AX-Consulting

Green Foundry LIFE project (LIFE17 ENV/FI/173)

Action B1 Emissions of different binder systems during small-scale test cats

DeB1B Results of emission measurements of organic binder system chamber test casts in URV foundry in Finland

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FINAS
Finnish Accreditation Service
T232 (EN ISO/IEC 17025)

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1 Introduction

Uudenkaupungin Rautavalimo Oy (URV) is a ferrous foundry that produces cast components for diesel and electric motors and for process, pump, mining and elevator industries. The production began at Uusikaupunki in 1950 and at the present location in 1980.

The melting capacity consists of two 2 tons and one 4 tons induction furnaces and the total production capacity is 6 tons per hour.

URV produces ductile and gray cast iron, ADI iron (Austempered Ductile Iron) and SiMo ductile iron. The weight range is between 2 to 5000 kg, but typical product weight is between 20 to 500 kg.

The moulding is made by hand moulding. The binder systems for moulds is phenolic-formaldehyde (Alphaset) resin. The cores are made by using Alphaset or Cold-Box binder systems. Both these core making methods are based on phenolic resin binders.

The sand used for moulds and cores is high quality silica sand. About 70…75 % recycled sand is used for moulds but only new silicate sand is used for cores. The painting of the moulds and cores is made by Mg- or Ti-oxide based coatings.

Cooled moulds are shaken out by the vibration. The feeders are removed by pressure air or hand hammering. The surfaces of the castings are refined by steel shot blasting. URV has invested into machining and delivers now most of the castings as machined.

Annual production capacity is 10000 tons. but the production in recent years has been about 5000 tons URV foundry has about 100 employees.

Emisison measurements of the small scale test casts with organic binder system (Alphaset) were carried out in URV on 29. – 31.1.2019. The aim of the measurements was to find out the concentration of components, emissions and mold temperatures during the casting process. During normal casting process, it is impossible to measure released emission concentrations, so test castings were carried out with special arrangements. Pictures from the arrangements are presented in APPENDIX 15.

2 Measurement results

Measurement results are presented in APPENDICES 1-13. Trends from the temperature measurements are presented in APPENDIX 14.

3 Conclusions

Measurements were carried out during two days on the row. During both days the casted amount and quality was same (500 kg). Measurement arrangement was structurally same too (APPENDIX 15). Because of the measurement arrangements, the exhaust gas coming to analyzer had to be diluted. Results are presented with using the dilution factor. However, it has to be noticed that the dilution air was taken from the same casting hall, to where the exhaust gas from the test casting was extracted. There was also background concentrations in the hall, because it was inside the factory.

During the first measurement day the exhaust air flow rate was about 200 l/s, and through the molds cooling air pipe was coming about 100 l/s. Rest 100 liter was coming from the dilution hole on top of the casting and from the pipe connections' leakage air. During the first measurement day the dilution factor was around 2.08. The melt was poured around 16:15, and after that the measurement was carried out until 22:00. From that on when counting the results, it has been assumed, that concentrations are going down linearly.

During the second measurement day, the exhaust air flow rate was reduced around 150 l/s, and through the molds cooling air pipe was coming about 80 l/s. Rest 70 liter was coming as a leakage air from the pipe connections. On this measurement day, the dilution hole was closed. On the second measurement day the dilution factor was around 1.87. The melt was poured around 15:34, and after that measurement was carried out until 18:00. From that on when counting the results, it has been assumed, that concentrations are going down linearly.

3.1 Carbon monoxide (CO)

Both test results can clearly show that there was short-termly really high concentrations during melt was poured, and after that, they are starting evenly to go down. Carbon monoxide has clearly the highest concentrations, especially during melt was poured, concentration was very high and it exceeded the measurement area of the analyzer.

3.2 Volatile Organic Compounds (VOC)

During the melt was poured, VOC compound concentrations were quite high. After that, concentrations were going down more slowly than carbon monoxide, because different compounds are evaporating from the mold in different temperatures. Because mold is warming up and different compounds have different evaporating temperature, VOC concentration is not going down as fast and linearly than other measured gaseous components.

3.3 Sulphur dioxide (SO_2) and nitrogen oxides (NO_x)

During the melt was poured, there was also small peak in the concentration of the Sulphur dioxide. Fastly after melt was poured, the concentration went down.

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During the measurements there was not noticed any nitrogen oxides.

3.4 Oxygen (O_2) and carbon dioxide (CO_2)

Oxygen concentration was going down for a while during melt was poured from 20.9 to 20.7%. At the same time there was small amount of carbon dioxide. Anyway, concentrations went down really fast to the level of normal air.

3.5 Particles

Particle concentration was also measured from the exhaust air. The average concentration from the first test measurements was around 34 mg/Nm^3 and from the other around 26 mg/Nm^3.

4 Procedure

4.1 O_2, CO_2, CO, NO_x and SO_2

Sample from the exhaust air for the measurement of O_2 , CO_2, CO, NO_x and SO_2 were taken with heated sond through heated filter and sample tube to the sample unit, where is the sample pump. In the sample unit, water was removed from the sample gas and dry gas was shared to the analyzers. Uncertainty of the concentration is ±15 %.

4.2 Volatile Organic Compounds (VOC)

VOC measurement was made with flame ionization detector analyzer (FID). Sample from the exhaust air to the analyzer was taken with sond through heated sample tube. Measurement was carried out in accordance with the USA Environmental Protection Agency (EPA) Method 25.

Absolut VOC and carbon concentration were defined from the adsorption samples, which were taken at the same time. Quantitative analysis from the hydrocarbon compounds was done one by one and real concentration response of the FID analyzer was defined from that. Measurement was carried out in accordance with the SFS 3861 standard.

Samples were analyzed by Finnish Institute of Occupational Health, laboratory in Tampere. Laboratory is FINAS accredited test laboratory T013. Uncertainty of concentration is ±15 %.

4.3 Particles

Particle concentrations from the exhaust air were measured from samples taken with sond and pump in accordance with SFS-EN 13284-1 and SFS 3866 standards. Size of the sond and absorption rate were set so that the speed of the sample rate was as isokinetic with the speed of the exhaust air as possible. Uncertainty of concentration is ±15 %.

4.4 Phenols

Phenols in the gas phase were collected from the exhaust air with the pump into the XAD2 adsorption tubes. The analysis was carried out by the Finnish Institute of Occupational Health, laboratory in Tampere, with liquid chromatograph analysis. Measurement was carried out in accordance with the SFS 3861 standard. Laboratory is FINAS accredited test laboratory T013. Uncertainty of concentration is ±15 %.

4.5 Aldehydes

The aldehyde samples were taken from the exhaust air with the sample pump to the SepPAK-DNPH tubes. The analysis was carried out by the Finnish Institute of Occupational Health, laboratory in Tampere, with liquid chromatograph analysis. Measurement was carried out in accordance with the SFS 3861 standard. Uncertainty of concentration is ±15 %.

