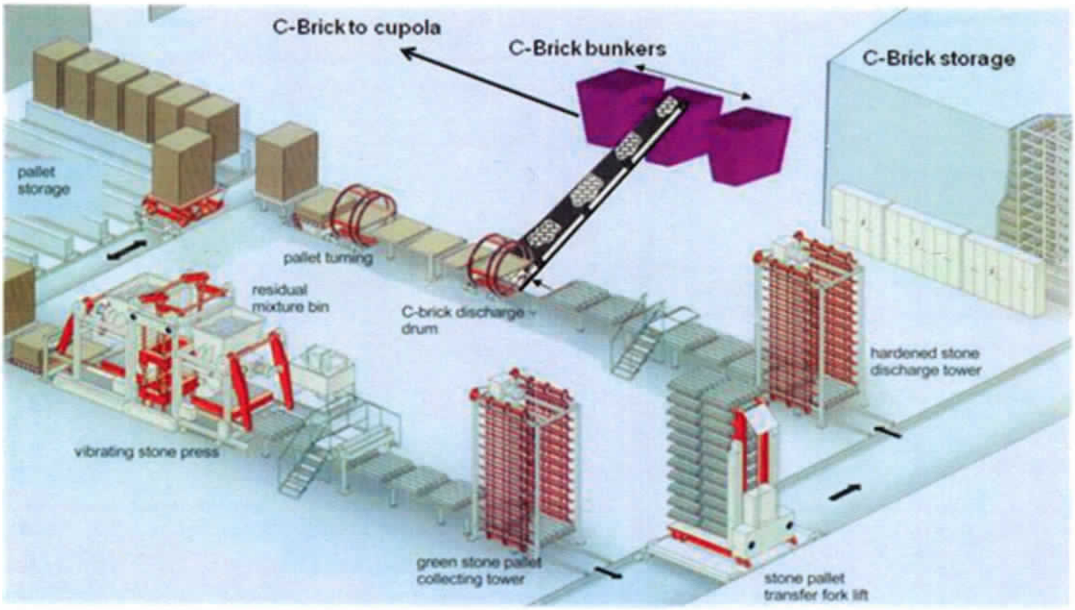


Figure 4. General arrangement of a brick-making plant.

During continuous operation the pallet with the green brick on top is moved forward to the curing hall while an empty pallet is moved into the brick press simultaneously. Green brick pallets up to 30 are collected in a high rack frame and moved to the curing hall for storage and dry out. The movements are done by special designed and fully automated fork lifters. After being cured for three days another fork lifter takes out the a full frame from the back side of the curing hall and moves it over to a de-stacker machine. This machine moves the pallets to another transportation system where the dry brick are finally discharged from the pallets and moved into the silos of the furnaces or on open stock piles nearby. The empty pallets are recycled on walkway back to the brick press machine.

4.2 The OxyCup melting plant

The OxyCup plant is designed to melt the furnace burden by using hot blast and coke and to separate the liquids to hot metal and slag. The plant can be divided into different units as:

- The furnace stockyard, stock house and burdening system,
- The melting units,
- The hot blast generation
- The slag granulation and the
- The gas cleaning plant.

The stockyard, stock house and burdening system handles the materials to prepare the batches and elevates the batches to the top of the furnace. It includes the area for raw material dumping and transporting to the stock houses as well as stock houses with bunkers for C-brick, 2 different grades of coke and fluxes like gravel, limestone or slag. Scrap and skulls are handled by crane in separate scrap yards, **Figure 5**.

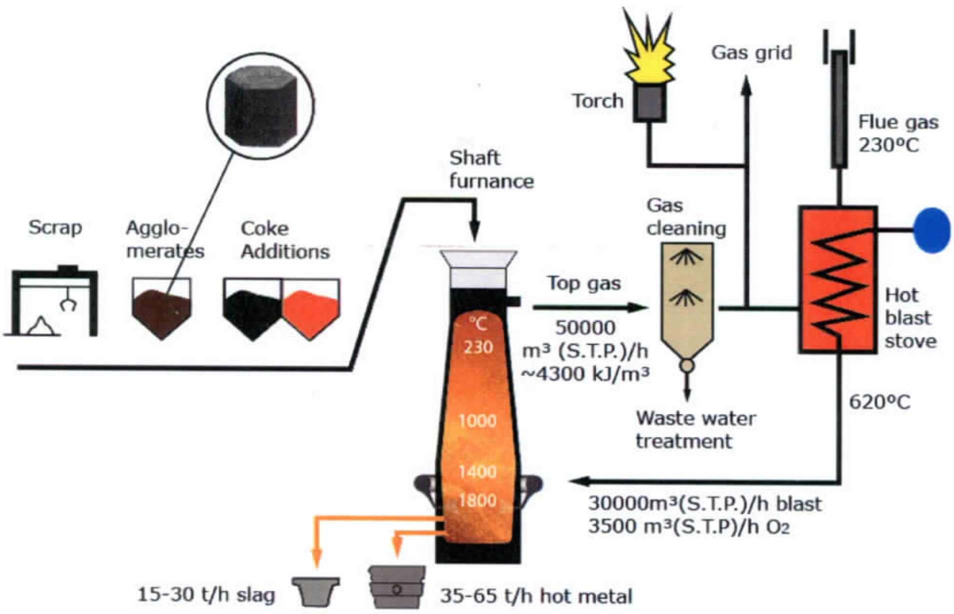


Figure 5. General arrangement of an OxyCup plant

Coke and fluxes are delivered by truck and dumped into an underground unloading station. An inclined conveyor transports and moves burden materials via a swiveling conveyor to two reversible conveyors that fill the two lines of storage bunkers. C-brick are also transported by belt conveyor to this feeding line. In one of the handing over points they are screened and can be discharged in emergency case to a external stock pile. The discharge feeders are also provided with a screen to control the fines content of the C-brick. The fines from the screens are collected by belt conveyor and filled into containers that are recycled to the material dumping area of the brick making. Pit scrap (max. size 800 mm) is dumped into different boxes for each scrap type and charged by vibration feeders into the charging bucket.

Below the bunker row and the metallics vibration feeder's two buckets on rail-based transfer cars collect the burden to the furnace. Both buckets can be filled individually with each of the materials in varying portions according to a pre-selected recipe by the operator. At first the heavy materials like scrap or C-bricks are fed in the appropriate amount to the bucket. Subsequently, coke and additives are given on top into the same bucket. This practice guarantees a homogenous material distribution in the shaft and a good permeability of the burden volume in the furnace. The bucket transfer cars moves the buckets to a vertical lifting crane that transports the bucket on top of the furnace head. Here the bucket is discharged by opening the door in the bottom. During elevating the transfer car is collecting the next burden charge into the second bucket. **Figure 6** shows the general layout of the system.

