

Research Concerning Reducing the Pollution Degrees in the Sectors of Production of Metal Materials

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This paper contains the results of researches and experimentations on the reduction of the concentration of gaseous emissions and powders in the manufacture of ferrous alloys in aggregates of electric arc furnaces (EBT) coupled with a treatment plant (LF) located at Mechel Targoviste using new technology. Experiments have shown that using the new technology one achieves a reduction in pollutant gaseous emissions by about 30% and in dust content by about 25% compared to the use of classical technology, with particularly beneficial effects on the environment. The results have confirmed the validity of the new technology that used iron sponge in the loading phase, foamed slag in the melting phase and long electric arc in the production phase. The paper presents the results of the experiments using both technologies, as well as the equipment established and used in the experiments for the measurement and recording of the gaseous emissions and powders content, which ensured an accurate evaluation of the obtained results.

Keywords: pollutant gaseous emissions, powders, technology

An undeniably present day problem which is currently given special attention, on both a national and international level, is represented by the environmental protection in the metallic materials production sector, because this sector's activity entails the consumption of large quantities of energy, leading to the generation of significant amounts of gaseous emissions, wastes and wastewaters.

During the course of the different stages of the technological flow within an integrated steel or chemical unit, besides the primary product, significant quantities of gaseous emissions and materials, usually called waste, are generated, but due to the possibilities of recovery through recycling and / or reuse, these may fall under the category of by-products [1-6]. Depending on the specific conditions of each integrated industrial unit and the demand on the local market (variable in time) for each usable material, any waste can become by-product and any by-product can become waste [7, 8].

As such, at present, on a national level, it becomes both necessary and appropriate to address the problem of reducing pollutant emissions, by establishing new technologies with a low pollution degree (hippopoluting), firstly, through the reduction of emissions directly within the manufacturing process, and subsequently through the superior valorification of the resulting pulverulent wastes, valorification done with minimum costs. Achieving these goals, ensures both the needs of human society, and environmental protection, which represents a major problem in the current millennium. The proposed technology and the experiments carried out, have shown that it is possible to achieve a significant decrease in gaseous emissions and dust concentration resulting from the metallic materials manufacturing process.

Experimental part

In order to carry out the experiments, the sources of pollution were identified during each sequence of the technological flow producing the studied metallic materials, flow represented by the scrap metal warehouse - the melting hall using electric arc furnaces - the casting hall - the stripping hall - semifinished products, and the

nature of the polluting agents was established. This analysis showed that the primary polluting agents are gaseous emissions and dusts, and that the largest share in their production is represented by the melting sector, which is equipped with the possibility of argon bubbling and the vacuum treatment of steel. The experiments were carried out using an electric arc furnace with a capacity of 80 t, of type EBT (electric bottom tapping), in which the loading, melting and evacuation operations were carried out, and which has a 80 min batch time, compared to a classical electric arc furnace, with a batch time of 2.5 hours and a LF (ladle furnace) installation with a 80 t capacity. The section in which the experiments were carried out was equipped with a modern plant for collection and treatment of combustion gasses. Figure 1 shows the scheme for this collection and treatment plant.

During the experiments carried out using the classical technology, as well as the established technology, concentration measurements of gaseous emissions and dusts were taken on the route from the electric arc furnace to their evacuation into the atmosphere through the exhaust chimney. Note that the LF-exhaust chimneys installation is connected to the same plant for collection and treatment

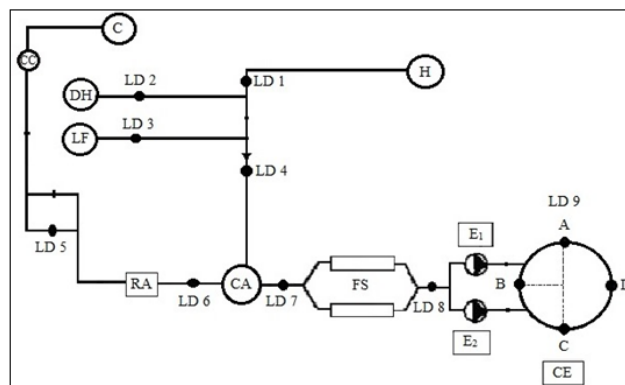


Fig.1. Scheme of the plant for collection and treatment of combustion gasses. C - electric arc furnace; LF - treatment pot; D.H. - dog-house; H - hood; C.C. - combustion chamber; R.A. - atmospheric cooler; C.A. - mixing chamber; F.S. - sack filters; E₁, E₂ - exhausts; C.E. - exhaust chimney; L.D.1 - L.D.9 - measuring locations

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of combustion gasses resulting from the steel manufacturing process using the electric arc furnace. The high-performance equipment used to collect samples and to determine pollutant concentrations, ensured an accurate evaluation of plant performance and of the obtained results, with beneficial effects on the environment. The values of these concentrations, measured at the point L.D.9, when discharged into the atmosphere through the chimney, must be within the maximum admissible values (C.M.A) and the alert threshold values (P.A.), as shown in table 1.

The steel Rul 1 brand was studied and 11 experimental batches were made for both the classical and the new technology. In order to determine the pollution level of the electric arc furnace, when producing the steel Rul 1 brand using the classical technology, measurements were made to determine the concentrations at the established measuring locations. For the new technology, the same measurements were made, at the same measuring points, using the same measuring equipment.

The new technology, unlike the classical one, uses a certain amount of iron sponge and foamed slag in the production stage, and the long arc in the melting stage, aiming at lowering pollutant emissions resulted from the technological process. The working technology using foamed slag, consists in the formation of a thick layer of foamed slag, by simultaneously injecting coal dust and oxygen during the melting of the scrap iron, thus enabling working with long arcs and providing high power factor values [1]. Table 2 present the prescribed and the technological chemical composition of steel Rul 1.