4.6 Flow rate

The flow rate of the exhaust air was measured continuously with the pitot tube and the micromanometer. The result was calibrated with measuring the flow rate randomly from the exhaust air, using multi-point method with the micromanometer and the pitot tube, according to the SFS 5512 standard. The dry and wet temperatures were measured with the instant thermometer. Uncertainty of concentration is ±5 %.

The temperature was measured continuously with the thermoelement and the datalogger. Uncertainty of temperature is approximately ±1 °C.

5 Measurement equipment

The analyzer equipment and used standards and guidance, according to the measurements of the different components that were carried out, are presented in table 1.

Table 1. The measurement equipment, standards and guidance that were followed in the measurements.

Component	Device mark	Measurement	Standard
Measurement method is accredited			
O_2	Horiba PG-250	Paramagnetism	SFS 3869 SFS-EN 14789-2005 ISO 12039
CO_2	Horiba PG-250	IR / NDIR	SFS 3869 ISO 12039:2001
CO	Horiba PG-250	IR / NDIR	SFS 3869 SFS 5412 ISO 12039:2001
NO_x	Horiba PG-250	Chemiluminescent	SFS 3869 ISO 5425 SFS-EN 14792:2005
SO_2	Horiba PG-250	UV-Fluorescence / NDIR	SFS 3869 ISO 7935:1992
Flow rate, pressure	Micromanometer and pitot-pipe	Pressure difference, pressure	SFS 3866 SFS 3869 SFS-EN 13284-1:2001
Temperature	Thermoelement	Voltage difference	SFS 3866 SFS 3869 SFS-EN 13284-1:2001
Measurement method is not accredited			
VOC	CAI FID Adsorption equipment	Flame ionization detector analyzer,absorption	EPA 25 SFS 3869
Phenols Aldehydes	Absorption equipment	Absorption	SFS-EN 1948 SFS 3869
Particles	PIHI-particle measure-ment equipment	Gravimetric	SFS-EN 13284 SFS 3866 (adjusted)
H_2O	Cooling equipment	Condensation	SFS 5624

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Summary concentrations and emissions from the exhaust air from test casting

	Test casting	1	2	average	
	period *h*	7,75	3,93	5,84	h
	casting *kg*	500	500	500	kg
	sand *kg*	503	503	503	kg
	air flow *Nm³/s*	0,188	0,151	0,169	*Nm³/s*
Concentration *mg/Nm³*	dust	33,6	25,7	29,7	mg/Nm³
	CO	1 117	1 725	1 421	mg/Nm³
	SO_2	20,9	36,1	28,5	mg/Nm³
	VOC	428	485	457	mg/Nm³
	benzene	151	39,5	95,1	mg/Nm³
	toluene	37,7	15,5	26,6	mg/Nm³
	ethylbenzene	0	0	0	mg/Nm³
	xylene	28,3	19,7	24,0	mg/Nm³
	asetaldehyde		11,4	11,4	mg/Nm³
	formaldehyde		0,27	0,3	mg/Nm³
	phenol		15,30	15,3	mg/Nm³
	o-cresol		21,30	21,3	mg/Nm³
	p-cresol		10,40	10	mg/Nm³
Emission *g/h*	dust	22,8	13,9	18,1	g/h
	CO	757	936	867,0	g/h
	SO2	14,2	19,6	17,4	g/h
	VOC	290	263	278,7	g/h
	benzene	102	21,4	58,0	g/h
	toluene	25,5	8,4	16,2	g/h
	ethylbenzene	0	0	0,0	g/h
	xylene	19,2	10,7	14,6	g/h
	asetaldehyde		6,2	7,0	g/h
	formaldehyde		0,1	0,2	g/h
	phenol		8,3	9,3	g/h
	o-cresol		11,6	13,0	g/h
	p-cresol		5,6	6,3	g/h
Emission per period *g/period*	dust	176,5	54,8	105,7	g/period
	CO	5 867	3 681	5 065	g/period
	SO2	109,9	77,1	101,7	g/period
	VOC	2 250	1 035	1 628,0	g/period
	benzene	792	84,3	339,0	g/period
	toluene	198	33,1	94,8	g/period
	ethylbenzene	0	0	0,0	g/period
	xylene	148	42,1	85,6	g/period
	asetaldehyde		24,3	40,6	g/period
	formaldehyde		0,6	1,0	g/period
	phenol		32,7	54,5	g/period
	o-cresol		45,5	75,9	g/period
	p-cresol		22,2	37,1	g/period
Emission per casting *mg/ton*	dust	353	110	211	g/ton (casting)
	CO	11 735	7 362	10 129	g/ton (casting)
	SO2	220	154	203	g/ton (casting)
	VOC	4 500	2 071	3 256	g/ton (casting)
	benzene	1 583	169	678	g/ton (casting)
	toluene	396	66,2	190	g/ton (casting)
	ethylbenzene	0	0	0	g/ton (casting)
	xylene	297	84,3	171	g/ton (casting)
	asetaldehyde		48,7	81,3	g/ton (casting)
	formaldehyde		1,2	1,9	g/ton (casting)
	phenol		65,3	109	g/ton (casting)
	o-cresol		90,9	152	g/ton (casting)
	p-cresol		44,4	74,1	g/ton (casting)
Emission per sand *mg/ton*	dust	351	109	210	g/ton (sand)
	CO	11 665	7 318	10 069	g/ton (sand)
	SO2	218	153	202	g/ton (sand)
	VOC	4 474	2 058	3 237	g/ton (sand)
	benzene	1 574	168	674	g/ton (sand)
	toluene	394	65,8	188	g/ton (sand)
	ethylbenzene	0	0	0	g/ton (sand)
	xylene	295	83,8	170	g/ton (sand)
	asetaldehyde		48,4	80,8	g/ton (sand)
	formaldehyde		1,1	1,9	g/ton (sand)
	phenol		64,9	108	g/ton (sand)
	o-cresol		90,4	151	g/ton (sand)
	p-cresol		44,1	73,7	g/ton (sand)

