Reduction of greensand emissions by minimum 25% – Case study

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Abstract: This paper describes the development of an inorganic alternative to coal or coal replacement for bentonite bonded molds (greensand molding) and the realization in an operating foundry. Through a time period of 1.5 years, Componenta Foundry changed in many steps from a classical green sand system to a coal free system, based on ENVIBOND® developed in the GO-APIC project and further development as an S&B project. At Componenta Foundry, the percentage of casting defects or scrap did not increase. There was a tendency of an increase in stress (scabbing) defects and of a decrease in penetration defects. Benzene emission is reduced by 40%, odor emission has lower values (not statistically proven). Visible is less smoke in the foundry, especially at the cooling line. The benefits for health and emissions are clearly seen.

Key words: greensand emissions; bentonite bonded molds; binder system; coal

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1 Introduction

The European Community funded in The 5th Framework Program (2000–2004) to develop a greensand system without organic additives, GO-APIC project. This was published during the 66th World Foundry Congress 2004 in Istanbul, Turkey). In 2004 S&B Industrial Minerals started a project in cooperation with the Universities of Freiberg – Germany and Krakow – Poland to optimize the reduction of greensand emissions and to establish a methodology to evaluate results after a switch to a sea coal free molding sand system.

Bentonite (clay) bonded moulds are in principle an inorganic binder system without organic emissions. The clay burns only partly down and most of the clay (over 90%) is available to be used again as an inorganic binder (see Fig. 1).

When a mold is prepared in green sand, only pressure from a molding machine is required for hardening without a catalyst or heat is required. This concept relates to the efficiency and sustainability to prepare molds for the metal casting process.

A foundry commonly adds coal and occasionally a

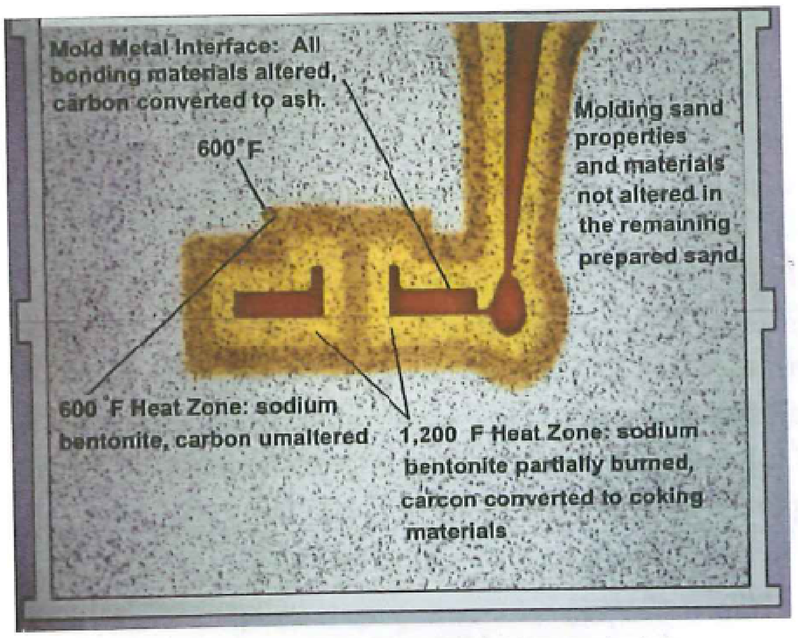

Fig. 1: The conversion of carbon to coking materials causes emissions of cracking products and carbon monoxide (600°F = 315°C, 1,200°F = 650°C)

hydrocarbon resin to a green sand molding system to improve the castings surface, achieve a reduction in casting defects and ameliorate the separation of molding sand from the casting during the "shakeout" phase of the metal casting process. When molding sand containing coal is used in the metal casting process, the mould generates emissions of hazardous components due to incomplete burning and cracking processes when molten metal is poured into the prepared mold. This has a negative impact on health of foundry workers and the surrounding environment. The emittea gasses contain aromatic compounds, benzene, carbon monoxide. Also there is contamination of waste which restricts re-use of molding sand.