In order to achieve the steel quality objectives, the following restrictions are imposed on the metallic material prepared: gas content: $O_2 < 20$ ppm; $N_2 < 100$ ppm; $H_2 < 3.0$ ppm and $\Sigma (S + P + O_2 + N_2 + H_2)$ max. 250 ppm. That is why, within the metallic load, restrictions were imposed on the quantity of residual elements (Cu, Sn, Cr, Ni, Mo), differentiated by product types, as well as by the proportion of the load components. Loading the furnace with scrap iron and iron sponge can be done using the 2, 3 or 4 bin method. During experiments, loading was done with 3 bins, using scrap iron with a volumetric mass of $0.8-1.0$ t/m³ and iron sponge, as a substitute for 25% of the old heavy iron. The melting was conducted using an intensive regimen by choosing an electric regimen favorable to the rapid melting of the load, and by increasing the melting speed with the help of oxygen blown through a 1" pipe with a flow of about 20 Nm³/min, the insufflation starting about three minutes after loading each bin. After loading the last bin, 10-15 kg/t of crude dolomite was added to form the slag.

During the last part of the melting process and after melting, foamed slag was used in order to protect the walls

and the roof from the long arcs' radiations and to ensure a suitable energy efficiency ($> 60\%$). A dephosphorus, foamed slag was produced, with the following characteristic elements:

CaO = 33-40 %	Al ₂ O ₃ max. 8 %
SiO ₂ = 10-15 %	FeO, about 20%
MgO max. 8 %	IB(CaO/SiO ₂), about 2.2
MnO max. 10 %	CaO/FeO, about 2

Melting was considered terminated when the entire metallic load became liquid and the bath temperature reached about 1550 °C. The metal bath was thoroughly mixed and the sample P1 (steel, slag) was taken. Further work was carried out with O₂ spraying slag, about 0.5 Nm³/t-min (about 2100 Nm³/h) and graphite, about 0.5 kg/t-min (about 35 kg/min), maintaining the carbon content of the metal bath to a maximum of 0.15% C. After heating the steel to about 1600-1640 °C, sample P₂ (steel, slag and gas) was taken and the activity of a_[O] was measured. After the refining period, steel was drained in a clean, warm (at least 1100 °C) pot equipped with a porous plug (argon discharge rate of about 0.5 Nl/t . min), and transported to the LF treatment plant.

In order to carry out the experiments, determine the gaseous emissions and powders generated by the technological process and determine the level of the pollutant emissions, the measuring sites were established, the equipment used and the measurement plan were established. So:

1) The locations of the measuring points and the accessories necessary to perform the measurements precisely determined, namely:

-LD 1, located on the roof hood (H); -LD 2, located on the Dog-house; -LD 3, located on the route from the LF installation to the atmosphere; -LD 4, located on the collector channel to the mixing chamber (CAM); -LD 5, located on the underground channel to the atmospheric cooler (RAtm); -LD 6, located on the route between the atmospheric cooler (RAtm) and the mixing chamber (Cam); -LD 7, located on the route between the mixing chamber (CAM) and the sack filters (FS); -LD 8, located on the route between the sack filters (FS) and the exhausts (E₁, E₂); -LD 9, located in the exhaust chimneys (CEv), having 4 measuring points (A, B, C, D).

In order to ensure tightness when introducing extensions or sensors at the measuring points (LD), rubber stoppers were made and used and electrical sockets with a voltage of 220 V, necessary for the use of measuring devices, were installed near the combustion gas collection and treatment plant.

2) The necessary measuring equipment was selected and established. Because of the large dimensions of

Corrected measured concentration		CO	NO _x	SO ₂	Powders
C _{max}	[mg/Nm ³]	180.34	9.1	12.05	12.74
C _{min}	[mg/Nm ³]	173.83	8.7	11.6	12.74
C.M.A.	[mg/Nm ³]	250	500	2000	100
P.A.	[mg/Nm ³]	175	350	1400	70

Table 1
MAXIMUM ADMISSIBLE VALUES AND
ALERT THRESHOLD VALUES

Chemical composition	C	Mn	Si	S	P	Cr	Ni	Cu	Ni+Cu	Al _{tot}	Ti
Prescribed	0.90 1.05	0.25 0.45	0.15 0.35	≤ 0.025	≤ 0.030	1.35 1.65	≤ 0.30	≤ 0.30	≤ 0.50	-	≤ 0.0003
Technological	0.93 1.03	0.25 0.35	0.25 0.33	≤ 0.003	≤ 0.010	1.40 1.50	≤ 0.20	≤ 0.20	≤ 0.40	0.010 0.020	≤ 0.0030

Table 2
CHEMICAL
COMPOSITION
STEEL [%]

the pipe system used to collect and treat the combustion gas, and in particular the temperature regime, the range of devices used for measurements was narrowed.

Priority was given to the use of direct reading equipment (for speeds, static pressures, relative humidity) and the TESTO Combustion Gas Analyzer, where the results of the temperature and emission measurements were printed instantaneously, and whose measuring probe, guaranteed up to 1200 °C, did not pose any problems for any of the established sampling operations.

Thus, the following measuring equipment was used: TESTO gas analyzer, registering the measurements for temperature and exhaust gases (CO, NO_x, CO₂, SO₂); TESTO Thermohygrometer, displaying relative temperature and humidity values; Anemometer for temperatures, speeds and static pressures; Velometer - Pitot-Prandtl tube with direct reading. Sequential measurement scales in the range 0-50 m/s; Manual Dräger pump; Dräger tubes for CO, NO_x, SO₂; Two dust sampling pumps for Sartorius filters: - flowmeter 0 - 1500 l/h with reach Ø 7 mm; - flowmeter 0-20l/min with reach Ø 3.5 mm.