Gas formic concentrations and emissions from the exhaust air from test casting

Situation			Concentration					Flow rate		Emission			Incombustible		
		time	O_2	CO	CO_2	SO_2	VOC	flow rate	exhaust air temperature	CO	SO_2	VOC	CO	VOC	total
			%	*ppm*	*%*	*ppm*	*ppm*		*°C*	*mg/s*	*mg/s*	*mg/s*	*mgC/s*	*mgC/s*	*mgC/s*
Test casting 1	pouring	16:15-16:30	20,8	5 715	0,2	39	1 318	0,203	15,4	1 447	23	179	621	125	745
	entire measurement	16:15-22:00	20,9	1 141	0,1	8	887	0,196	21,6	279	5	65	120	46	165
	measurement+forecast	16:15-00:00	20,9	894	0,1	7	780	0,188	23,9	217	4	53	93	37	130
Test casting 2	pouring	15:34-16:00	20,7	4 615	0,2	37	1 595	0,160	18,8	928	18	141	398	98	496
	entire measurement	15:34-18:00	20,8	2 011	0,1	18	1 159	0,155	29,5	396	8	99	170	69	239
	measurement+forecast	15:34-19:30	20,9	1 380	0,1	12	884	0,151	34,0	272	6	75	117	52	169

Measured particle concentrations and emission

Measuring point	date	starting	ending	concentration	undiluted concent-ration	flow rate	emission		undiluted emission	
				mg/Nm³	*mg/Nm³*	*Nm³/s*	*mg/s*	*g/h*	*mg/s*	*g/h*
Exhaust air		16:12	16:50	**8,5**	**17,7**	0,2	1,7	6,2	3,6	12,9
		17:17	18:09	**21,1**	**43,9**	0,2	4,2	15,3	8,8	31,9
	average			**16,1**	**33,6**	0,2	3,3	11,7	6,8	24,4
Exhaust air		15:34	18:03	**13,8**	**25,7**	0,15	2,1	7,5	3,9	14,0

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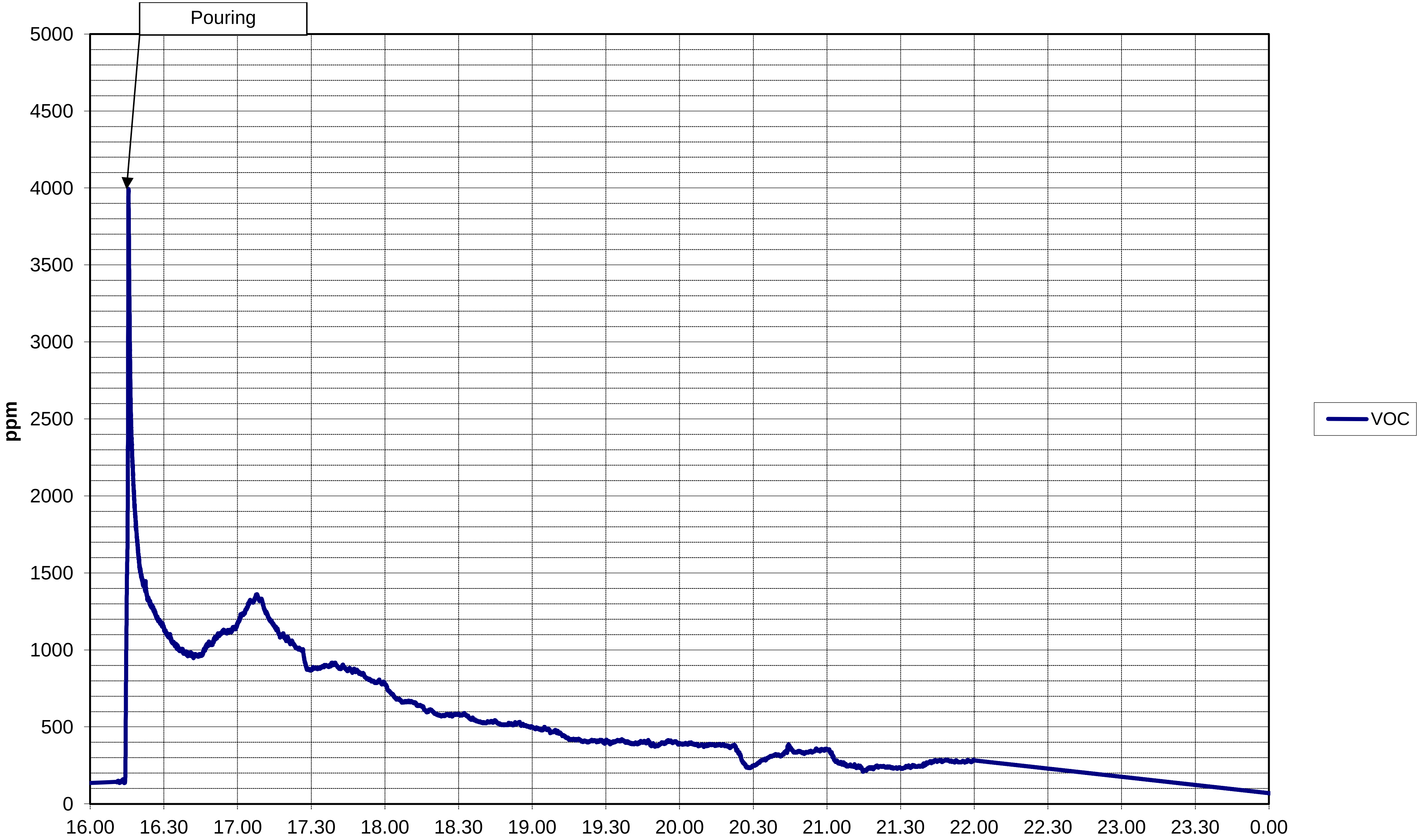
Test casting 1 exhaust air VOC-concentrations