Normally the ratio of binder (bentonite) to carbonaceous

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Male, born in 1954, Apeldoorn, Netherlands. He studied analytical chemistry and worked in laboratory of a paper mill for 5 years. He changed to foundry industry in 1980 and was in charge of the foundry lab. During this period he became foundry engineer. He started in 1994 as product manager in foundry supplying industry and changed to S&B Industrial Minerals in 1998, to be head of R&D foundry. In 2008 he took over the position of manager of R&D bentonite division. He introduced many new ideas, products and processes in foundry mold and core technology. He published many papers and was inventor of several patents.

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additives is 75% – 25%.

2 Development of greensand without coal

Greensand without coal does not automatically include greensand without organics. We have to realize that core binders which are used in the foundry industry to produce prepared sand shapes (known as cores) can condensate in greensand as a result of the metal casting process. In fact these organic binders systems with emitting gasses and odors are tolerable thanks to the adsorption properties of clay bonded moulds. There are many references in the foundry trade journals that review this concept. Fortunately a greensand system that does not contain a carbonaceous component exists in the foundry industry today. This technology contains minerals that do not emit organic volatiles compounds which do not produce lustrous carbon. (Lustrous carbon is the result of the metal casting process that precipitates graphite from a hot gas atmosphere that is over saturated with carbon compounds onto the mould surface of the green sand). Through the elimination of the lustrous carbon, the properties of coal into the prepared molding sand, (swelling, plasticity, and formation of coke residues) will create a situation in which the casting surface deteriorates and result in greensand adhering onto casting surface increases.

In the GO-APIC project several prospective inorganic coal replacements were tested. Most of the components that was added to prepared greensand resulted in lowering the mechanical performance of the prepared green sand molds. It was determined that with the addition of a sufficient amount of graphite into the processed bentonite resulted in a new and different bentonite bonding material, and then combined with the addition of a specific natural zeolite to replace carbon residues performed as expected in the metal casting process. If a foundry requires a different shakeout requirement (based upon specific foundry applications), special additives or a different bentonite could be introduced.

Foundry trials of the prepared mineral blend verified that the lack of carbonaceous additives to greensand did not change the metallographic structure of nodular cast iron just below the metal surface.

This system was optimized and introduced in Componenta Foundry during May 2007 and December 2008.

3 Case study, Componenta

At Componenta environmental issue is an important part of many business decisions, and their management systems have been designed to help guide environmental efforts. Choosing optimal materials and minimizing the number of rejects help make production more environmentally sustainable. Another requirement of management is not to consume more materials or energy than it will be necessary.

◇ Core business consists of foundries and machine shops in Finland, Sweden, the Netherlands and Turkey;

◇ Net sales 635 MEUR;

◇ Personnel 5,100 (incl. leased personnel);

◇ Products are ready-to-install cast, machined, surface treated and pre-assembled components;

◇ Customers are globally operating companies in off-road, heavy trucks, automotive, diesel & wind and machine building industries;

◇ Componenta's shares are quoted on the OMX Nordic Exchange in Helsinki;

◇ Componenta Döktas' shares are quoted on the Istanbul Stock Exchange.

In this scope Componenta Heerlen decided to substitute the classical lustrous carbon preblended product with a product based on S&B product development to minimize the impact on the preblend would have on the environment and improve working situation in their plant. S&B commercial name of this product is ENVIBOND®.

The Componenta Heerlen plant has a furan sand production line and a greensand HWS production line. The HWS (860 mm × 630 mm × 330/330 mm) molds are ~580 kg and iron pouring weight 120 kg. The line produces 130 molds per hour. The only new sand addition used in the preparation of molding sand is the result of the addition of cores into the metal casting process. Componenta Heerlen greensand makes 1.5 cycles per shift (8 h). Typical castings are hydraulic parts, hubs, gear box casings.

4 Considerations

The first question that was considered was the impact of lustrous carbon formers on emissions (not all emissions from green sand and core binders). It was concluded that by calculating the quantity of the organic volatiles in the prepared greensand the VOC (Volatile Organic Component) potential of the LCP (Lustrous Carbon Former) was 73%. Then by replacing the traditional LCP by 50% with ENVIBOND® a reduction in the emission potential was 38%. An overview of the main emission contributors in LCP greensand and core binder is shown in Fig. 2.