3) The measurement plan and the sampling (measuring) locations were established as follows:

- Measurements of relative temperature, speed and humidity at the chimney exit (LD 9), to allow the final assessment of the combustion gas flow rate in the atmosphere.

- Quasisimultaneous measurements at the sack filter entrance (LD 7) and, respectively, at the chimney (LD 9), of temperatures, emissions and dusts, which allow the determination of two very important things, namely: the efficiency of the sack filter and the fitting of dust and gaseous emission concentrations within acceptable limits.

- Quasisimultaneous measurements between the 3 aerial exhaust sites (H - roof hood - LD1, DH - Dog house - LD 2 and LF - LD 3) and, respectively, the collector channel (LD 4) for temperatures, speeds, emissions, powders and static pressures.

- Successive measurements, all recording temperatures and emissions, using shorter or longer time spans, between the exit from the underground channel (LD 5) and the entry into the sack filter (LD 7).

This paper deals mainly with the measurements made at sites LD1 and LD9. The experiments under study are no.6 and no.5 using new technology (labeled as E6 and E5) and batch no.7 and no.2 using the classical technology (labeled as E7 and E2), considered to be

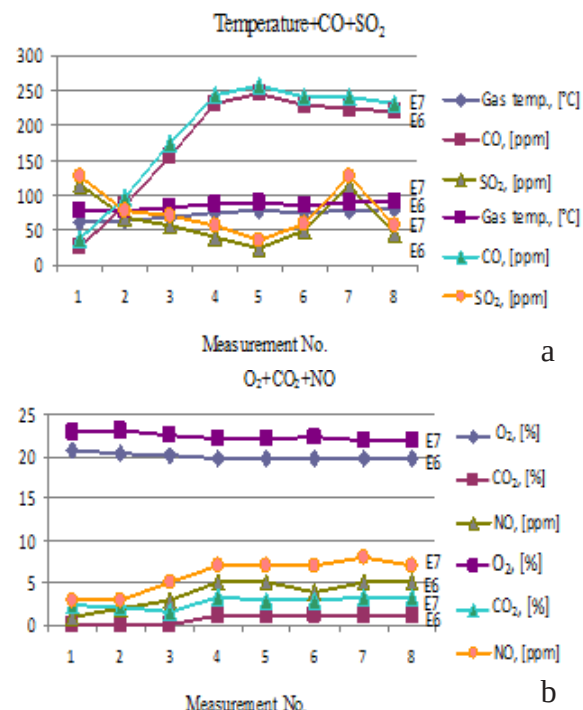


Fig. 2. Variation of parameters temperature, CO, SO₂ (a) and variation of parameters O₂, CO₂, NO (b)

representative, the analysis taking into account the couples E6-E7 and E5-E2.

Results and discussions

a) - The results of the measurements of temperatures and emissions of polling gas emissions at site LD 1 (discharge into the atmosphere through hood-H) are shown in table 3.

The temperatures were measured at the measuring points coupled to the TESTO direct reading thermohygrometer and the TESTO gas analyzer, the values printed at smaller or larger time intervals are shown in table 3 and in figure 2 (a), (b). Based on these recordings, the graphical representations shown in figure 3 were made, allowing for a simpler and faster appreciation of the variation pattern of the mean values in the representative sections.

Table 3 shows the values of the exhaust gas temperature and the concentrations of the pollutant emissions in the combustion gas, and figures 2a, 3b show their variation over time, measured at site LD 1, for the batches produced using the new technology (batch 6-E6), and using the

Table 3
EXPERIMENTAL DATA

Temperatures and emissions at point LD 1														
Measurement no.	Gas temp., [°C]		O ₂ , [%]		CO ₂ , [%]		CO, [ppm]		NO, [ppm]		NO ₂ , [ppm]		SO ₂ , [ppm]	
	E6	E7	E6	E7	E6	E7	E6	E7	E6	E7	E6	E7	E6	E7
1	60.7	77.9	20.7	22.9	0	2.4	25	37	1	3	0	0	115	128
2	64.3	77.5	20.4	23.1	0	2.1	84	96	2	3	0	0	69	78.6
3	68.7	81.6	20.2	22.4	0	1.6	157	174	3	5	0	0	57	71.5
4	76.1	87.3	19.8	22	1.1	3.4	232	244	5	7	0	0	39	57
5	76.8	89.3	19.8	22	1.1	2.9	246	258	5	7	0	0	24	34.3
6	75.1	85.3	19.8	22.3	1.1	3	228	240	4	7	0	0	49	60.2
7	77.4	89.6	19.7	21.9	1.2	3.4	225	240	5	8	0	0	114	128
8	80	92.2	19.7	21.9	1.2	3.4	220	232	5	7	0	0	44	56
Mean value	72.4	84.6	20.01	22.21	0.71	2.91	177.12	189.1	3.75	5.75	0	0	63.87	75.87
The measurements were taken with the flap in the CLOSED position														

The measurements were taken with the flap in the CLOSED position

Temperatures and emissions at point LD 1														
Measurement no.	Gas temp., [°C]		O ₂ , [%]		CO ₂ , [%]		CO, [ppm]		NO, [ppm]		NO ₂ , [ppm]		SO ₂ , [ppm]	
	E5	E2	E5	E2	E5	E2	E5	E2	E5	E2	E5	E2	E5	E2
1	79.9	92.1	19.8	22	1.1	3.3	181	193	5	7	0	0	18	20
2	41.1	53.3	20.8	23	0	2.2	26	38	0	2	0	0	28	30
3	36.1	48.3	20.8	23	0	2.2	7	19	0	2	0	0	0	2
4	35.5	47.7	21	23.2	0	2.2	4	16	1	3	0	0	2	4
Mean value	48.2	60.4	20.6	22.8	0.275	2.475	54.5	66.5	1.5	3.5	0	0	12	14
The measurements were made with the flap in the OPEN LEVEL 1 position														