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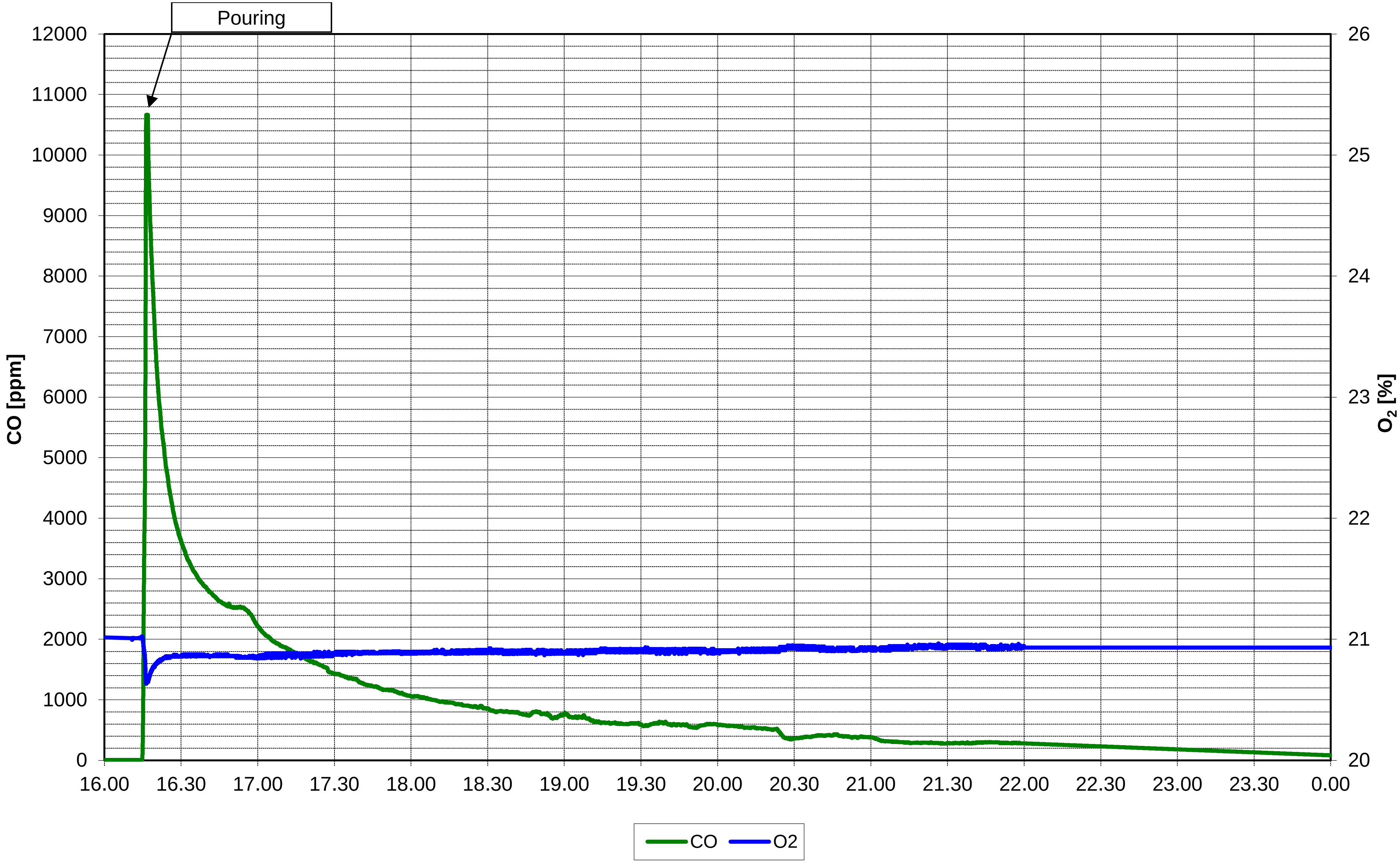
CO and O_2 concentrations from the test casting 1 exhaust air

APPENDIX 5 1/1



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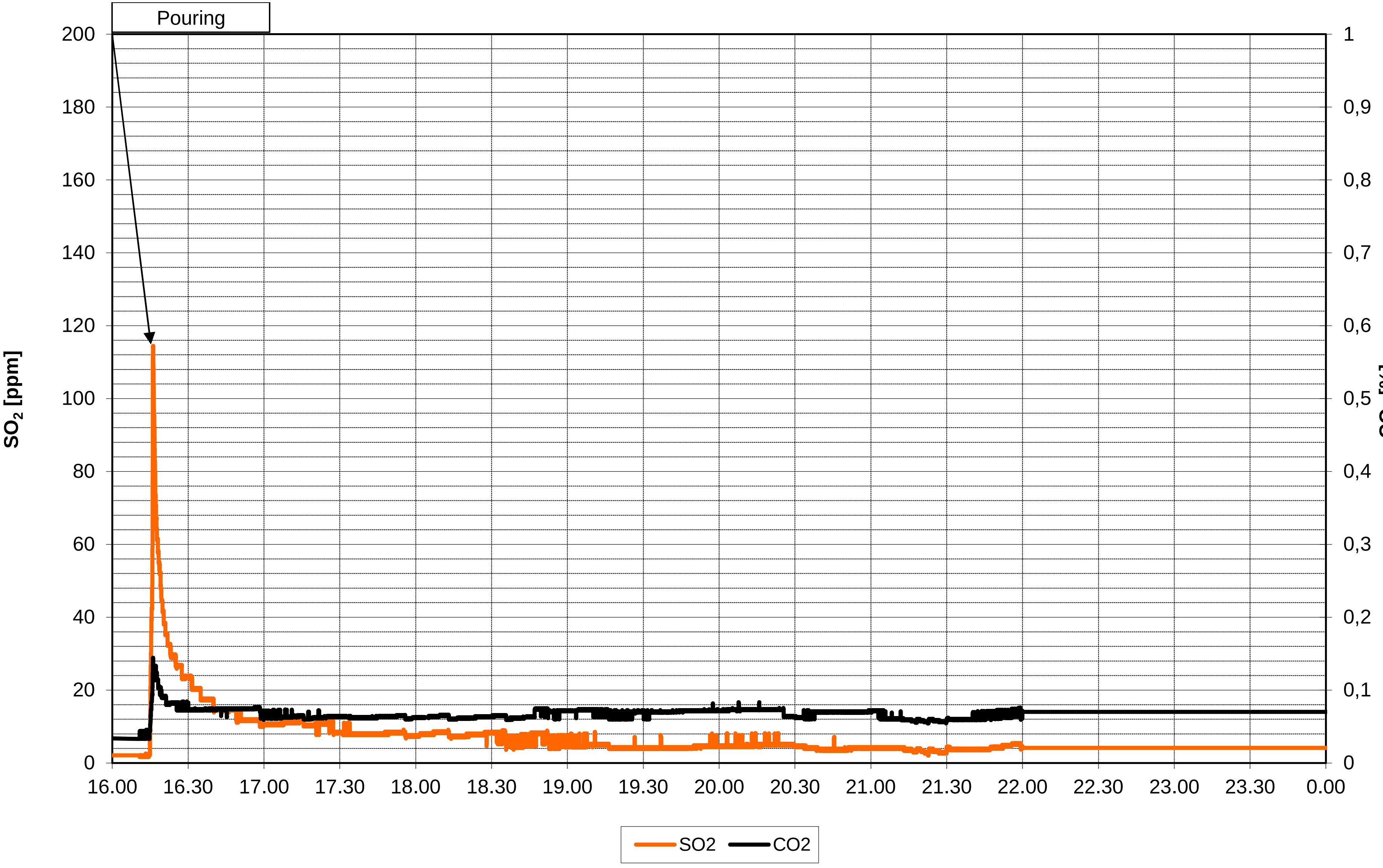
SO_2 and CO_2 concentrations from the exhaust air of the test casting 1