5 Introduction of coal free (LCP free) greensand

The original formulation at Componenta used a blend of 50% pure bentonite and 50% LCP. The addition of these products was from two silos into the one muller. This was changed in a ready to use preblend of 22% LCP and 78% bentonite. As a result of preblending the two formulations only one silo was needed and the second was available for the ENVIBOND® product.

An introduction schedule was created, starting with 10% ENVIBOND® and increasing each month by 10%. All process parameters of the greensand were collected before starting the introduction of each phase of the addition. An external company did emission measurements at various locations in the foundry. These locations were at the production of castings and at shake out. Multiple emission measurements

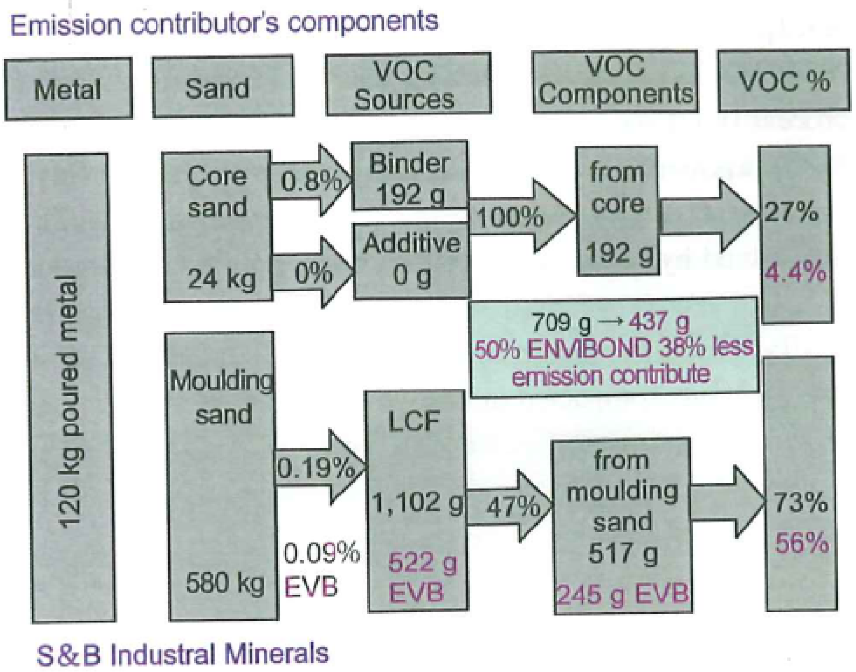

Fig. 2: An overview of the main emission contributors in LCP greensand and core binder. Componenta works with a very low binder content in PUR Cold Box, 0.4% Part 1 – phenolic resin and 0.4% Part 2 – isocyanate (this has a positive effect on emissions too). Demonstrated is an average mold, 580 kg green sand and 24 kg core sand, before and after the introduction of 50% ENVIBOND®. The LCP input goes from 0.19% per mold to 0.09%. Later Componenta came to 100% ENVIBOND®.

were completed so that comparable results after each phase of introduction of additional ENVIBOND® were available.

At the beginning of the series of production trials the green sand had a LOI of 4% and active clay was around 8.5%. During the introduction to 100% ENVIBOND®, the LOI dropped to 2.5%. The remaining LOI was generated from the graphite, LOI of bentonite and from core binder residues. The remaining TOC (Total Organic Carbon) was 1.0%. Figure 3 shows that May 2007 started replacing LCP and December 2008 no additional LCP was added.

Before the introduction of the green sand without coal samples were stored and measured in parallel with those test samples after each test period. The stored green sand was again prepared by mixing in a lab muller and with the addition 0.2% moisture. The comparison of these test results can be found in Table 1.