Table 4
EXPERIMENTAL
DATA

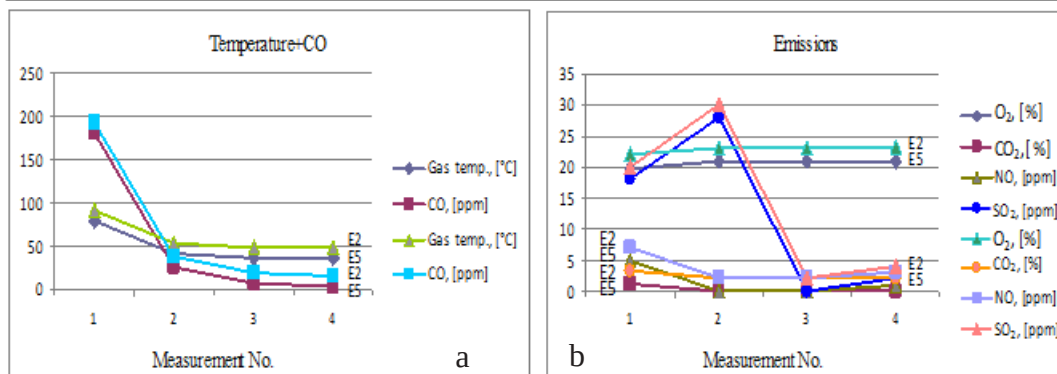


Fig. 3. Variation of parameters temperature and CO (a) and variation of polluting emissions (b)

Table 5
EXPERIMENTAL DATA AT SITE LD 1

Powders			
Measurement no.	Δm, [g]	powders, [mg/m ³]	
1	0.004	E6	E7
		44.4	45.2

Table 6
EXPERIMENTAL DATA AT SITE LD 1

Powders			
Measurement no.	Δm, [g]	powders, [mg/m ³]	
		E5	E2
1	0.0028	34.4	37.8
2	0.0024	29.5	32.1
3	0.0053	65.2	72.8
4	0.0027	33.2	36.3
5	0.0033	40.6	53.1
6	0.0068	83.6	90.5
Mean value		40.2	53.8

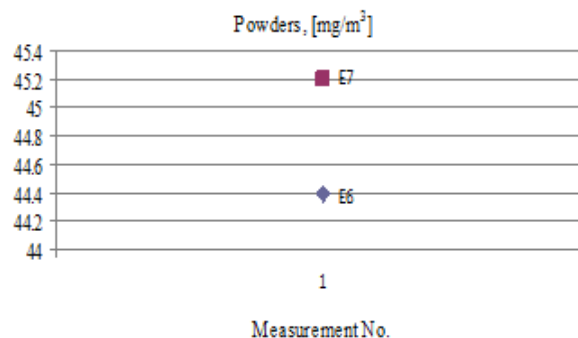


Fig. 4. Powder content

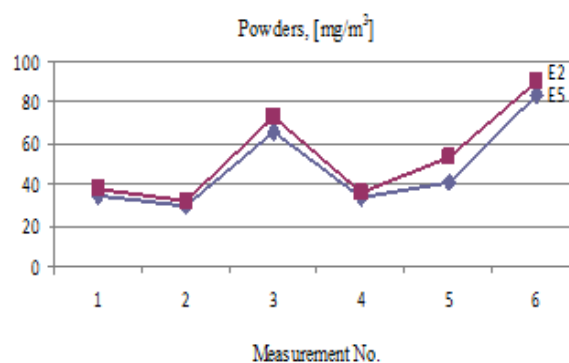


Fig. 5. Powder content variation

classical technology (batch 7-E7), considered representative.

1a) measurements at point LD 1 (batch 6-E6 and 7-E7)

1b) measurements at point LD 1 (batch 5-E5 and 2-E2)

Table 4 shows the values of exhaust gas temperatures and the concentrations of the pollutant emissions in the combustion gas, while figures 3(a), (b) show their variation over time, measured at site LD 1, for the batches produced using the new technology (batch 5-E5), and using the classical technology (batch 2-E2).

b) The results of powder measurements at point LD 1 (batch 6-E6 and 7-E7) are shown in table 5 and figure 4.

The results of powder measurements at point LD 1 (batch 5-E5 and 2-E2) are shown in table 6 and figure 5.

Figure 5 shows that the powder concentration of the new technology is lower than that of the classical technology.

c) The results of the measurements of polluting gas emissions at site LD 9 for batches 6-E6 and 7-E7 are shown in table 7.

In order to determine the concentration of exhaust gases (CO, NO_x, SO₂) present in the combustion gases, two measurement techniques (sampling tubes + Dräger pumps) were used in parallel, along with the TESTO gas analyzer, in which the measurement results were printed. The temperature limits between which the Dräger equipment operates, can be used to compare the values