APPENDIX 6 1/1



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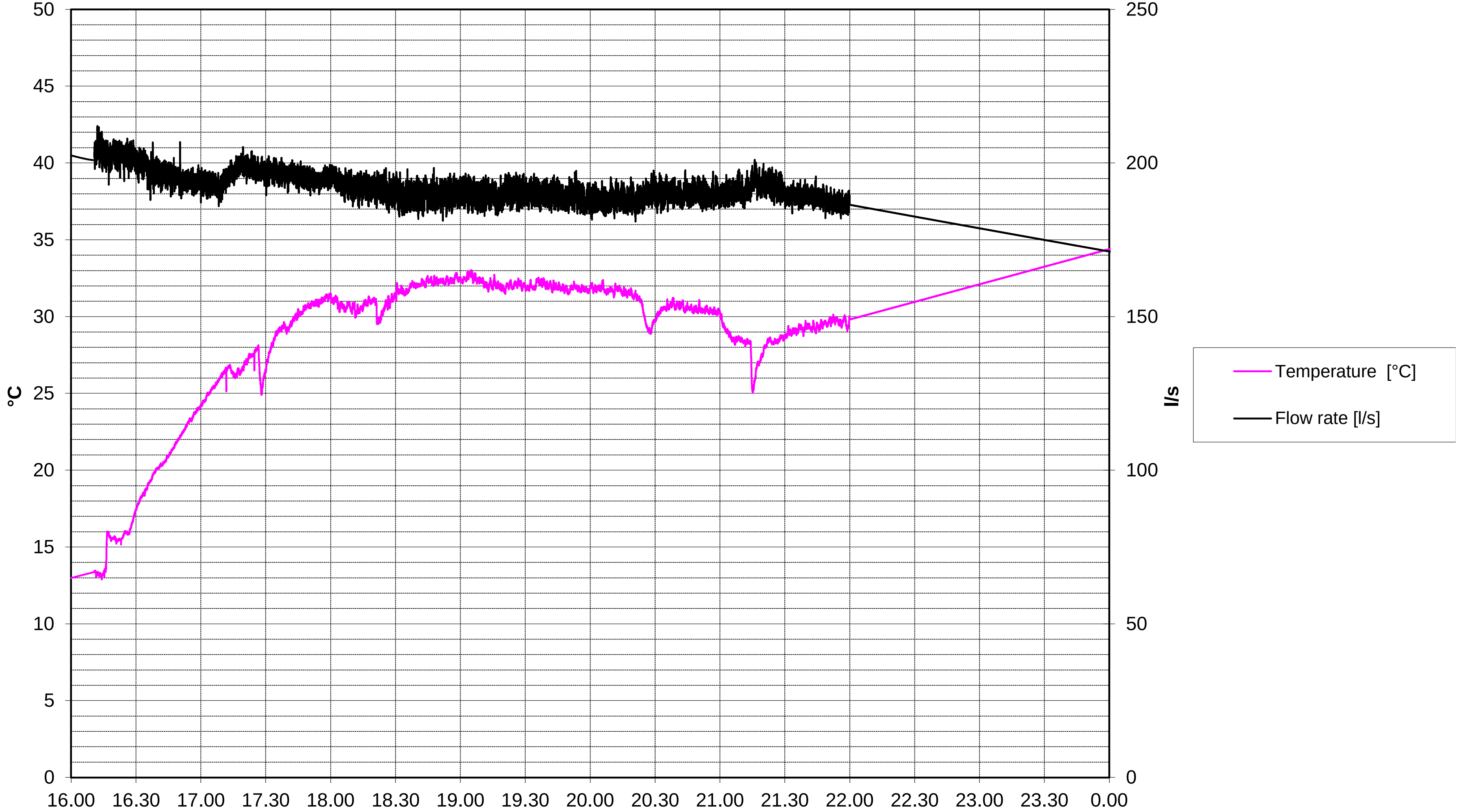
Exhaust air temperature and flow rate from the test casting 1

APPENDIX 7 1/1



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Exhaust air VOC concentration from the test casting 2

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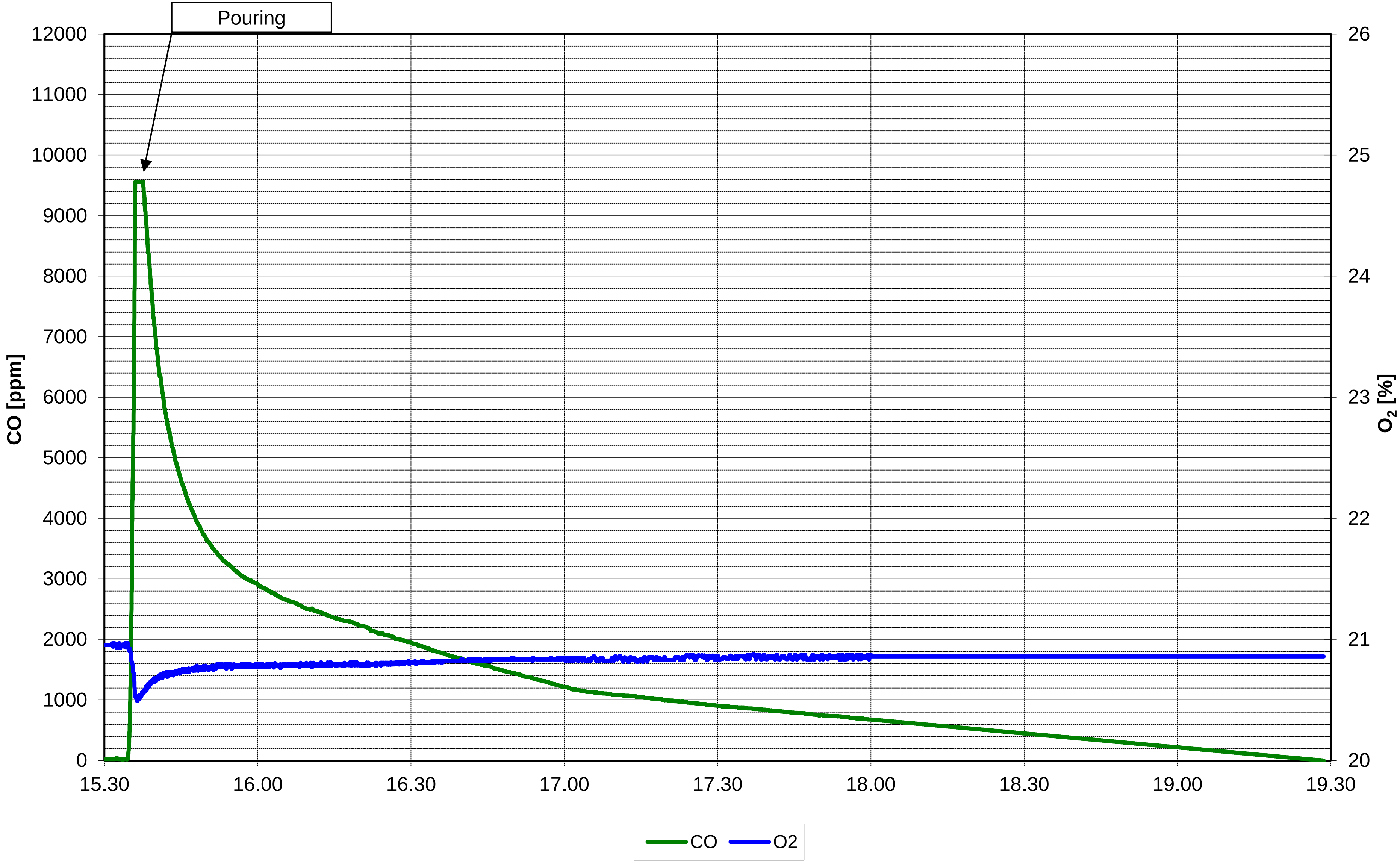
Exhaust air CO- and O_2-concentrations from the test casting 2