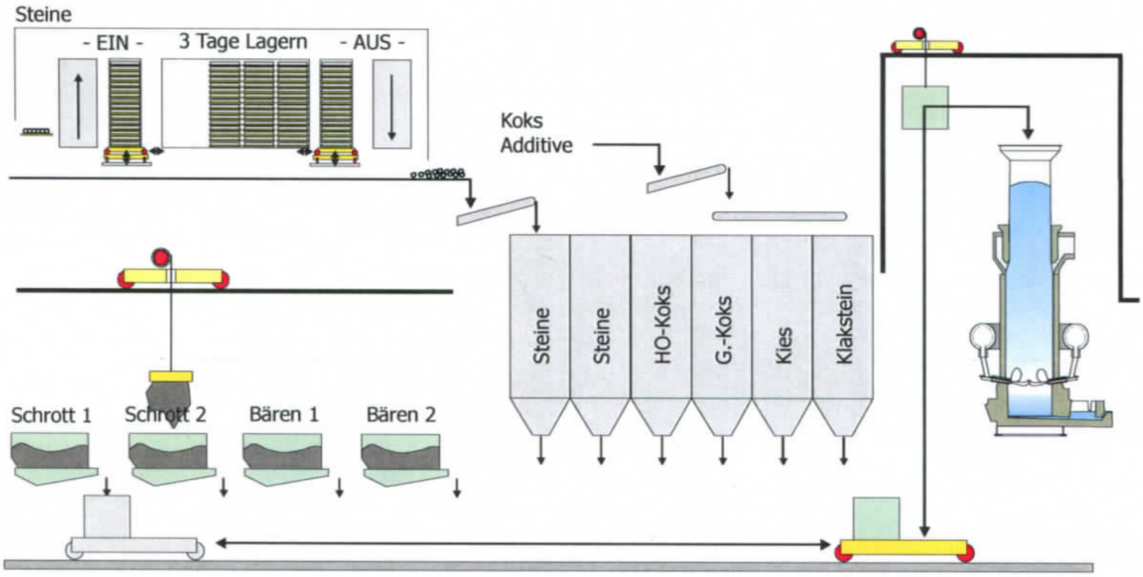


Figure 6. Layout of the stockyard, stock house and burdening system

The shaft furnace itself can be divided into the furnace top, the shaft and the combined hearth. The furnace top includes the burdening zone and the annular gas outlet chamber below the charge level. The gas outlet chamber is refractory protected to avoid superheat of the steel shell in the area.

The furnace is equipped with a **water cooling system**. The shell in the throat area is spray water cooled from outside. The upper furnace shaft is refractory lined as well. The furnace shell in this area is cooled from outside by spray water cooling. The water is collected in a ring type basin attached to the furnace hearth. In the lower furnace shaft the tuyeres are located. They are designed similar to blast furnace tuyeres and cooled with water from a closed loop which is operated at normal pressures. The tuyere cooling water is cooled indirectly by the shell cooling water in a water to water cooler downstream the furnace. There is no water loss in the closed loop circuit. Leakage control of the tuyeres is guaranteed by a level meter located in the upper part of the expansion/overflow tank. In addition the water flow at each tuyere is measured and monitored.

The blower for **hot blast generation** is designed with a 10% overcapacity to ensure the maximum melt rate also in case of leakages. The blower is controlled by frequency converter. The flow rate is measured by a flow meter located in the cold blast pipe. The hot blast required for the combustion of coke is generated by using a recuperator and a combustion chamber that is fired with the cleaned top gas from the furnaces. The design of the recuperator ensures a hot blast temperature of > 750 °C in continuous operation which if favorable to reduce the overall fuel consumption. The off gas temperature of the recuperator is only approx. 270 °C. The burnt gas is leaving the stack without further treatment. Coke oven gas burners are installed for pre-heating the combustion chamber and to ensure ignition of the furnace gas. The hot air is fed into the main hot blast bustle pipe and distributed to the 10 water cooled copper tuyeres. Through the tuyeres the hot blast, oxygen and auxiliary fuel is blown into the melting zone of the furnace. The oxygen volume is split to a general enrichment of the blast and a portion which is injected via special, supersonic, laval type lance nozzles through the tuyeres into the furnace. The oxygen accelerates the coke combustion and generates the superheat necessary to run the process

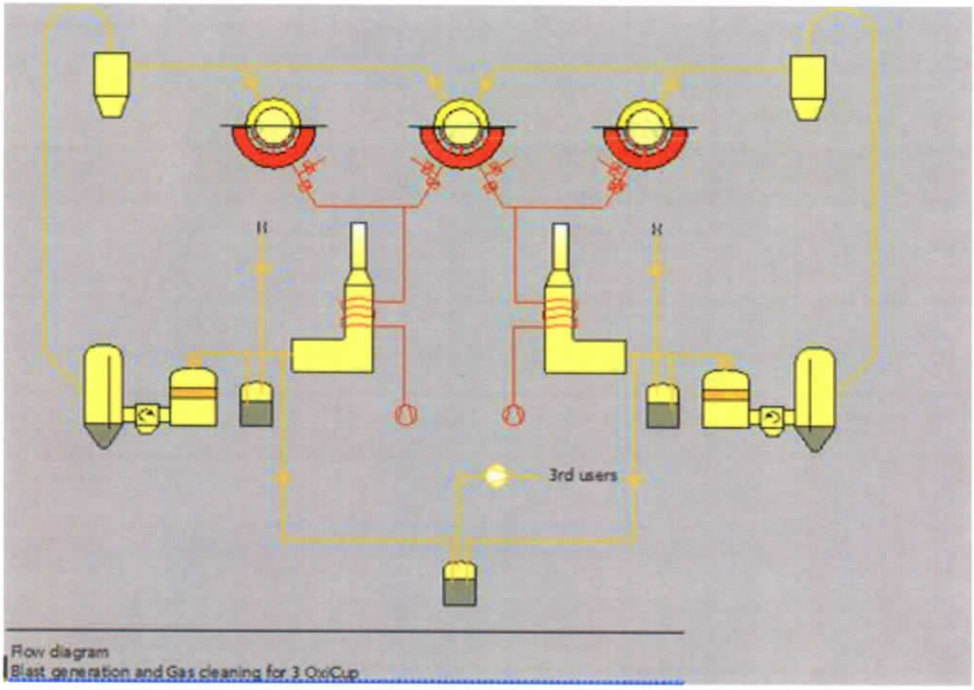


Figure 7. Two lines for gas cleaning and hot blast generation serving two of three shaft furnaces simultaneously

The **top gas** from the furnace is exhausted from the furnace through a gas outlet chamber below the furnace throat and passed to a wet gas cleaning plant. The furnace throat is during the blow-down phase covered by a tilting to provide from dilution of air or flames outlet from the upper shaft. The pressure at the gas outlet is controlled at 0 to -1.5 mbar to guarantee gas tightness. This technology ensures a visible emissions free operation of the plant in all different operation modes.

The **top gas cleaning plant** is designed to reduce the dust content in the furnace gas to less than 10 mg/m^3 according to the requirements of the gas using utilities. The water treatment including cooling tower, settling tank and sludge de-watering consists of compact units arranged in the vicinity of the furnace. After extraction from the furnace the top gas first enters a spray tower that acts both as a cooler and a pre de-dusting unit for the coarse particles. In the subsequent disintegrator, a high turbulent rotational scrubber, the fine dust is removed to less than 10 mg/m^3. Fine water droplets in the scrubbed gas are finally caught in the de-mister downstream the disintegrator. The cleaned gas is then partially used in the hot blast generation. The excess gas is exported to the TISCO works grid and converted to electricity in a separate on-site power station. The sludge water is first pumped into a settling basin and further to a feeding basin prior to the filter press for de-watering. The washing water is re-circulated via a cooling tower and treated with chemicals to maintain the desired pH-value (7.5-8.0) and to facilitate the settling of the sludge. Depending on the enrichment of soluble compounds like chlorine always a certain amount of cleaning water has to be replaced by fresh water. Fresh water will also cover the evaporation losses of the cooling towers.