Pollutant	Measured value, [ppm]		Corrected value				Measurement no.
	E6	E7	[ppm]		[mg/m³]		
			E6	E7	E6	E7	
SO ₂	3.2	2.8	3.225	2.82	8.61	7.53	1
NO _x	2	6	2.016	6.05	3.87	11.62	
CO	10	10	10.08	10.08	11.8	11.8	
SO ₂	3.5	5.8	3.528	5.85	9.42	15.6	2
NO _x	3	0	3.024	0	5.81	0	
CO	10	100	10.08	100.8	11.8	117.94	
SO ₂	3.7	1.2	3.729	1.21	9.96	3.23	3
NO ₂	0	3,5	0	3.53	0	6.8	
CO	9	150	9.07	150.8	10.6	176.4	
SO ₂	3.8	0.6	3.830	0.605	10.23	1.62	4
NO _x	1	5	1.008	5.04	1.94	9.68	
CO	10	134	10.08	135.7	11.8	158.03	
SO ₂	0.6	3	0.605	3.024	1.62	8.07	5
NO _x	5	2	5.06	2.016	14.4	3.87	
CO	10	135	10.08	136	11.8	159.1	
SO ₂	3.5	8.2	3.529	8.26	9.42	22.05	6
NO _x	4	6	4.032	6.05	7.7	11.62	
CO	10	209	10.08	211	11.8	246.9	

Table 7
CONCENTRATIONS OF
POLLUTANT EMISSIONS IN
THE COMBUSTION GASES
(BATCH 6-E6 AND BATCH
7-E7)

For E6: CM-SO₂ = 7.57 mg / m³; CM-NO_x = 6.3 mg / m³; CM-CO = 16.8 mg / m³

1 ppm SO₂ = 2.67 mg/m³ SO₂; 1 mg / m³ SO₂ = 0.37 ppm SO₂

1 ppm CO = 1.17 mg / m³ CO; 1 mg / m³ CO = 0.86 ppm CO;

1 ppm NO₂ = 1.92 mg / m³ NO₂; 1 mg / m³ NO₂ = 0.52 ppm NO₂

F = atm. pres. / effective pres. = 760 / 754 = 1.0079575

F = correction factor which is multiplied with the measured value

For E7: CM-SO₂ = 9.7 mg / m³; CM-NO_x = 7.3 mg / m³; CM-CO = 145.03 mg / m³

1 ppm SO₂ = 2.67 mg/m³ SO₂; 1 ppm CO = 1.17 mg / m³ CO

1 mg / m³ SO₂ = 0.37 ppm SO₂; 1 mg / m³ CO = 0.86 ppm CO

1 ppm NO₂ = 1.92 mg / m³ NO₂; 1 mg / m³ NO₂ = 0.52 ppm NO₂

F = atm. pres. / effective pres. = 760 / 754 = 1.0079575

obtained using the variants. The measurement results at site LD 9 using Dräger equipment are shown in table 7.

Analysing the data in table 7 for the 6 measurements, the following results:

- in experiment E6, the SO₂ concentration has lower values than in experiment E7, that is only 0.6-3.7 ppm, compared to 0.6-5.8 ppm.

- in experiment E7, the NO_x concentration has higher values than in experiment E7, that is 0-5 ppm, compared to 0-6 ppm.

- in experiment E6, the CO concentration has lower values than in experiment E7, that is only 9-10 ppm, compared to 10-150ppm.

These values confirm the decrease of gaseous emissions when using the new technology, compared to the classical technology.

d) The results of the measurements of powder concentrations at sites LD 1 and LD 9 for batches 6-E6 and 7-E7 are shown in table 8.

The measurements were performed with SARTORIUS type filters, the most suitable for the granulometry of the particulates released by such technological processes. In order to correlate the measurements in the representative sections, two sampling pumps were used simultaneously, one with a maximum flow rate of 1500 L/h and 7 mm reaches, and the second with 20 L/min and reaches of 3.5

Table 8

EXPERIMENTAL RESULTS FOR BATCHES E6 AND E7

Measurement no.	LD 1			LD 9		
	Δm, [g]	[mg/m ³] E6 E7		Δm, [g]	[mg/m ³] E6 E7	
1	0.0040	44.4	45	0.0007	8.6	35.2
2	-	-	-	0.0010	11.7	50.4
3	-	-	-	0.0015	18.4	62.2
4	-	-	-	0.0014	17.2	37.4
5	-	-	-	0.0003	3.6	28.6
Mean sample				12.74	42.7	

mm. In all cases sampling time was 5 min . The results for batches 6-E6 and 7-E7 at sites LD1 and LD9 are shown in table 8.

Table 8 shows that at the point of atmospherei evacuation, the power contentof experiment E6 is to that of experiment E7. Instead, at point LD 9, that is evacuation into the atmosphere through the chimney, it is observed that batch 6 produced using the new technology, has a mean power content, determined using 5 measurements, of only 12.74 mg/m³, that is 4 times smaller than the value obtained for batch 7, which was 42.7 mg/m³, which confirms the validity of the new technology.

Table 9
MEAN TEMPERATURES, [°C]

t_{min}	60.3		43.6		85		47.7		250.4				63.03			60.35
t_{max}	80.0	79.9	47.0	46.7	106.0	73.7	50.6	354.0	281.2	164.6	288.0	352.0	80.2	70.3	70.2	73.9
t_{min}	64.3	35.5	42.6	41.4	98.6	56.4	43.0	258.0	182.2	136.5	241.7	288.7	51.1	68.4	49.7	42.6
t_m	72.4	48.2	44.5	42.7	103.3	66.7	47.7	314.3	224.7	149.7	257.7	305.4	60.7	69.6	58.8	60.35
	LD 1		LD 2		LD 3		LD 4	LD 5				LD 7			LD 9	

