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Green Foundry

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Conclusion report of the chamber emission tests in Finland and Poland.

1. Introduction

This report combines the results and experiences from all the emission tests in Finland and Poland. Emissions were measured from the moulds made by using organic and inorganic binder systems

In Finland the emission tests were made by using a closed chamber, where the mould was placed in. The weight of the test casting was about 200 kg and the amount of sand in the mould was also ca. 200 kg. The tests were made in two ferrous foundries: URV and Karhula.

In Poland small scale chamber tests were made in the laboratory foundry of AGH-UST and in the ferrous foundry Hardkop. The weight of the test casting in the AGH-UST laboratory test as about 150 g and the amount of the sand in the mould was also ca. 150 g. The weight of the test casting in Hardkop was ca 23 kg and the amount of sand in the mould was ca. 65 kg.

The detailed test arrangements and the means of measurements are presented in separate reports.

2. Tested inorganic binder systems

Totally four different inorganic binder systems were tested, table 1.

Table 1. Tested inorganic binder systems.

Inorganic binder system:.Brand name and manufacturer	Binder type	Hardener/promotor/additive type	Recommended contents of binder and hardener/promotor for steel casting	Need for separate drying
Cordis, Huettenes-Albertus	Liquid: Modified Silicate solution, 100 % inorganic	Solid Anorgit additive: 100 % inorganic mixture of synthetic and natural powders	Binder ca. 2% and additive 0,6..1,0 % of the sand amount	In oven at temperature of 130...180 C° or bý hot air
Inotec, ASK	Liquid: Alkali Silicate type, 100 % inorganic	Solid promotor: 100 % inorganic, consisting of minerals and synthetic raw materials	Binder 2..2.2% and promotor 0,6..1,0 % of the sand amount	In oven at temperature of 160...200 C° or by hot air
Clean Cast, Peak	Liquid: Alkaline Silicate type, 100% inorganic	Liquid hardener: organic ester mixture	Binder 2..3% and hardener 0,2..0,3% of the sand amount	Self-setting at room temperature
Geopol, SandTeam	Liquid: Modified silicate type: artificially prepared geopolymers, 100% inorganic	Liquid hardener: organic ester mixture	Binder 1.8%..2% and hardener 0,3..0,36% of sand amount	Self-setting at room temperature

For comparison, following organic binder systems were also tested:

- Furan: binder + hardener = furfuryl alcohol resin + phosphorus acid
- Alphaset: binder + hardener = phenol resin + ester acid
- Green sand: bentonite binder + carbon dust

These three organic binder systems are currently the mostly used binder systems in ferrous foundries.

3. Chamber tests in Finland

One organic binder system and two inorganic binder systems were tested:

- Organic Alphaset in URV iron foundry
- Inorganic Inotec in Karhula Foundry
- Inorganic Peak in Karhula Foundry

The mould and other test arrangements are shown in figure 1.

Figure 1. Test arrangements in chamber tests in Finland

After pouring the melt into the mould, the chamber was closed by a cover, and the emitted gases were measured for 6 hours. Emission gases are formed in burning processes caused by the heat of the molten metal. Due to the porosity of the sand moulds, the gases flow through the moulds to the surface and mix into the surrounding atmosphere.

If the used binder or hardener include flammable organic material, harmful gases can be formed. These are eg. toluene, benzene, ethylbenzene, and xylenes concentrations (BTEX) and polycyclic aromatic hydrocarbons (PAHs). BTEX gases can be carcinogenic and long-term health effects of exposure to PAHs may include cataracts, kidney and liver damage, and jaundice. Other possible harmful gases formed are CO and SO_2. Gas formation in the moulds and especially in the cores can impair the quality of the castings due to risk of gas porosity formation. That is why the volumes of the mentioned harmful gases and total volume of gases were measured in the chamber tests.
The complete results of the measurements are presented in separate reports. Here are presented the measured gas volumes in correlation with the sand amount. These results give the best practical comparison, because the recommended contents of binders and hardeners in correlation with the sand amount are somewhat different, see table 1.

Emission measurement results of three different binding systems are presented in table 2.

Table 2. Emission results per casted material amount, used sand amount and used binder amount from the chamber tests made in Finland

	Test	URV chamber	Karhula chamber	Karhula chamber
	Resin	Alphaset phenolic	Inorganic 1	Inorganic 2
Emission per casting [g/ton casting]	dust	211	56,10	7,40
	CO	10 129	361	128
	SO_2	203,31	6,51	3,30
	VOC	3 256	111,6	35,2
	BTEX	665	8,50	1,05
	asetaldehyde	81,3	8,76	0,72
	formaldehyde	1,92	6,23	0,63
	phenol	109	0,89	0,13
	o-cresol	152	<1,50	<0,08
	p-cresol	74,1	<1,50	<0,05
Sum		14 883	563	177
Emission per sand [g/ton sand]	dust	210	56,1	7,05
	CO	10 069	361	122
	SO_2	202	6,51	3,14
	VOC	3 237	112	33,5
	BTEX	661	8,5	1,00
	asetaldehyde	80,8	8,8	0,69
	formaldehyde	1,91	6,2	0,60
	phenol	108	0,89	0,13
	o-cresol	151	<1,50	<0,07
	p-cresol	73,7	<1,50	<0,05
Sum		14 794	563	168
Emission per binder [g/kg binder]	dust	7,8	1,33	0,35
	CO	373	8,56	6,10
	SO_2	7,49	0,15	0,16
	VOC	120	2,65	1,68
	BTEX	24,5	0,20	0,05
	asetaldehyde	2,99	0,21	0,03
	formaldehyde	0,07	0,15	0,03
	phenol	4,02	0,02	0,01
	o-cresol	5,59	<0,036	<0,004
	p-cresol	2,73	<0,036	<0,002
Sum		548	13,3	8,4

Conclusions of the chamber tests in Finland

The measured emissions from both inorganic binder moulds are only a fraction (3,8% and 0,8%) compared to the emissions of the organic Alphaset binder mould.