Hot metal is continuously tapped via a runner system into special transport ladles. The hot metal can be De-Sulphurized if required by using a special ladle equipped with a nitrogen purging porous plug and by addition of lime or/and calcium carbide. The De-Sulphurization slag is overflowed and collected in a slag pot (approx. 1 m^3). The treated hot metal is fed via tilting runner into a special 30 t ladle which transfer on demand to the BOF or the EAF plant. Hot metal temperature and composition is controlled by samples on a regular base. In case of abnormal hot metal analysis the liquids can be casted to pigs..

Liquid slag is tapped by one of the two siphons and is converted by using a **slag granulation** facility to a hot granulated sand by a jet of water in the granulation tundish located under the slag overflow of the siphon. Granulate and water flow down a launder into an OCP collecting basin where the slag cools down and settles on the ground before being removed by a programmable controlled electric grab-hoist and moved to a sand pile on the floor. The granulation water is pumped from the OCP basin to a cooling tower by using special hot water pumps. Cold water from the cooling tower flows into a cold water basin from where it is pumped by using cold water pumps back to the granulation tundish. The cold water basin is connected to the cold water supply by a float switch in order to compensate for evaporative losses. Furthermore it is necessary to bleed off a certain quantity of water to maintain an acceptable level of dissolved components. No manual operation is necessary due to fully automated operation of this system.

5 FIRST RESULTS FROM THE OXYCUP PLANT AND DISCUSSION

In the start-up phase C-brick were made mainly from BOF dust and BF dust and sludge. Different cement grades were tested in the laboratory in order to select the best suitable for the mixture. Fine grained coke breeze have been used as reducing agent in the bricks. The compression strength was above the required 5 N/mm^2.

After starting the furnace with scrap the addition of bricks was ramped-up very fast and within 24 hours the desired composition of 80% bricks and 20% scrap was achieved. The hot metal temperature was between 1480 °C and 1530 °C and the analysis showed about 4% C and 1.3% Si. Slag basicity varied between 0.8 and 1.1, **Table 1 and 2**. During the following weeks the carbon and silicon content was lowered to 3.3% C and 0.8 %Si by reduction of the coke rate from initially 21% to 16%. Due to this effect the melting rate was increased up to the design level of 45 t/h brick plus skull in the charge without major operation problems. The final acceptance was given end of 2011.

Material	Fe_{met}	C	Si	Mn	P	S	N	Ti	Cr	Ni	T
	%	%	%	%	%	%	%	%	%	%	°C
CS[2] Hot Metal	94,23	3,79	1,39	0,23	0,081	0,24		0,04			1.501
SS[1] Iron Alloy	81,01	3,00			0,040				10,76	4,73	1.480

1) CS = Carbon Steel
2) SS = Stainless Steel

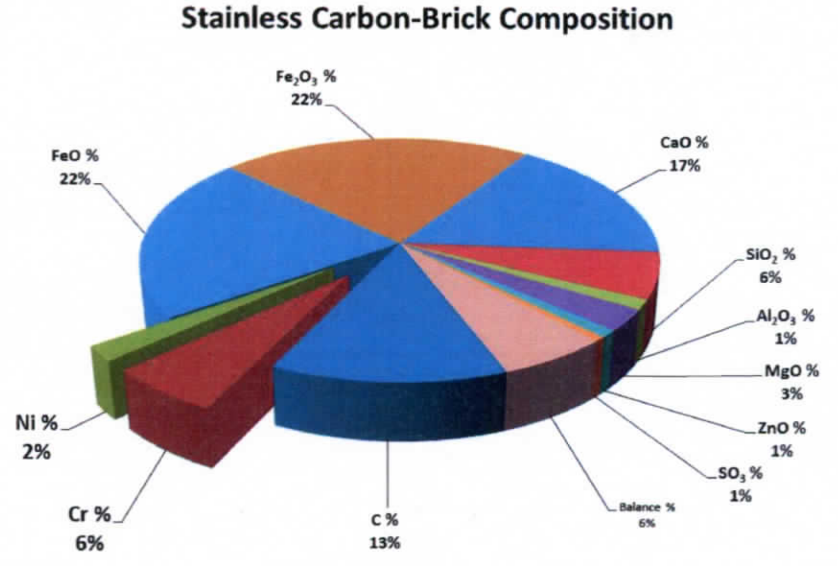
Table 1. Typical Hot Metal and Iron Alloy Qualities at TISCO

Material	CaO	MgO	SiO_2	Al_2O_3	P_2O_5	S	FeO	$Na_2O + K_2O$	ZnO	CaO/SiO_2
	%	%	%	%	%	%	%	%	%	-
CS[2] Slag	37,20	6,70	42,60	11,30		0,90	1,98			0,87
SS[1] Slag	60,00	10,61	22,17	4,57	0,00	0,01	0,99			2,71

1) CS = Carbon Steel
2) SS = Stainless Steel

Table 2. Typical Slag analysis at TISCO

Typical residues from the stainless steel production like EAF dust, AOD dust and sludge are the main raw materials for the Stainless Steel (SS)-brick production. The chromium content of these residues varies between 5% and 20%, nickel is in the range of up to 4.5%. Mixing of the residues with the appropriate amount of carbon fines and cements result in the composition of C-bricks as shown in **Figure 8**.



Firgure 8. Stainless Steel Brick Composition

The analysis of the liquid iron-chromium-nickel-alloy and of the corresponding slag is given in the **Tables 1 and 2**. Several melting campaigns with the SS-bricks have been carried out in the meantime. All results showed a perfect match between the analysis of the liquid alloy tapped during OxyCup operation and the forecast results of the laboratory trials and the material balance calculation done previously in the feasibility stage of the project. The predictions were based on thermo chemical calculations which are shown in **Tables 3 and 4**.

	Formula	Mol <in>	Mol <out>	kg <in>	kg <out>	% <in>	% <out>	Mol fraction
Gravel	SiO2	166.43	0.00	10.00	0.00	100.0	0.0	1.090E-05
Coke	C <F> ...	14986.26	0.00	180.00	0.00	90.0	0.0	-
	H <F> ...	1984.25	0.00	2.00	0.00	1.0	0.0	-
	N <F> ...	28.56	0.00	0.40	0.00	0.2	0.0	-
	O <F> ...	12.50	0.00	0.20	0.00	0.1	0.0	-
	S <F> ...	43.66	0.00	1.40	0.00	0.7	0.0	-
	Al2O3 ...	19.62	0.00	2.00	0.00	1.0	0.0	-
	CaO	17.83	0.00	1.00	0.00	0.5	0.0	-
	Fe2O3 ...	12.52	0.00	2.00	0.00	1.0	0.0	-
	MgO	24.81	0.00	1.00	0.00	0.5	0.0	-
	SiO2	166.43	0.00	10.00	0.00	5.0	0.0	-
Brick	Al2O3 ...	19.62	0.00	2.00	0.00	0.2	0.0	-
	C	14986.27	0.00	180.00	0.00	18.0	0.0	-
	CaO	1943.74	0.00	109.00	0.00	10.9	0.0	-
	Cr2O3 ...	1059.28	0.00	161.00	0.00	16.1	0.0	-
	Fe3O4 ...	1701.66	0.00	394.00	0.00	39.4	0.0	-
	MgO	570.66	0.00	23.00	0.00	2.3	0.0	-
	MnO	902.20	0.00	64.00	0.00	6.4	0.0	-
	MoO3	6.95	0.00	1.00	0.00	0.1	0.0	-
	NiO	535.55	0.00	40.00	0.00	4.0	0.0	-
	SiO2	432.73	0.00	26.00	0.00	2.6	0.0	-

Table 3. Thermochemical calculations for coke and SS-brick

Table 3 shows the input data of coke and SS-brick. The table shows the analysis in mol, kg and %. Because these input materials are converted completely to metal, gas and slag the output data are zero.