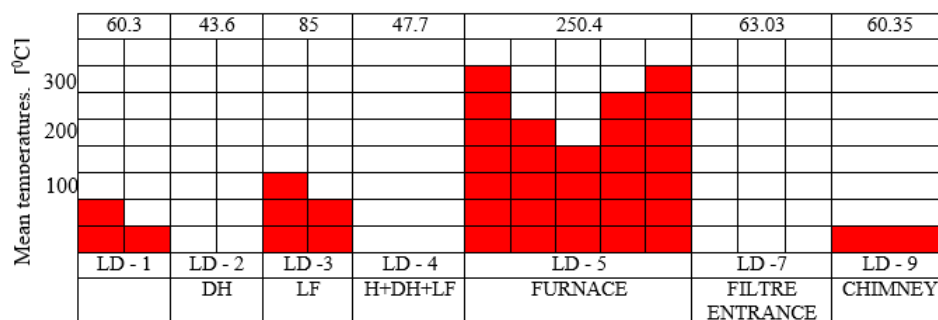


Fig. 6. Presentation of the synoptic graph of temperatures

e) - The results of the measurements of combustion gas speeds at site LD 9 for E6 and E7, allowed for the calculation of the exhaust gas flow. The measurements were performed with an ANEMOMETER with a penetration length inside the chimney of 25 cm, and with a VELOMETER (Pitot-Prandtl tube with direct reading) equipped with a penetration of 1.1 m. Because the chimney diameter was 4.2 m, the second solution was preferred, using three of the four existing measuring points (A, B, C - fig. 1), measurements being performed every 10 cm, from the interior, to the chimney wall. The gas speed dropped with the distance from the chimney wall, but the gas flow was upward.

f) - The results of the measurements of relative humidity at the measuring point LD9 for E6 and E7 obtained using a TESTO thermohygrometer, over a minimum of several hours of measurements and at 10 minute intervals, at the four measuring points (LD 9, A, B, C, D), attests that these are very low (6.8 - 22.85%), which correlated with the simultaneously determined temperature regime, leads to a very low moisture content in the combustion gases, which excludes the possibility of water vapor condensation. It was found that the combustion gas temperature increases with the evacuation duration, and their humidity decreases.

- Following the processing of the recorded experimental data on the temperature values on different exhaust sequences of the combustion gases, the mean values were computed, presented in table 9 and the synoptic graph presented in figure 9 was drawn. From the analysis of the experimental data obtained from measurements during all the 11 experimental batches, at all 9 measuring points and the calculation of the average temperature values and gaseous exhausts, the synoptic graphs presented in fig. 9-13 were drawn, from which resulted the share of each section of the flow on the concentration of exhaust gases in the combustion gases. In the upper part of the graph in fig. 6, the average temperatures (t_m) for each measurement sequence, the minimum (t_{min}) and maximum (t_{max}) temperatures recorded for batches 7-E7 and 6-E6 are indicated, thus being able to appreciate the fluctuations around the mean, as well as the average value of the average temperatures for each measuring place.

By analysis this graph, the following result:

- The temperature level in all measurement sections is lower than the one recommended technologically, a fact that, corroborated with the low combustion gas flow, contributes to a low air circulation speed through the treatment plant, which leads to a reduction of the discharged gaseous emissions.

Table 10
CO CONCENTRATIONS, [ppm]

Mean values	115.8		37		14.1		19.8		1150.6				170.41			124
[ppm]	177.12	54.5	31.11	42.85	18.5	9.66	16.8	22.75	657.2	1564.2	1443.2	17.1	2071.12	130.2	210.05	95.57
LD	LD 1		LD 2		LD 3		LD 4	LD 5				LD 7			LD 9	

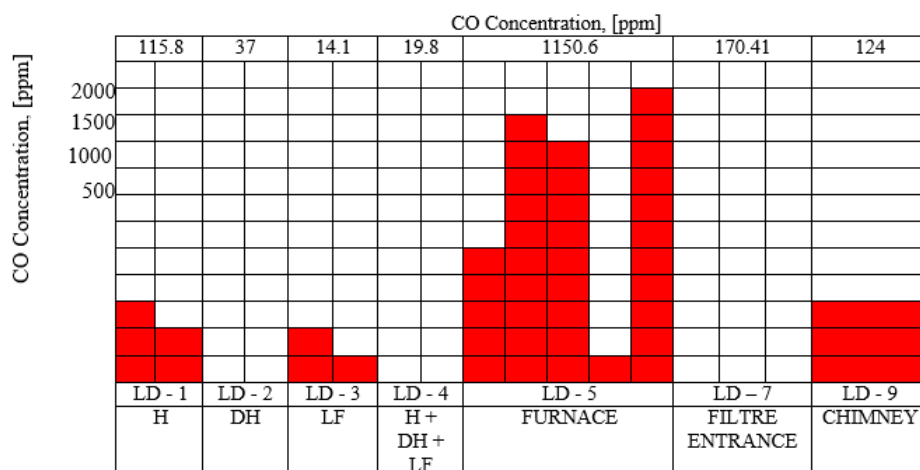


Fig. 7. Presentation of the synoptic graph of CO concentrations

- Although the mean on the measurement sequence LD 5 was 250.4°C, this was lower than the indicated one of 420°C.

- Following the processing of the experimental data on the CO concentration values on different sequences, the mean values of the pollutant gas emissions were computed, presented in table 10 and the synoptic graph presented in figure 7 was drawn.

The analysis of this graph shows that the highest share of the CO concentration in the combustion gases is represented by the sequence LD 5 with a value of 1150.6 ppm, that is, the technological process of the electric arc furnace used in the experiments. From the measurements it resulted that the momentary values of the CO concentration exceeded 4000 mg/m³, a dangerous concentration for the gas analyzers used in the measurement of this parameter. After the mixing chamber and including at the chimney discharge, the CO concentration remains below the alert threshold. The error between the simultaneous measurements at the entrance of the filters performed with the TESTO (LD 7) gas analyzer, and that at the evacuation from the chimney (LD 9) measured with the Dräger tube, was about 5% in favor of the first apparatus.