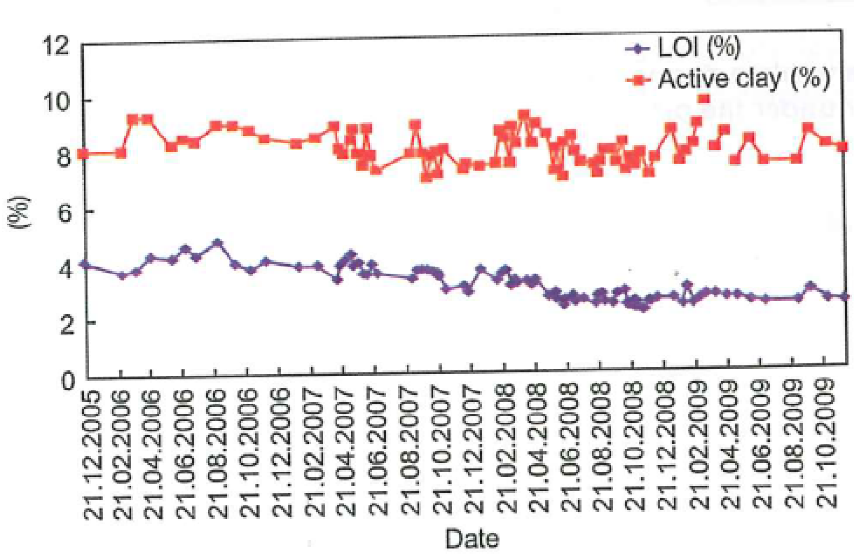

Fig. 3: May 2007 started replacing LCP and December 2008 no additional LCP was added

Table 1: Coal less green sand has slightly different properties

Technological parameters	2007	2008	Change (%)
Weight of test specimen (g)	143.0	142.5	-0.3
Compressibility (%) (100 N·cm^{-2})	41.4	41.2	-0.5
Moisture content (%)	3.4	3.6	5.6
Green compressive strength (N·cm^{-2})	17.4	17.1	-1.7
Green tensile strength (N·cm^{-2})	3.2	2.9	-7.8
Dry compression strength (N·cm^{-2})	40.7	47.0	15.5
Wet tensile strength (N·cm^{-2})	0.29	0.30	2.4
Permeability	153	158	3.3
Shatter-index (%)	77.5	77.9	0.5
Flowability Orlov (%)	79.9	76.2	-4.6
Abrasion loss after 2 min. (%)	3.65	2.68	-26.6
Abrasion loss after 5 min. (%)	24.3	20.0	-17.7
Deformability (mm)	0.37	0.39	5.4
Green shear strength (N·cm^{-2})	5.36	5.49	2.4

It can be expected that the lack of coal or carbonaceous components will have an effect on the greensand properties at high temperatures or after the green sand has an opportunity to cooling down.

Table 2 contains information comparing these test results. For "shake out" (separating sand from casting) the hot compressive strength is important. It seems that the collapsing of the new prepared molding sand system molds are better up to 400℃ and then lower when the prepared molding sand is over 400℃, see Fig. 4. This is understandable because coal reacts at higher temperatures. At Componenta Foundry these differences in shake out properties were observed and did not result in sincere problems.

The dilatation of greensand was measured during flame heating, see Fig. 5 [2]. There was no difference in the expansion of greensand when compared to the classical greensand. The stress [3], the pressure from green sand that is enclosed and

Table 2: High temperature properties of greensand

Technological parameters	2007	2008	Change (%)
Compactability (%)	41	40.9	-0.2
Moisture (%)	3.38	3.45	2.1
Specimen weight (g)	143	143	0.0
Green compressive strength (N·cm^{-2})	17.7	16.6	-6.2
Hot compressive strength (N·cm^{-2})			-
150 °C /3 h	38.7	38.1	-1.6
350 °C /1.5 h	37.5	30.7	-18.1
550 °C / 45 min	21	28.3	34.8
750 °C / 30 min	14.9	14.9	0.0
Hot shear strength (N·cm^{-2})			
Heating 15 s	2.3	2.1	-8.7
Heating 60 s	3.7	4.7	27.0
Expansion test (mm)			
30 s heating	0.15	0.17	13.3
60 s heating	0.33	0.33	0.0
180 s heating	0.6	0.58	-3.3
Stress during heating (N·cm^{-2})			
30 s	9.22	9.09	-1.4
60 s	18.3	20.8	13.7
max	22.9	26.7	16.6