	Formula	Mol <in>	Mol <out>	kg <in>	kg <out>	% <in>	% <out>	Mol fraction
Slag	Al2O3 ...	0.00	14.74	0.00	1.50	0.0	0.6	5.683E-03
	CaO	0.00	410.93	0.00	23.04	0.0	9.1	0.158
	CaAl2Si2O	0.00	0.00	0.00	0.00	0.0	0.0	1.348E-07
	CaMgSi2O6	0.00	0.04	0.00	0.01	0.0	0.0	1.389E-05
	Ca2SiO4 .	0.00	761.66	0.00	131.19	0.0	51.9	0.294
	CaS	0.00	27.28	0.00	1.97	0.0	0.8	0.011
	CaSO4 ...	0.00	0.00	0.00	0.00	0.0	0.0	3.809E-18
	CrO3	0.00	0.00	0.00	0.00	0.0	0.0	9.327E-15
	Cr2O3 ...	0.00	147.69	0.00	22.45	0.0	8.9	0.057
	FeO	0.00	20.76	0.00	1.49	0.0	0.6	8.004E-03
	FeS	0.00	0.17	0.00	0.02	0.0	0.0	6.726E-05
	MgO	0.00	562.70	0.00	22.68	0.0	9.0	0.217
	MgAl2O4 .	0.00	24.49	0.00	3.48	0.0	1.4	9.443E-03
	MgSiO3 ..	0.00	0.35	0.00	0.03	0.0	0.0	1.332E-04
	Mg2SiO4 .	0.00	3.27	0.00	0.46	0.0	0.2	1.261E-03
	MgSO4 ...	0.00	0.00	0.00	0.00	0.0	0.0	6.192E-22
	MnO	0.00	603.45	0.00	42.81	0.0	17.0	0.233
	Mn2SiO4 .	0.00	0.22	0.00	0.04	0.0	0.0	8.312E-05
	MnS	0.00	15.73	0.00	1.37	0.0	0.5	6.066E-03
	MoO3	0.00	0.00	0.00	0.00	0.0	0.0	8.907E-13
	Mo2S3 ...	0.00	0.00	0.00	0.00	0.0	0.0	1.651E-18
	NiO	0.00	0.01	0.00	0.00	0.0	0.0	2.052E-06
	NiS	0.00	0.00	0.00	0.00	0.0	0.0	8.835E-07
	NiS2	0.00	0.00	0.00	0.00	0.0	0.0	4.348E-14
	Ni3S2 ...	0.00	0.00	0.00	0.00	0.0	0.0	1.085E-11
	SiO2	0.00	0.03	0.00	0.00	0.0	0.0	9.983E-06
Iron	Al	0.00	0.00	0.00	0.00	0.0	0.0	1.067E-08
	Cr	0.00	1823.17	0.00	94.80	0.0	21.9	0.263
	Fe	0.00	3833.98	0.00	214.12	0.0	49.5	0.554
	Fe3C	0.00	406.36	0.00	72.96	0.0	16.9	0.059
	FeO	0.00	55.41	0.00	3.98	0.0	0.9	8.004E-03
	FeS	0.00	0.47	0.00	0.04	0.0	0.0	6.726E-05
	Mn	0.00	261.41	0.00	14.36	0.0	3.3	0.038
	Mo	0.00	6.95	0.00	0.67	0.0	0.2	1.003E-03
	Ni	0.00	535.54	0.00	31.43	0.0	7.3	0.077
	S	0.00	0.00	0.00	0.00	0.0	0.0	7.039E-08

Table 4. Thermochemical caculations

Table 4 shows the data of slag and metal. From 1,59 mol of Chromium oxide in the SS-brick only 147 mol remain as oxide and are melted to the slag. The rest is reduced to metallic chrome to be found in the metal, Nickel and molybdenum are reduced to 99%. All metals are accelerated in the metal.

Based on these calculations it was clear that only small amounts of chromium and nickel should remain as oxides to be solute in the furnace slag in case temperatures over 1,500 °C could be maintained. The practical results confirm the predictions. Due to the operation temperatures being always over 1,480 °C no problems are expected with the viscosity of the metal and the slag. To make sure that also at high chromium contents over 8% due to the increase in liquidus temperature no problem will come up, electrical heated holders are installed in the SS-line to guarantee a superheat sufficient for transport and handling of the liquid alloy to the stainless steelmaking facilities.

6 CONCLUSION

The OxyCup technology for the recycling of steelmaking iron containing residues, based on the production of self-reducing Carbon brick and reduction and melting in a special designed cupola furnace is a proven technology with several industrial plants in operation worldwide over the past 15 years. A new line was installed at TISCO, Taiyuan, China to recycle the integrated steelplant residues to commercial hot metal and granulated slag. Since TISCO is operating a stainless steel production line at the same site the OxyCup plant was designed to process the residues from the stainless production in a separate line. The shaft furnace plant is completed with a third furnace shell to be operated on both of the standard lines in case of maintenance to increase the overall availability. For the first time ever it was demonstrated that a recovery rate for chromium and nickel of almost 100% can be achieved by using a high temperature reduction and melting process. The plant erection and commissioning was achieved within the planned schedule. The first operation started in June 2011. Meanwhile all required PG-testing could be finalized successfully.

7 REFERENCE

1. PHILIPP, J.A.; MAAS, H.: “Abfallwirtschaft in einem Hüttenwerk“, *Stahl & Eisen 104(1984), No.8, Page 403-407*
2. PHILLIPP, A., JOHANN, H.P., SEEGER, M., BRODERSEN, H.A., THEOBALD, W.: “Recycling in der Stahlindustrie“, *Stahl&Eisen 112(1992), No.12, Page 75-86*
3. SCHEIDIG, K.: “Roheisen aus dem Sauerstoff-Kupolofen als alternativer Einsatzstoff für den Elektrolichtbogenofen“, *Stahl&Eisen 115(1995), No. 5, Page 59-65*
4. RACHNER, J.-G.: “Einblasen feinkörniger Feststoffe in den Kupolofen“, *Dr.-Ing. Thesis, RWTH Aachen, 1995*
5. BARTELS VON VARNBÜHLER, C., BIRKHÄUSER, L., STOESSER, K.,: „Entwicklung eines Schachtofenprozesses zur Erzeugung von Roheisen aus Hüttenwersstäuben und –schlämmen“, *Proceedings 15. Aachener Stahlkolloquium, April 2000, Page 75-84*