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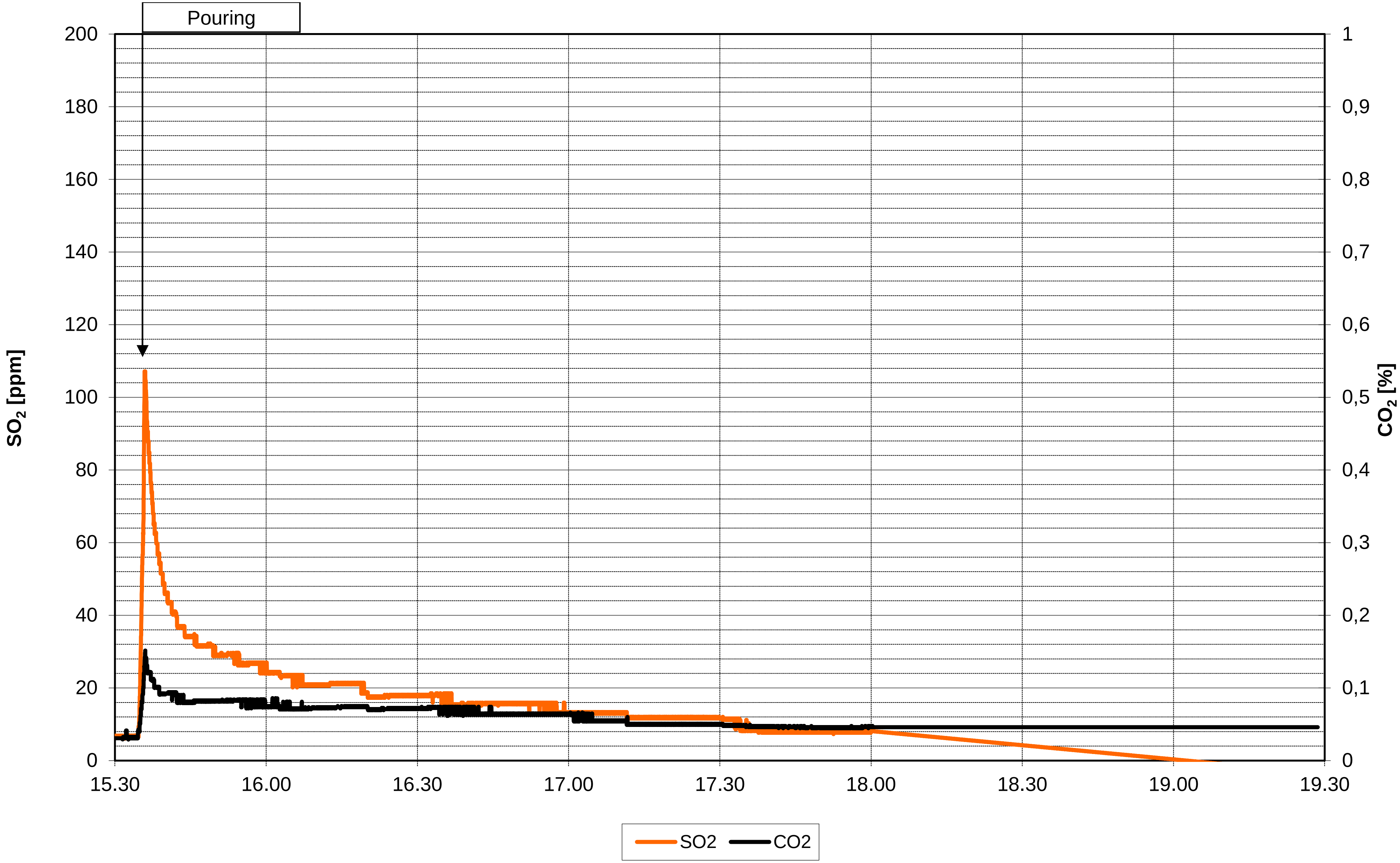
Exhaust air SO_2 and CO_2 concentrations from the test casting 2