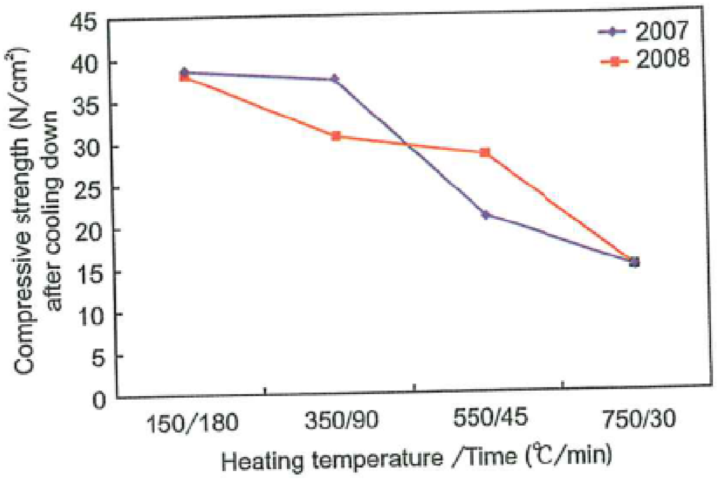

Fig. 4: Shake out of castings, at low and very high temperatures both systems perform equal. At 350°C the 2008 is better and at 550°C 2007 is better (better = lower value)

cannot move is, lower in the classical green sand. This can be explained because of the addition of more graphite (higher compaction) and lack of burning coal [4]. In the metal casting process (no flame and oxygen) this effect will be less rigorous. At Componenta we observed more scabbing (under flask, after ingot) after going to 100% coal-less green sand. This was solved by using two ingots and a bentonite modification. The tendency to penetration defects of grey iron disappeared totally, probably due to lower moisture demand and more, homogeneous compacted molds. Figure 6 is the measurement of the stress from a heated greensand plate during flame heating. The total lack of coal increases slightly the stress, measured by the sensor under the plate.