6. PETERS, M., BARTELS-V. VARNBÜHLER, C., LANZER, W., BIRKHÄUSER, L.: "Cupola funrnace for the processing of in-plant waste materials", ***1103***, *2000.*
7. STILL, G., SIGMUND, H., FRITZ, B., KESSELER, K., ;MÖLLER, J.: „Stoffstrommanagement in der Stahlindustrie am Beispiel von ThyssenKrupp Stahl und Voestalpine Stahl", *Stahl & Eisen 123(2003), No.2, Page 73-78*
8. STILL, G.; KESSELER, K.; MÖLLER, J.; BUTTERMANN, R.: „Material flow management at ThyssenKrupp Stahl", *Steel Grips 2(2004), No.1, Page 5-9*
9. STILL, G.; KESSELER, K.; MÖLLER, J.: "The shaft furnace process for the recycling of iron bearing residuals", *Steel Grips 2(2004), No.1, Page 10-13*
10. BARTELS-V.VARNBÜHLER, C., KESSLER, K.: "Construction and First Results of the New Commercial OxiCup Plant at ThyssenKrupp Stahl AG", *Stahl 11/2004, Scrap Substitute and Alternative Ironmaking IV AIST, Baltimore, Oct. 31 – Nov. 2, 2004*
11. KESSELER, K.: "Schachtofen: Zero waste management at ThyssenKrupp Steel", *Stahl&Eisen 125(2005), No.2, Page 21-24*
12. KESSELER, K.: "ThyssenKrupp Steel recycles steel mill wastes into hot metal", *MPT International, 1/2005, Page 30-33*
13. LEMPERLE, M.: "OxyCup Shaft Furnace – Processing of In-Plant By-Products ti Liquid Hot Metal and Slag", *MPT International, 2005, No. 6*
14. ENDEMAN, G., LÜNGEN, H.B., WUPPERMANN, C.D.: "Dust, scale and sludge generation and utilisation in German steelworks", *Stahl&Eisen 126 (2006), Nr. 9, Page 25-32*
15. BARTELS-V.VARNBÜHLER, LEMPERLE, M., KESSELER, K., STAHL, L.: „Zero Waste – Zero Cost Concept for intergrated Steel Mills – OxyCup Process for Steel Mill Waste Oxides", *Presentation, Küttner GmbH & Co. KG*
16. STEPHANY, C.: "Einblasen von Stäuben in Schachtofenprozesse zur Rückführung in den Rohstoffkreislauf", *Dr.-Ing. Thesis, RWTH Aachen, 2008*
17. INTERNET: WWW.KUETTNER.COM
18. KÜTTNER GMBH & CO. KG,: "Shaft Furnace Technology for Scrap and Waste Recycling", *Print Media Folder, 2010*
19. LEMPERLE, M., RACHNER, H.J., FECHNER, R., KASUN, D.: „OxyCup® Furnace - Smelting Steelmill Fines, Dust and Sludge to liquid Hot Metal and Slag", *Proceedings AISTech 2011, May 2nd – 4th, 2011, Indianapolis, Indiana, USA*
20. LEMPERLE, M.: "OxyCup Furnace Operation at TISCO, China", *Proceedings AISTech 2012, May 7th – 10th, 2012, Atlanta, Georgia, USA*

ANNEX 1

The following pictures were shot during the erection phase and during hot commissioning.

Figure 10. The 3 shaft arrangement during erection

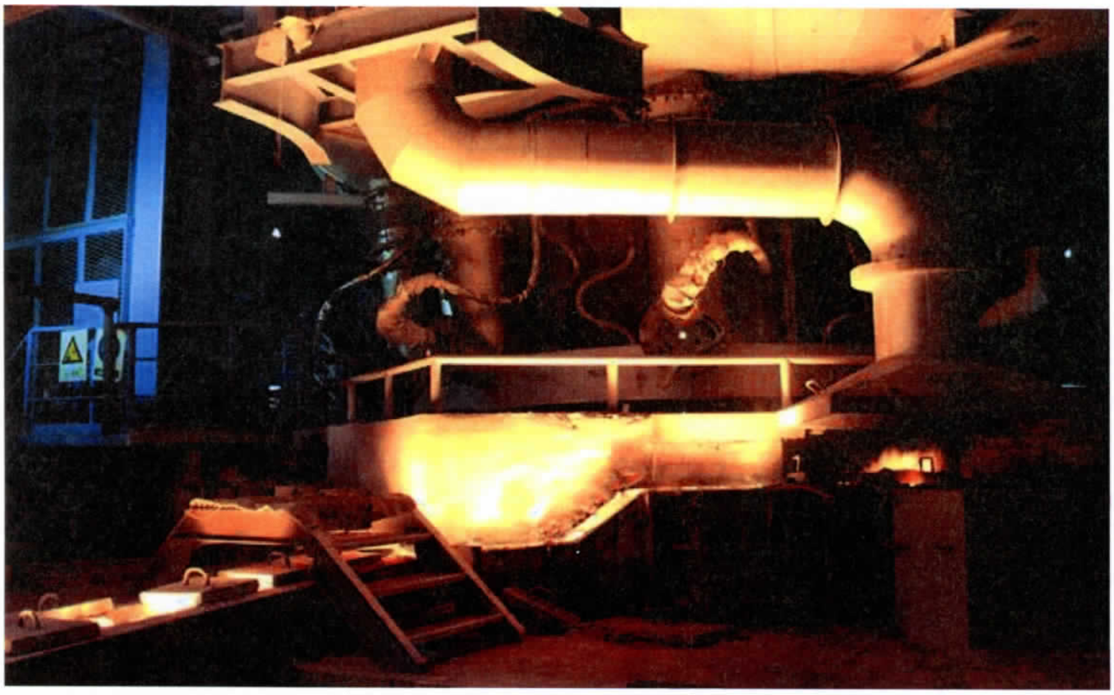


Figure 11. Liquid hot metal leaving the furnace at low dust emission

Figure 12: Scrap and skull yard with handling crane

Figure 13. The charging bucket on its way to the lifting point.