APPENDIX 10 1/1



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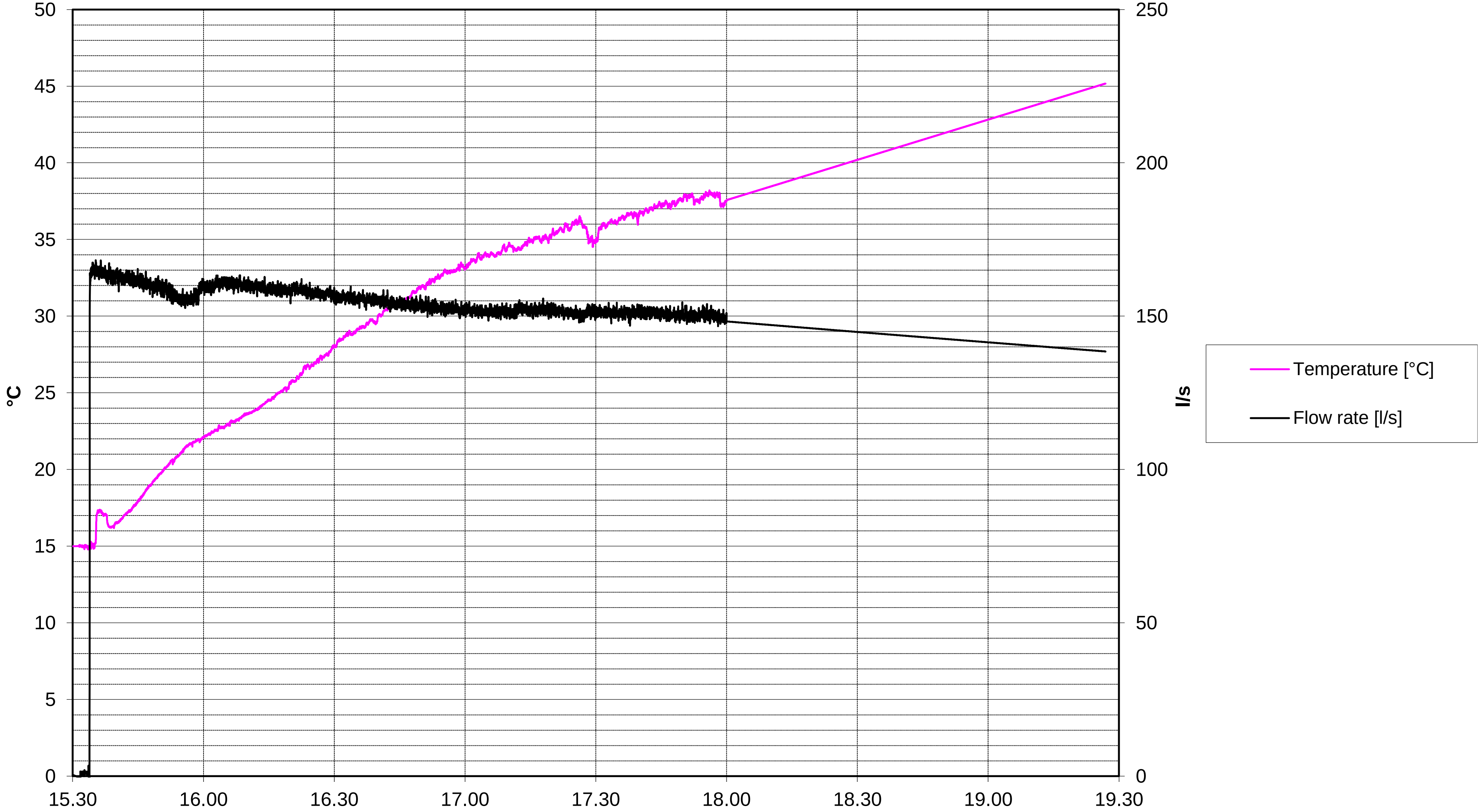
Exhaust air temperature and flow rate from the test casting 2

APPENDIX 11 1/1



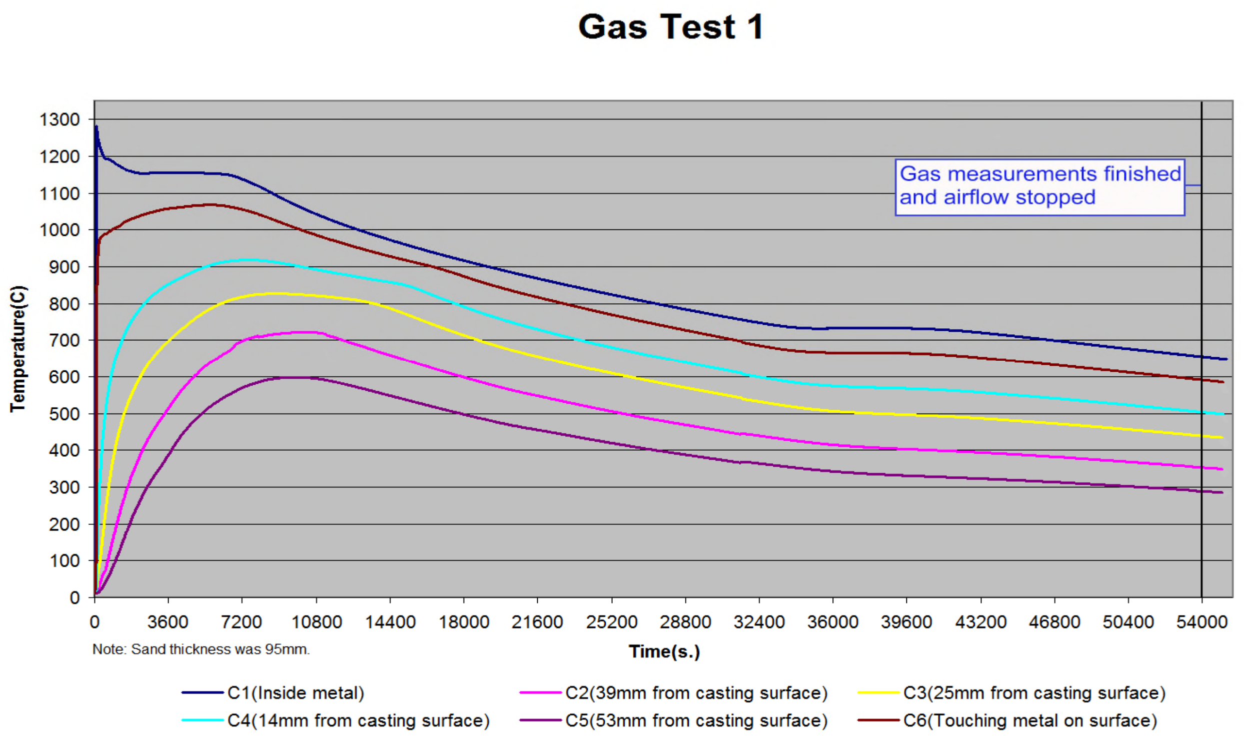
Measuring point	test casting 2	undiluted	test casting 2	undiluted
Starting time	15:36:00	15:36:00	15:59:00	15:59:00
Ending time	15:52:00	15:52:00	17:58:00	17:58:00
VOC-concentration	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*
1H-Inden	<1,0	<1,9	0,2	0,42
gamma-Butyrolacton	4,5	8,5	31,7	59,2
Acetone	10	19	9,1	17
Bentzene	80,8	151	21,2	39
Butanes	30,3	56,5	6,0	11,3
Ethanol	85,8	160	91,4	171
Heptane	<1,0	<1,9	<0,2	<0,3
Ksylene	15,1	28,3	10,6	19,7
Naphtalene	2,0	3,8	0,8	1,4
2-Propanol	70,7	132	78,6	147
Toluene	20,2	37,7	8,3	15,5
Triethylamine	<3,5	<6,6	<0,5	<1,0
1,3,5-Trimetylbentzene	10,1	18,8	12,8	24,0
1,2-Propanediole	0	0	19,7	36,7
Dimethylfenol	0	0	6,0	11,3
Ethylfenol	0	0	10,6	19,7
o-Cresol	0	0	14,4	26,8
p-Cresol	0	0	7,6	14,1
Trimethylfenol	0	0	0,8	1,4
Other VOCs	10,1	18,8	21,9	40,9
total	**345**	**644**	**352**	**658**
Part of the compound	*%*	*%*	*%*	*%*
1H-Inden	<0,3	<0,3	0,1	<0,1
gamma-Butyrolacton	1,3	1,3	9,0	9,0
Acetone	2,9	2,9	2,6	2,6
Bentzene	23,4	23,4	6,0	6,0
Butanes	8,8	8,8	1,7	1,7
Ethanol	24,9	24,9	26,0	26,0
Heptane	<0,3	<0,3	<0,04	<0,0
Ksylene	4,4	4,4	3,0	3,0
Naphtalene	0,6	0,6	0,2	0,2
2-Propanol	20,5	20,5	22,3	22,3
Toluene	5,8	5,8	2,4	2,4
Triethylamine	<1,0	<1,0	<0,2	<0,2
1,3,5-Trimetylbentzene	2,9	2,9	3,6	3,6
1,2-Propanediole	0,0	0,0	5,6	5,6
Dimethylfenol	0,0	0,0	1,7	1,7
Ethylfenol	0,0	0,0	3,0	3,0
o-Cresol	0,0	0,0	4,1	4,1
p-Cresol	0,0	0,0	2,1	2,1
Trimethylfenol	0,0	0,0	0,2	0,2
Other VOCs	2,9	2,9	6,2	6,2
total	**100,0**	**100,0**	**100,0**	**100,0**