- Following the processing of the recorded experimental data on the NO_x concentration values on different sequences, the mean values of the pollutant gas emissions were computed, presented in table 11 and the synoptic graph presented in figure 8 was drawn.

The graph analysis shows that the main share of the NO_x concentration in the gaseous emissions is represented by the entire technological process of the furnace, that is, the sequence (LD 5) with a value of 30.7 ppm. It also appears that the NO_x exhaust concentrations (at emission) are well below the alert threshold and the concentration values at the entrance of the sack filters (LD 7) are comparable to those at the emission (LD 9).

- Following the processing of the recorded experimental data on the SO₂ concentration values on different sequences, the mean values of the pollutant gas emissions were computed, presented in table 12 and the synoptic graph presented in figure 9 was drawn.

The synoptic representation in figure 9, drawn based on the mean values of different measurement segments, shows that the main share of the SO₂ release, is represented by the LF line (LD 3) with a value of 111.65 ppm, and by aspiration through the hood (LD 1) with a value of 37.93 ppm. The SO₂ furnace releases (LD 5) are well below the first two sources mentioned, having a value of only 6.73 ppm.

- Following the processing of the recorded experimental data on the powder concentration values on different sequences, the mean values of the powder concentrations were computed, presented in table 13 and the synoptic graph presented in figure 10 was drawn.

From the graphical representation of data in figure 13, results an equal participation of different gaseous emission collection sources, with a higher share of collection from the Dog-house and maybe from the furnace exhaust, were

Table 11

NO_x CONCENTRATIONS, [ppm]

Mean values	2.625		0.22		1.79		4.65		30.7					13.94			7.3
[ppm]	3.75	1.5	0.44	-	2.25	1.33	6.3	3	30.8	25.45	85.99	9.3	29	9.36	25.11	7.37	7.3
LD	LD 1		LD 2		LD 3		LD 4		LD 5					LD 7			LD 9

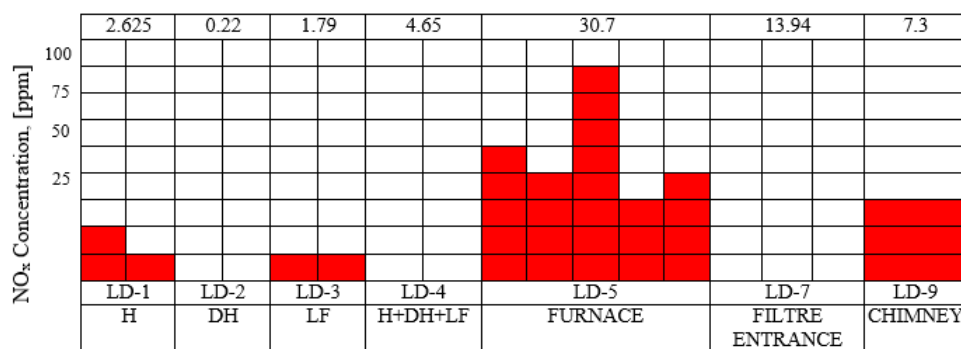


Fig. 8. Presentation of the synoptic graph of NO_x concentrations

Table 12

SO₂ CONCENTRATIONS, [ppm]

Mean values	37.93	-	111.65	3.85	6.73	1.32	9.7									
[ppm]	63.875	12	-	131.5	91.8	7.57	0.14	1.2	17.36	4.93	-	10.16	3.9	0.055	-	9.7
LD	LD 1	LD 2	LD 3	LD 4	LD 5	LD 7	LD 9									

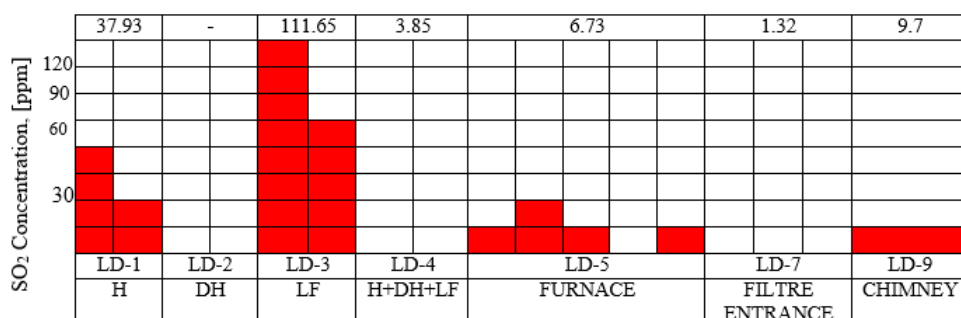


Fig. 9. Presentation of the synoptic graph the of SO₂ concentrations

Table 13

MEAN POWDER CONCENTRATIONS, [mg/m³]

Mean values	44.4	67.54	40.2	47.75	75.21	12.74
LD	LD 1	LD 2	LD 3	LD 4	LD 7	LD 9

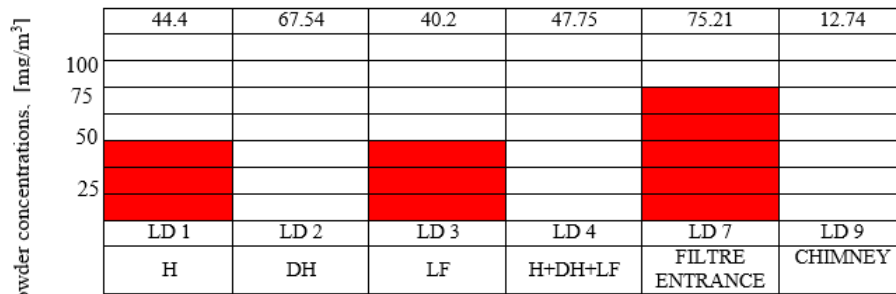


Fig. 10. Presentation of the synoptic graph the powder concentrations

Table 14

CONCENTRATION VALUES AT EMISSION SITE - L.D. 9

Measured and corrected	Exhaust concentraion		CO	NO _x	SO ₂	Powders
	C _m	[ppm]	124.72	3.8	3.6	
	C _m	[mg/m ³]	145.03	7.3	9.7	12.74
	C ₀	[mg/Nm ³]	177.09	8.9	11.8	12.74
	C _{max}	[mg/Nm ³]	180.34	9.1	12.05	12.74
	C _{min}	[mg/Nm ³]	173.83	8.7	11.6	12.74
	C.M.A.,	[mg/Nm ³]	250	500	2000	100
	P.A.,	[mg/Nm ³]	175	350	1400	70