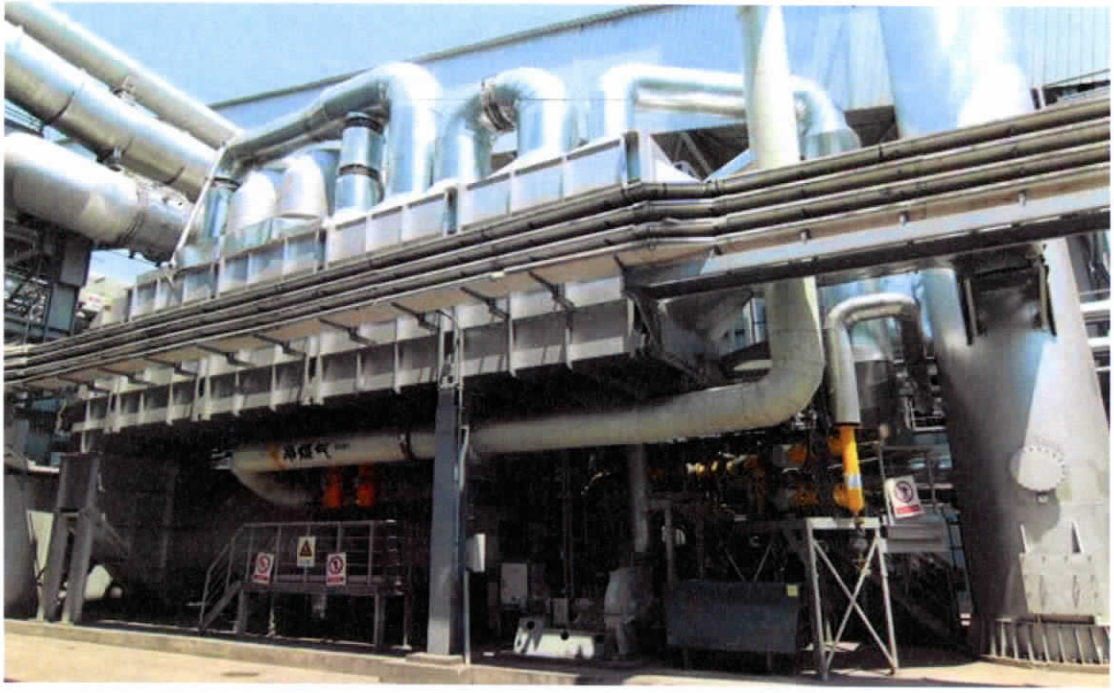


Figure 14. Heat exchanger system for the supply of 800 °C hot blast

ANNEX 2

				OxyCup TISCO Taiuan 18.09.11
	1	Schachtofen		Siphon 1
Baudaten	2	Gestelldurchmesser	m	2,4
	4	Inneres Volumen	m^3	
	5	Anzahl Blasformen	n	10
	6	Anzahl Stichlöcher	n	2
	9	Roheisensorte	-	Stahl Roheisen
Roheisen	12	Erzeugung in 24 Blasestunden	t/24 h	521
	13	Gestellflächenleistung	t/(m^2*24 h)	
	16	Anzahl Abstiche	1/Tag	11
	18	Betriebszeit	h	24,0
	19	Nutzungszeit	h	22,9
	20	Ausnutzung (Nutzungszeit/Betriebszeit)	%	95,4
Möller	29	Saure Zuschläge	kg/t RE	78,7
	33	Schrott/Umschmelzeisen/sonst. met. Einsatz	kg/t RE	687,1
	34	C-Bricks	kg/t RE	1.025,0
	35	Bruttomöller (Summe 22 + 24 bis 34)	kg/t RE	765,8
	36	Gichtstaub (tr.)	kg/t RE	86,4
	38	Nettomöller (35 - 36 - 37)	kg/t RE	679,5
	39	Fe-Einbringen bezogen auf Nettomöller	kg/t RE	1416
Brenn-stoffe	46	Koks (tr.)	kg/t RE	378,1
	50	Sonstige	kg/t RE	
	51	Kohlenstaub	kg/t RE	
Energie	53	Gesamter Stromverbrauch, ohne Windgebläse	kWh/t RE	
	54	Windgebläse (elektrisch betrieben)	kWh/t RE	
	57	Gaswärmeverbrauch für Winderhitzer	MJ/t RE	
	58	Gichtgasgutschrift	MJ/t RE	
	60	Gesamtnettoenergieverbrauch	MJ/t RE	
Wind	62	Windmenge (tr.) einschl. O2-Zusatz	1000 m^3 (i. N.)/h	22,1
	63	Windverbrauch (tr.) einschl. O2-Zusatz	m^3 (i. N.)/t RE	970,6
	64	Windtemperatur	°C	683
	65	Windfeuchte	g/m^3 (i. N.)	
	66	Winddruck (P abs.)	bar	1,02
	67	O2-Gehalt des Windes	%	32,0
	68	O2-Zusatz (gesamt)	m^3 (i. N.)/t RE	94,8
	69	O2-Zusatz über Lanzen	m^3 (i. N.)/t RE	94,8
	70	Windgeschwindigkeit	m/s	
	71	Gewechselte Blasformen	n	
	72	Flammentemperatur	° C	
Gichtgas	73	Gichtgasdruck (P abs.)	bar	
	74	Gichtgastemperatur	°C	291
	75	Unterer Heizwert	kJ/m^3 (i. N.)	4.551
	76	Gasanfall (trocken)	m^3 (i. N.)/t RE	1.405
	78	CO	%	34,5
	79	CO2	%	9,9
	80	H2	%	1,9
	81	ETA CO	%	22,3
Schlacke	83	Schlackenanfall	kg/t RE	334
	84	Anteile granulierter Schlacke	%	100
	85	CaO	%	37,2
	86	MgO	%	6,7
	87	Al2O3	%	11,3
	88	SiO2	%	42,6
	89	TiO2	%	
	90	S	%	0,90
	91	Mn	%	0,93
	92	P	%	
	93	Na2O	%	
	94	K2O	%	
	95	Basizität (CaO+MgO)/SiO2	-	1,03
Roheisen	96	FeO	%	1,98
	97	C	%	3,79
	98	Si	%	1,39
	99	Si Standardabw.	%	
	100	Mn	%	0,23
	101	P	%	0,081
	102	S	%	0,244
	103	N	%	
	104	Ti	%	0,040
	105	Roheisentemperatur (Fuchs)	°C	1.501

TISCO

KÜTTNER

Date: 日期	2011-9-01 08:00 2011-9-02 08:00	Melting time 熔炼时间	12 h 47 min

Siphon 2

Charged / 上料

	Weight 重量	kg per bucket 公斤/料筐	
Sum of buckets 料筐数量		118 piece	
Steel 废钢	384 t	3.256 kg	79,9%
Scrap 2		0 kg	0,0%
BriCS 碾碎	97 t	820 kg	20,1%
Bricks 2		0 kg	0,0%
Total 总量	481 t	4.076 kg	
BFCoke 高炉焦	0 t	0 kg	0,0%
F-Coke 冶金焦	114 t	964 kg	23,7%
Total 总量	114 t	964 kg	23,7%
Lime 石灰石	11 t	95 kg	2,3%
Gravel 砾石	14 t	119 kg	2,9%

Liquid iron / 铁水

Daily production (Srap+Bricks) 日产量（废钢加碾碎）	481 t
Melting rate 熔炼率	37,6 t/h
Temperature iron runner 铁水沟铁水温度	1.516 °C
Temperature iron holder 中间罐铁水温度	#DIV/0!

Analysis / 分析

	Iron runner 铁水沟	Iron holder 中间罐
C	4,276%	#DIV/0!
Si	0,698%	#DIV/0!
S	0,059%	#DIV/0!
Mn	0,374%	#DIV/0!
P	0,040%	#DIV/0!
Ti	0,030%	#DIV/0!