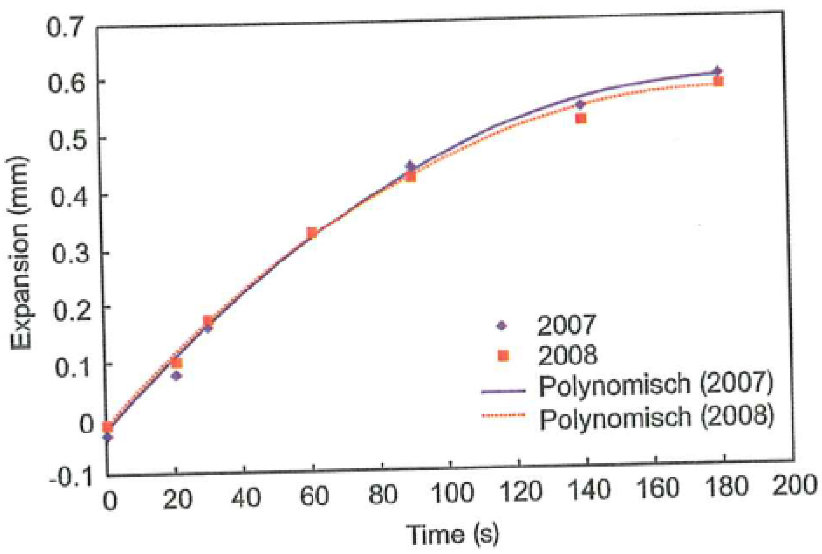

Fig. 5: The dilatation curves of green sand 2007 and 2008 are equal


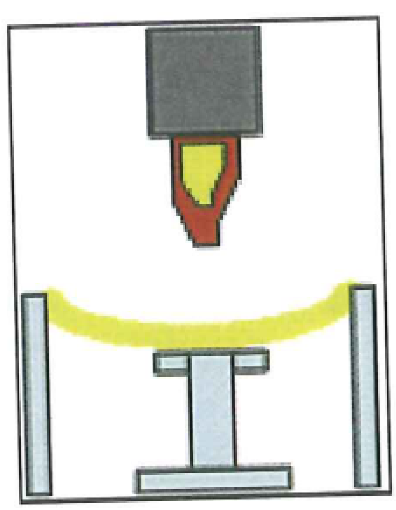
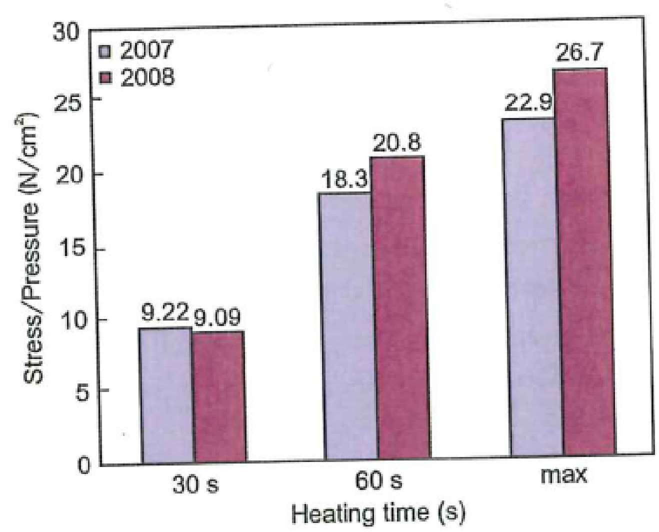

Fig. 6: The measurement of the stress from a heated greensand plate during flame heating. The total lack of coal increases slightly the stress, measured by the sensor under the plate

6 Environment, health and safety aspects

The use of no coal has positive impact on safety aspects, for transporting the preblend, storage and handling the product (ENVIBOND®) or dusty components of it, that do not contain dangerous components. The coal less preblended product has no self heating process due to the auto oxidation of coal and its potential to explode.

For determination of the environmental and health benefits of coal less greensand parallel testing of coal and coal free sand was completed in a pilot situation (Fig. 7).

The second way to test changes that occur when introducing the coal less system is to measure the foundry emissions. To complete this evaluation it was obligatory to create as good as possible the exact same process conditions before and after the introduction of the coal free system. In this measurement situation a core less casting and a casting often used in production were completed. The external measurements were executed by Pro-Monitoring Lab.

The pilot casting is shown in Fig. 7. A standard test specimen of 200 g of the greensand to be evaluated was compacted with 3 rams and poured with iron of 1,400℃. All gasses can only escape via the metal pipe. BTEX (Benzene, Toluene, Ethylbenzene) is collected in the adsorbent (charcoal).

The emission values of the pilot casting are worst case values. The test specimen is heated in a heating range of shock on the surface of the green sand to 1,400℃ and relatively slow in the centre to 900℃.