because of high temperatures, direct measurements of power concentrations on this exhaust path could be taken. The concentration of powers discharged into the atmosphere of 12.74 (mg /m³) is significantly lower than the alert threshold specified by the legal norms.

- Comparison of pollutant concentrations measured at emission (LD 9), corrected and compared to the admissible values, is presented in table 14.

a) Mean values measured in ppm for emissions in normal conditions were transformed in mg/m³ and were corrected in order to be brought to normal physical conditions (273 °C, 1013 mbar), by applying the following formulas:

$$C_0 = C_m T/T_0 \quad [\text{mg/Nm}^3] \quad (1)$$

where:

C_m - mean of measured values
T, T₀ - effective temperature, respective normal physical temperature.

Conclusions

Experiments have confirmed the reduction of gaseous emissions and powders when using the new technology that limits their production directly at source, that is, during the technological process, by using iron sponge during the load production stage, and by driving the production process using foamed clay, which has multiple advantages. Thus, by using the new technology, the average CO₂ content of the pollutant emissions discharged into the atmosphere through the hood, decreased from 2.91 to 0.71 ppm, the CO content decreased from 189.1 to 177.12 ppm, the NO content decreased from 5.75 to 3.75 ppm and the SO₂ content decreased from 75.87 to 63.87 ppm. In another set of experiments, the average CO₂ content of the pollutant emissions when discharged into the atmosphere through the hood, decreased from 2.475 to 0.275 ppm, the CO content decreased from 66.5 to 54.5 ppm, the NO content decreased from 3.5 to 1.5 ppm and the SO₂ content decreased from 14 to 12 ppm. These results show that the new technology achieves a reduction of about 30% of the content of pollutant gaseous emissions.

The average powder content, when discharged into the atmosphere through the hood, when using the new

technology, during the first set of experiments decreased from 45.2 to 44.4 mg/m³, that is, by about 12%, and during the second decreased from 53.8 to 40.2 mg/m³, that is, by about 40%, resulting in a total decrease of about 20%.

As a result of the experiments, it was concluded that using the new technology, compared to the classical technology, the average values of the gaseous emissions during evacuation into the atmosphere through the chimney (LD9) decreased, that is, the CO content dropped from 10-150 ppm to 9-10 ppm, the SO₂ content decreased from 0.6-5.8 ppm to 0.6-3.7 ppm and the NO_x content dropped from 0-6 ppm to 0-5 ppm. These values confirm the reduction of gaseous emissions when using the new technology, compared to the classical technology.

The average powder content when discharged through the chimney into the atmosphere, decreased when using the new technology, from 42.7 mg/m³ to 12.74 mg/m³, that is, by about 75%, which fully confirms the validity of the new technology.

The analysis of the experimental data obtained from the measurements taken for all 11 experimental batches, at all 9 measuring points, the calculation of the average values of the temperatures and gaseous exhausts, allowed for the drawing of synoptic graphs, from which one can observe the share of each section of the flow on the concentration of exhaust gases in the combustion gases. From the synoptic representation in figure 6 it has been shown that the temperature level in all the measuring sections is inferior to the technologically recommended one, which in conjunction with the lower combustion gas flows, contributes to a reduced air circulation rate in the treatment plant, leading to a reduction in the evacuation of gaseous emissions. The analysis of the graph in fig.7 shows that the highest share of the CO concentration in the combustion gases is represented by the LD 5 sequence with a value of 1150.6 ppm, that is, the technological process of the arc electric furnace used for the experiments. The measurements have shown that the momentary concentrations of CO exceed 4000 mg/m³, a dangerous concentration for the gas analyzers used to measure this parameter. After the mixing chamber and including during

the evacuation through the chimney, the CO concentration remains below the alert threshold.

The analysis of the graph in fig.8 showed that the main share of the NO_x concentration in the gaseous emissions is represented by the entire technological process of the furnace, that is, the sequence (LD 5) with a value of 30.7 ppm. It also appears that the NO_x exhaust concentrations (at emission) are well below the alert threshold and the concentration values at the entrance of the sack filters (LD 7) are comparable to those at the emission (LD 9). The synoptic representation in figure 9, drawn based on the average values of the various measurement segments, shows that the main share of these emissions, that is SO₂, is the LF (LD 3) line with a value of 111.65 ppm and aspiration through the hood (LD 1) with a value of 37.93 ppm. The SO₂ emissions from the furnace (LD 5) are well below the first two sources mentioned, having a value of only 6.73 ppm. From the graphical representation of the data in figure 10, it results that there is a relatively equal participation of the various sources of powder collection. The concentration of powders discharged into the atmosphere, with a value of 12.74 (mg/m³) is far below the alert threshold specified by the legal norms. Comparing of the average concentrations of gaseous pollutants determined at emission (LD 9) and corrected (CO, NO_x, SO₂) as well as the concentration of powders, with the maximum admissible concentrations, indicates that the determined values are below the admissible values.

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