Slag analysis / 炉渣分析

SiO_2	36,7%	CaO	38,6%	MgO	6,3%	Al_2O_3	15,7%	R2	1,05	R3	1,22
FeO	1,27%	S	0,8%	MnO	1,7%			R4	0,86		

Blast generation / 热风生成

Vol.	19.745 Nm3/h	Press.	13 kPa	Temp. H	709 °C	Temp.Exhaust gas	225 °C
O_2-Enr.	0 Nm3/h	O_2-Lan.	1.882 Nm3/h	O_2-Content	31%	O2 / to iron	160 m3/to

Clean gas data 清洁煤气数据				Tuyere Cooling风口冷却		Shell Cooling炉壳冷却	
During Export Gas ON		CO	35,0 %	Flow	169 m3/h	Flow head	101 m3/h
Export Gas	0 Nm3/h	CO_2	8,3 %	Temp. In	53 °C	Flow shaft	116 m3/h
C. C.	0 Nm3/h	O_2	0,0 %	Temp. Out	65 °C	Flow valve	5 m3/h
time Export gas	0,0 h	H_2	2,4 %	Desintegrator离心式洗涤器		Temp. In	37 °C
Energy Export gas	0 MWh	CO / CO_2	4,2	Current	1.417 A	Temp. Out	41 °C
During Export Gas OFF		hu	4665 kJ/m³	Water-Desint.	126 m3/h		
C. C.	6.601 Nm3/h	Top Gas Temp.	187 °C	Water-Cooler	304 m3/h		
Torch	23.578 Nm3/h						

Component	amount [t]	Xi_Si [mas.-%]	Xi_SiO2 [mas.-%]	total SiO2 [t]	Xi_Fe [mas.-%]	total Fe [t]
Scrap/ skulls	384	1,31	2,80	10,8	90,77	348,7
Bricks	97	2,96	6,33	6,1	32,90	31,8
BF-Coke	0	2,13	4,56	0,0	0,00	0,0
F-Coke	114	2,13	4,56	5,2	0,20	0,2
Limestone	11	1,09	2,34	0,3	0,10	0,0
Gravel	14	43,82	93,73	13,1	0,00	0,0
total amount	620	2,67	5,72	35,5	61,43	380,8
Hot metal	397	0,70	1,49	5,9	95,00	377,6
dust	25	2,24	4,80	1,2	10,00	2,5
Slag	77	17,18	36,74	28,3	0,80	0,6

Melting capacity	37,6	t/h
Scrap/ skull	30,1	t/h
Bricks	7,6	t/h
Hot metal	31,1	t/h
Slag	6,0	t/h

Meltig time 熔炼时间

		Duration持续	Remark注释			Duration持续	Remark注释
Blast ON 送风	19:13			Blast ON 送风			
Blast OFF 休风	0:00	04:47 h		Blast OFF 休风		00:00 h	
Blast ON 送风	0:00			Blast ON 送风			
Blast OFF 休风	8:00	08:00 h		Blast OFF 休风		00:00 h	
Blast ON 送风				Blast ON 送风			
Blast OFF 休风		00:00 h		Blast OFF 休风		00:00 h	
Total 总量		12:47 h					

Liquid iron analysis - iron runner 铁水分析-铁水沟

Uhrzeit时间	Nummer次数	C	Si	S	Mn	P	Ti
22:50	1	3,570%	0,430%	0,041%	0,250%	0,038%	0,028%
1:00	2	4,870%	0,350%	0,031%	0,290%	0,030%	0,016%
3:00	3	4,200%	0,690%	0,067%	0,470%	0,033%	0,026%
5:00	4	4,820%	0,910%	0,059%	0,490%	0,048%	0,033%
7:00	5	3,920%	1,110%	0,097%	0,370%	0,053%	0,045%
Average平均值		4,276%	0,698%	0,059%	0,374%	0,040%	0,030%

Liquid iron temperature 铁水温度

Uhrzeit时间	Nummer次数	°C
21:00	1	1.487 °C
22:00	2	1.460 °C
22:30	3	1.453 °C
23:00	4	1.492 °C
0:00	5	1.503 °C
1:00	6	1.523 °C
2:00	7	1.506 °C
3:00	8	1.562 °C
4:00	9	1.550 °C
5:00	10	1.526 °C
6:00	11	1.555 °C
7:00	12	1.540 °C
8:00	13	1.545 °C
	14	
	15	
	16	
	17	
	18	
	19	
	20	
	21	
	22	
	23	
	24	
Average平均值		1.516 °C

Liquid iron temperature iron holder铁水

Uhrzeit时间	Nummer次数	°C
	1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	
	10	
Average平均值		#DIV/0!

Slag analysis 炉渣分析

Uhrzeit时间	Nummer次数	SiO2	CaO	MgO	FeO	S	MnO	Al2O3	R1	R2
22:50	1	36,200%	35,830%	6,380%	2,990%	0,670%	2,390%	16,730%		0,99
1:00	2	36,920%	37,080%	6,220%	1,620%	0,690%	2,290%	16,860%		1,00
3:00	3	37,350%	40,450%	6,290%	0,600%	0,690%	1,920%	15,850%		1,08
5:00	4	37,220%	40,750%	6,200%	0,650%	0,900%	1,030%	14,100%		1,10
7:00	5	36,010%	39,050%	6,270%	0,470%	1,010%	0,930%	15,030%		1,08
Average平均值		36,740%	38,632%	6,272%	1,266%	0,792%	1,712%	15,714%	#DIV/0!	1,05

Liquid iron analysis - iron holder 铁水分析-中间罐

Uhrzeit时间	Nummer次数	C	Si	S	Mn	Ni	Cr
	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
	11						
	12						
	6						
	7						
	8						
	9						
	10						
	11						
	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
	11						
	12						
Average平均值		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

TISCO — KÜTTNER

Date: 日期	2011-7-23 08:00 2011-7-24 08:00	Melting time 熔炼时间	16 h 22 min

Charged / 上料

Sum of buckets 料筐数量		111 piece	
	Weight 重量	kg per bucket 公斤/料筐	
Steel 废铁	112 t	1.009 kg	24,2%
Scrap 2		0 kg	0,0%
BrICS 砖碎	350 t	3.157 kg	75,8%
Bricks 2		0 kg	0,0%
Total 总量	**462 t**	**4.165 kg**	
BFCoke 高炉焦	0 t	0 kg	0,0%
F-Coke 冶金焦	88 t	792 kg	19,0%
Total 总量	**88 t**	**792 kg**	**19,0%**
Lime 石灰石	1 t	6 kg	0,1%
Gravel 砾石	19 t	175 kg	4,2%

Liquid iron / 铁水

Daily production (Srap+Bricks) 日产量（废铁加砖碎）	462 t
Melting rate 熔炼率	28,3 t/h
Temperature iron runner 铁水沟铁水温度	1.527 °C
Temperature iron holder 中间罐铁水温度	1.425 °C

Analysis / 分析

	Iron runner 铁水沟	Iron holder 中间罐
C	4,614%	#DIV/0!
Si	0,910%	#DIV/0!
S	0,143%	#DIV/0!
Mn	0,245%	#DIV/0!
P	0,100%	#DIV/0!
Ti	0,030%	#DIV/0!

Slag analysis / 炉渣分析

SiO_2	41,8%	CaO	42,3%	MgO	5,4%	Al_2O_3	10,8%	R1	1,01	R2	1,01
FeO	0,60%	S	1,0%	MnO	0,7%						

Blast generation / 热风生成

Vol.	23.873 Nm3/h	Press.	25 kPa	Temp.	724 °C	Temp.Export	271 °C
O_2-Enr.	0 Nm3/h	O_2-Lan.	1.737 Nm3/h	O_2-Content	26%	O2 / to iron	238 m3/to

Clean gas data 清洁煤气数据				Tuyere Cooling 风口冷却		Shell Cooling 炉壳冷却	
C. gas	68.328 Nm3/h	CO	35,1 %	Flow	166 m3/h	Flow head	101 m3/h
Top. gas Tem.	196 °C	CO_2	8,7 %	Temp. in	63 °C	Flow shaft	103 m3/h
Torch	29.235 Nm3/h	O_2	0,0 %	Temp. Out	75 °C	Flow valve	5 m3/h
C. C.	8.888 Nm3/h	H_2	2,6 %	**Desintegrator 离心式洗涤器**		Temp. in	40 °C
Export	30.205 Nm3/h	CO / CO_2	4,0	Current	1.464 A	Temp. Out	44 °C
time Export gas	8,7 h	hu	4699 kJ/m³	Water-Desint.	127 m3/h		
Energy Export gas				Water-Cooler	329 m3/h		
343 MWh							