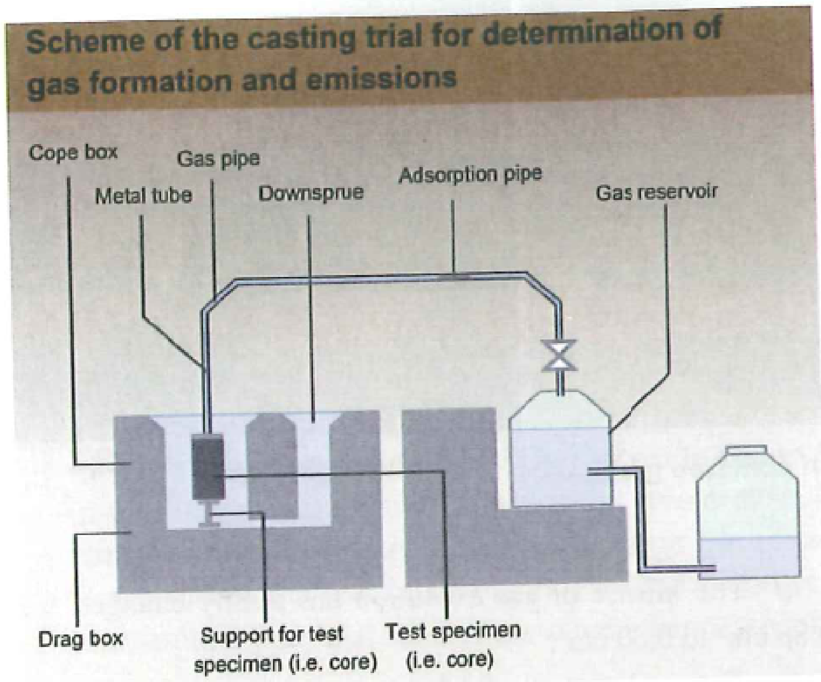

Fig. 7: Pilot casting and measurement of BTEX and gas volume. A specimen of ~ 200 g greensand is over poured with grey iron at 1,400°C (results in Table 3).

In this situation all prepared molding sand passes the temperature range of 400 – 900℃, which emits most of the volatile material, and the sand that is not surrounded with metal remains cold sand. This means that the values can not be extracted to foundry emission tonnage. The differences demonstrate a benzene emission reduction of 38%.

For casting quality a lower gas volume during casting is an advantage. More important are the kinetics of gas development, dV/dt. Coal less (ENVIBOND®) has a gas evolution of 0.5 $cm^3 \cdot (g \cdot s)^{-1}$ and with coal 0.88 $cm^3 \cdot (g \cdot s)^{-1}$.

It is surprising to see the relation between emitted benzene and benzene content of greensand. Benzene in green sand is below 1 $mg \cdot kg^{-1}$ and emitted benzene between 110 – 210 $mg \cdot kg^{-1}$. A very limited amount of benzene is adsorbed in greensand.

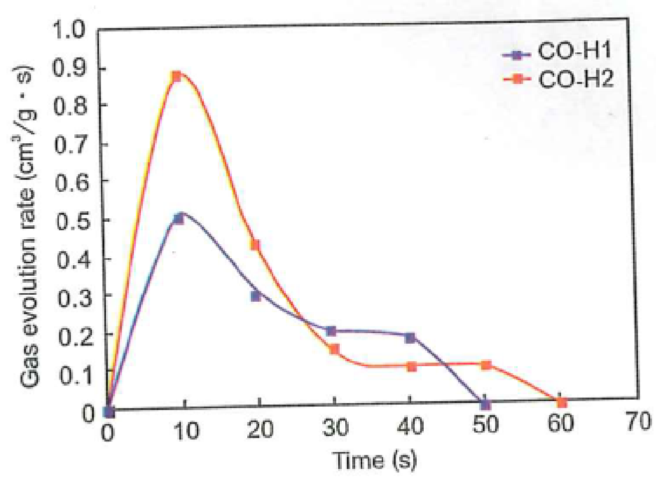

Fig. 8: Gas volume *dV/dt* before and after coal less (ENVIBOND®) red line 2007, black line 2008

Table 3: The introduction of coal less (ENVIBOND®) reduced the gas volume with 20% and benzene emission with ~40% (the gas contains also inorganic volatiles)

Sample	Weight of sample (g)	Volume of gases ($dm^3 \cdot kg^{-1}$)	Emission of gases ($mg \cdot kg^{-1}$ green sand) Benzene	Toluene	Ethylobenzene	Xylene
2008	191.29	20.91	141.15	16.73	0.52	3.66
2008	191.13	20.93	116.15	14.13	0.52	3.14
Average 2008	-	20.92	128.65	15.43	0.52	3.40
2007	189.32	25.35	206.53	28.52	1.58	7.92
2007	191.70	25.04	206.57	22.95	0.52	5.74
Average 2007	-	25.20	206.55	25.74	1.05	6.83

The Emissions of BTX and odor was measured in the foundry, pouring – cooling line (PC-Line) and shake out. During a defined process, 90 kg pouring iron, core less samples were taken 3 times, during 20 minutes. The emission was recalculated to mg BTX or OU per mold poured (OU = odor units).