Peaks inorganic binder system uses organic hardener (ester compound). Thus it is understandable that some organic emissions are measured. The recommended amount of the hardener is small, and the emissions are only 3,8% compared to the emissions from organic Alphaset mould.
In Inotec inorganic binder system both binder and hardener should be 100% inorganic, but minor organic emissions were found. There must be some organic matter added to the binder and/or promotor material to improve the technical performance of the binder system.

The emissions from both inorganic binder moulds are so small that a drastic decrease in harmful emissions from the foundries would be obtained by using these inorganic binders instead of organic binders. In addition, improvement in indoor air quality is expected, as well as in the quality of the castings due to the decreased risk of gas porosity.

4. Chamber tests in Poland

Three organic binder systems and three inorganic binder systems were tested both in small scale chamber tests in AGH-UST laboratory foundry and in Hardkop pilot iron foundry:

- Organic Alphaset
- Organic Furan
- Organic Green Sand
- Inorganic Inotec
- Inorganic Cordis
- Inorganic Geopol

AGH-UST laboratory foundry

The test arrangements are shown in figure 2.

Figure 2. Chamber test arrangements in AGH-UST laboratory foundry

The results from the AGH chamber tests are shown in table 3.

Table 3. Test results from AGH-UST laboratory chamber tests

CODE	Emissions per 1 kg of molding sand, mg				
Compounds	Total BTEX	Benzene	Total PAHs	Benzo(a)pyrene	Total gas content ml per 100 g moulding sand
Organic Furan	658	602	12,09	0.24	1973
Organic Alphaser	495	464	9,87	0.17	2497
Organic Greensand	176	161	5,8	0.15	2610
Inorganic Geopol	60	51	3,14	0.06	1376
Inorganic Cordis	24	16	2,18	0.01	1142
Inorganic Inotec	22	14	1,99	0.02	888

Hardkop pilot iron foundry

Test arrangements are shown in figure 3.

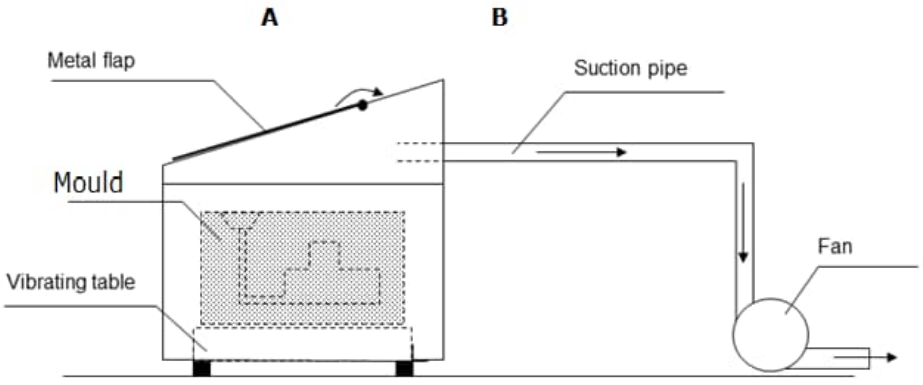

Figure 3. Test arrangements in Hardkop iron foundry.

Results of the pilot foundry chamber tests are presented in table 4.

Table 4. Test results from the chamber test in Polish pilot foundry Hardkop

CODE	Emissions per 1 kg of molding sand, mg				
Compounds	Total BTEX	Benzene	Total PAHs	Naphthalene	Total PAHs+ Total BTEX
Organic Furan	84	18	0,15	0,12	84,15
Organic Alphaset	34	23	1,8	1,43	35,8
Organic Greensand *	5,1	2,6	0,48	0,36	5,58
Inorganic Geopol	1,6	1,1	0,41	0,21	2,01
Inorganic Cordis	0,25	0,15	0,059	0,026	0,31
Inorganic Inotec	2,2	1,1	0,056	0,043	2,26

* part of coal dust was substituted by environment friendly additions

Conclusions from the chamber tests in Poland

Emissions of PAHs, as well as BTEX in case of moulding sands with organic binders is several dozen higher than the emission of these compounds from moulding sands with inorganic binders. Moulding sands with inorganic binders are characterized by lower harmfulness for the environment and employees than moulding sands with organic binders

The hardener of inorganic Geopol binder system is organic ester compound,
and thus emissions are somewhat higher than with fully inorganic Cordis and Inotec binder systems. But some organic material must have been added to them for technical performance reasons into Cordis and Inotec binders and/or promotors.