Component	amount [t]	Xi_Si [mas.-%]	Xi_SiO2 [mas.-%]	total SiO2 [t]	Xi_Fe [mas.-%]	total Fe [t]
Scrap/ skulls	112	1,31	2,80	3,1	90,77	101,7
Bricks	350	2,96	6,33	22,2	32,90	115,3
BF-Coke	0	2,13	4,56	0,0	0,00	0,0
F-Coke	88	2,13	4,56	4,0	0,20	0,2
Limestone	1	1,09	2,34	0,0	0,10	0,0
Gravel	19	43,82	93,73	18,2	0,00	0,0
total amount	**570**	**3,90**	**8,34**	**47,6**	**38,07**	**217,1**
Hot metal	225	0,91	1,95	4,4	95,00	214,0
dust	23	2,24	4,80	1,1	10,00	2,3
Slag	**101**	**19,55**	**41,81**	**42,1**	**0,80**	**0,8**

Melting capacity	**28,3**	**t/h**
Scrap/ skull	**6,4**	**t/h**
Bricks	**21,4**	**t/h**
Hot metal	**13,8**	**t/h**
Slag	**6,1**	**t/h**

Meltig time 熔炼时间

		Duration 持续	Remark 注释			Duration 持续	Remark 注释
Blast ON 送风	8:00			Blast ON 送风	12:00 AM		
Blast OFF 休风	15:38	07:38 h	Oxygen content was overproof 氧含量超标	Blast OFF 休风	2:00 AM	02:00 h	
Blast ON 送风	16:02			Blast ON 送风			
Blast OFF 休风	20:50	04:48 h	problem of limit switch of the traveling weighing bin 称量小车限位开关故障	Blast OFF 休风		00:00 h	
Blast ON 送风	22:04			Blast ON 送风			
Blast OFF 休风	0:00	01:56 h		Blast OFF 休风		00:00 h	
Total 总量		**16:22 h**					

Liquid iron analysis - iron runner 铁水分析-铁水沟

Uhrzeit 时间	Nummer 次数	C	Si	S	Mn	P	Ti
8:25 AM	1	4,390%	0,840%	0,187%	0,200%	0,095%	0,022%
9:30 AM	2	4,480%	0,910%	0,187%	0,210%	0,091%	0,023%
10:30 AM	3	4,490%	0,850%	0,179%	0,230%	0,096%	0,026%
11:25 AM	4	4,590%	0,810%	0,156%	0,240%	0,094%	0,026%
12:30 PM	5	4,340%	0,990%	0,108%	0,260%	0,102%	0,034%
1:30 PM	6	4,380%	1,050%	0,119%	0,260%	0,103%	0,034%
2:35 PM	7	4,260%	1,050%	0,119%	0,250%	0,099%	0,033%
3:30 PM	8	4,540%	1,190%	0,111%	0,270%	0,102%	0,040%
5:30 PM	9	4,980%	0,770%	0,095%	0,264%	0,099%	0,028%
6:10 PM	10	4,530%	0,820%	0,224%	0,240%	0,098%	0,027%
7:50 PM	11	5,120%	0,860%	0,148%	0,250%	0,099%	0,028%
8:50 PM	12	5,040%	1,090%	0,118%	0,280%	0,106%	0,036%
11:40 PM	13	4,940%	0,630%	0,164%	0,200%	0,105%	0,030%
1:03 AM	14	4,510%	0,880%	0,135%	0,270%	0,114%	0,031%
Average 平均值		4,614%	0,910%	0,143%	0,245%	0,100%	0,030%

Liquid iron temperature 铁水温度

Uhrzeit 时间	Nummer 次数	°C
08:25	1	1.512 °C
10:30	2	1.536 °C
12:30	3	1.537 °C
13:30	4	1.534 °C
15:30	5	1.519 °C
17:30	6	1.531 °C
18:10	7	1.531 °C
19:50	8	1.527 °C
23:40	9	1.531 °C
01:03	10	1.509 °C
Average 平均值		1.527 °C

Recipe

Date	Time	Charges	Seq	Scrap %	C-Brick %	F-Coke %	BF-Coke %	Gravel %	Lime %	H2S- %	Taba %	Charge kg
23.07.2011	8:08	85		15,0	85,0	20,0		4,6				4000,0
	18:47	19		15,0	85,0	20,0		5,1				4000,0
	22:35	5		100,0		20,0			3,2			4000,0
	23:13	1		100,0								4000,0
	23:17	1		100,0		20,0						4000,0

Slag analysis 炉渣分析

Uhrzeit 日期	Nummer 次数	SiO2	CaO	MgO	FeO	S	MnO	Al2O3	R1	R2
8:25 AM	1	42,630%	41,610%	5,550%	0,870%	0,890%	0,770%	10,800%		0,980%
9:30 AM	2	43,740%	41,280%	5,540%	0,680%	0,910%	0,780%	10,900%		0,940%
10:30 AM	3	42,740%	42,090%	5,460%	0,500%	0,950%	0,720%	11,020%		0,980%
11:25 AM	4	42,250%	42,500%	5,450%	0,520%	0,960%	0,720%	10,860%		1,010%
12:30 PM	5	42,070%	42,570%	5,430%	0,530%	0,950%	0,710%	10,810%		1,010%
1:30 PM	6	41,200%	42,620%	5,390%	0,460%	0,980%	0,630%	10,810%		1,030%
2:35 PM	7	41,020%	42,160%	5,500%	0,410%	1,020%	0,570%	10,930%		1,030%
3:30 PM	8	41,030%	42,700%	5,360%	0,320%	1,040%	0,550%	11,100%		1,040%
5:30 PM	9	41,940%	42,200%	5,280%	0,820%	0,940%	0,820%	10,640%		1,010%
6:10 PM	10	41,940%	42,980%	5,180%	0,620%	0,970%	0,770%	10,780%		1,020%
7:50 PM	11	41,680%	43,150%	5,110%	0,450%	0,980%	0,720%	10,780%		1,040%
8:50 PM	12	40,860%	42,710%	5,340%	0,390%	1,040%	0,590%	10,840%		1,050%
11:40 PM	13	40,550%	41,460%	5,670%	1,220%	0,890%	0,800%	10,570%		1,020%
1:03 AM	14	41,710%	42,520%	5,530%	0,670%	1,010%	0,620%	10,830%		1,020%
Average 平均值		41,811%	42,325%	5,414%	0,604%	0,966%	0,698%	10,834%	#DIV/0!	1,013%

Liquid iron analysis - iron holder 铁水分析-中间罐

Uhrzeit 时间	Nummer 次数	C	Si	S	Mn	Ni	Cr
	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
	11						
	12						
	6						
	7						
	8						
	9						
	10						
	11						
	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
	11						
	12						
Average 平均值		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Liquid iron temperature iron holder 铁水温度

Uhrzeit 时间	Nummer 次数	°C
09:30	1	1.411 °C
10:30	2	1.431 °C
15:30	3	1.432 °C
	4	
	5	
	6	
	7	
	8	
	9	
	10	
Average 平均值		1.425 °C