For odor it is known that core binder is affecting these through condensates in greensand and that the whole installation can have a memory effect (all pipes can be polluted with dust and condensates). This means that the OU value is less reliable than the BTX values, see Table 4.

7 Casting quality

It was observed that the surface of the castings produced at Componenta Heerlen was not different from a green sand

Table 4: BTEX and odor emissions at two foundry locations (Pouring / Cooling and Shake out)

	2007	2008	90 kg casting, 43 molds/h
Pouring / Cooling	BTX	BTX	
Benzene	100	60	Benzene set to 100
Toluene	53	0	
Xylene	40	0	
Shake out			
Benzene	67	53	
Toluene	67	67	
Xylene	67	0	
Pouring / Cooling	OU 2007	OU 2008	
1st measurement	1814	1986	
2nd measurement	3058	3087	
3rd measurement	2362	534	
			In tendency no difference
Shake out			
1st measurement	6232	3883	
2nd measurement	4492	1825	
3rd measurement	16483	1536	
			In tendency lower odor emissions during shake out

system without coal. But depending on casting geometry is observed that sand sticking increased after taking out more than 50% coal. This can be compensated by partly using less of the bentonite preblend. This reduction in the preblend resulted in a lower clay content in the prepared greensand (below 8.5%).

It was also observed that when over 70% of the coal in the greensand was taken out, there was a tendency of stress crack at the ingot / bottom of the mold. This was solved by use of more ingot and higher activation grade of bentonite.

All the penetration defects of mainly grey iron castings disappeared after the complete introduction of the coal free system.

Fig. 9: Typical castings made in coal free greensand

8 Summary

During a time period of 1.5 years Componenta Foundry changed in many steps from a classical green sand system to a coal free system, based on ENVIBOND® developed in the GO-APIC project and further development as an S&B project. At Componenta Foundry the percentage of casting defects or scrap did not increase. There was a tendency of an increase in stress (scabbing) defects and of a decrease in penetration defects. The benefits for health and emissions were clearly seen. Benzene emission is reduced by 40%, and odor emission has lower values (not statistically proven). Visible is less smoke in the foundry, especially at the cooling line.

The introduction of the new system was profitable for the foundry (taking into account a higher product price, less consumption, less maintenance of filter unit, etc).

The scientific observations of coal free greensand versus classical greensand show:

◇ No fundamental changes in greensand properties, and coal free has a better friability (Table 1);

◇ No change in dilatation curve (Fig.5);

◇ Minor changes in mold collapsing (Fig.4), better at low temperatures, less preferred at high temperatures;

◇ More stress during heating at high temperatures (Fig. 6);

◇ The adsorption of benzene in greensand is minimum (concentration in greensand is below 1 $mg \cdot kg^{-1}$ and the emission in worst case situation 100 – 200 $mg \cdot kg^{-1}$);

◇ The kinetic of gas evolution has totally changed from 0.88 cm^3 to 0.50 cm^3;

◇ The tendency of coal less greensand to emit less odor, not statistical prove due to memory effect of core binder and system pollutions;

◇ The benzene emission reduction is ~ 40%.

The introduction of a coal free system at Componenta Foundry was a major contribution to sustainable development in the foundry industry. This contributes to raw material, waste, energy reduction and improvement of working and environmental situations.

References

[1] Lemkow G. Greensand without organic additives for the production of iron castings. In: Prooceedings of the 66th Word Foundry Congress (Vol.1), Turkey, 2004: 489–501.

[2] Boenisch D. Höhere Guβgenauigkeit durch ausdehnungsarme Formteile — Untersuchungen mit dem Formstoffdilatometer. Giesserei, 1979, 66(Heft 21): 775–787.

[3] Patterson W, Boehnisch D. Das Schülpendiagramm für Naβguβande. Giesserei, 1964, 51(Heft 21): 634–641. (Druckspannungsmessung – Stress Measurement of greensand)

[4] Boenisch D,Patterson W. Wirkung des Kohlenstaubes im Naβguβsand. Giesserei, 1967, 54(Heft 18): 465–471.

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