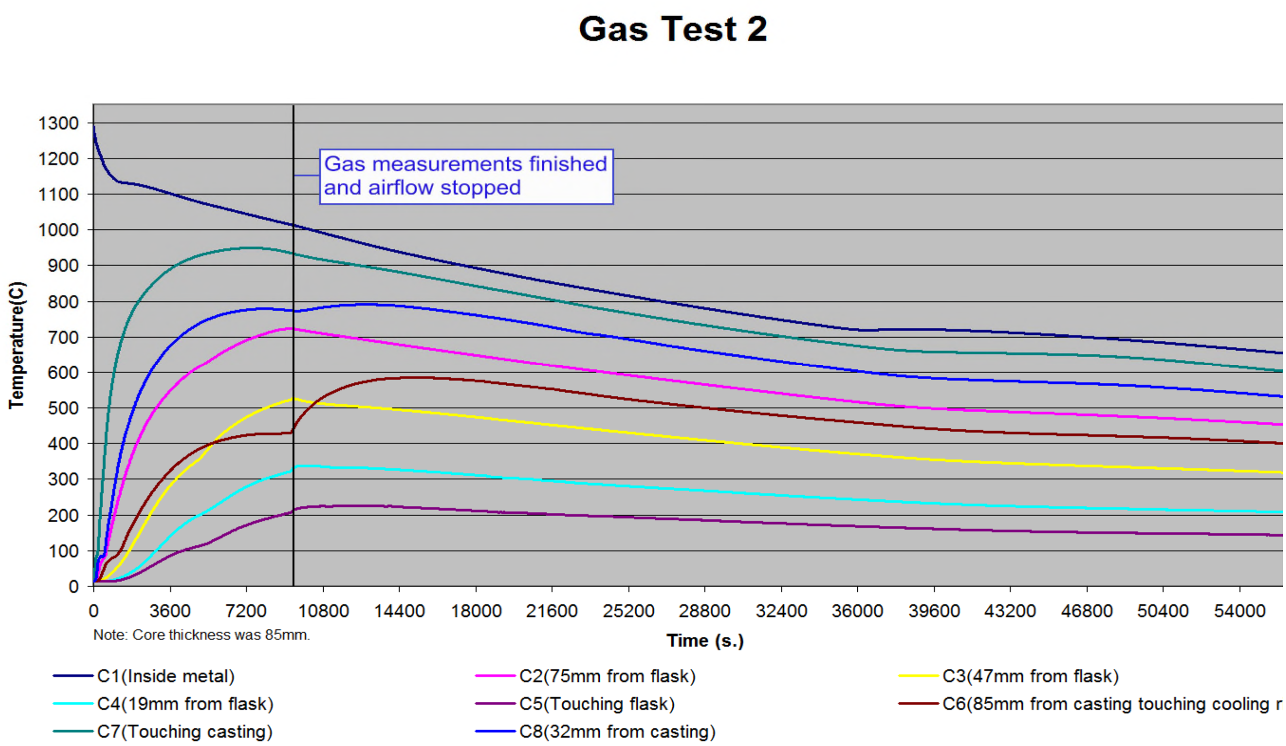
Aldehydecompounds

Measuring point	test casting 2	undiluted	test casting 2	undiluted
Starting time	15:36:00	15:36:00	15:59:00	15:59:00
Ending time	15:52:00	15:52:00	17:58:00	17:58:00
Concentration	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*
Asetaldehyde	8,9	16,6	3,4	6,3
Formaldehyde	0,2	0,3	0,1	0,3
total	**9,1**	**16,9**	**3,5**	**6,5**
Part of the compound	*%*	*%*	*%*	*%*
Asetaldehyde	98,3	98,3	96,1	96,1
Formaldehyde	1,7	1,7	3,9	3,9
total	**100,0**	**100,0**	**100,0**	**100,0**

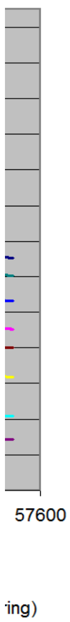
Phenol and cresol compounds

Measuring point	test casting 2	undiluted	test casting 2	undiluted
Starting time	15:36:00	15:36:00	15:59:00	15:59:00
Ending time	15:52:00	15:52:00	17:58:00	17:58:00
Concentration	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*	*mg/Nm³*
Phenol	2,2	4,1	14,2	26,6
o-Cresol	2,2	4,2	20,6	38,5
p-Cresol	0,8	1,5	10,3	19,2
total	**5,2**	**9,8**	**45,1**	**84,2**
Part of the compound	*%*	*%*	*%*	*%*
Phenol	41,9	41,9	31,5	31,5
o-Cresol	42,6	42,6	45,7	45,7
p-Cresol	15,5	15,5	22,8	22,8
total	**100,0**	**100,0**	**100,0**	**100,0**


Gas Test 1
Temperature(C)
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Gas measurements finished and airflow stopped
0
3600
7200
10800
14400
18000
21600
25200
28800
32400
36000
39600
43200
46800
50400
54000
Note: Sand thickness was 95mm.
Time(s.)
C1(Inside metal)
C2(39mm from casting surface)
C3(25mm from casting surface)
C4(14mm from casting surface)
C5(53mm from casting surface)
C6(Touching metal on surface)


Gas Test 2
Temperature(C)
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Gas measurements finished and airflow stopped
0
3600
7200
10800
14400
18000
21600
25200
28800
32400
36000
39600
43200
46800
50400
54000
Note: Core thickness was 85mm.
Time (s.)
C1(Inside metal)
C2(75mm from flask)
C3(47mm from flask)
C4(19mm from flask)
C5(Touching flask)
C6(85mm from casting touching cooling r
C7(Touching casting)
C8(32mm from casting)

Temperatures from test castings 1 and 2



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