INFLUENCE OF THE ELECTRODE GEOMETRY AND OF THE OPERATING CHARACTERISTICS ON THE EFFICIENCY OF ELECTROSTATIC PRECIPITATORS

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Abstract

A 400 mm duct spacing precipitator was compared with a similar precipitator having 300 mm duct spacing et the same power plant location. The analysis of the results raised questions which suggested a comprehensive investigation on the influence of the emitting wire diameter, carried out on a pilot plant. The paper presents the obtained results and suggests the conclusion that for obtaining the greatest presents the obtained results and suggests the conclusion that for obtaining the greatest precipitator efficiency the diameter of the emitting electrode must be optimized together with the duct spacing.

Introduction

The basic phenomena of the electrostatic precipitation are the production of the space charge by the corona discharge and the drift of the charged particle toward the collecting plate. However, many other physical phenomena contribute to the process which are interconnected by complex mutual influences. This means that the performances of similar precipitators may differ because of some operating condition which is difficult to clearly identify.

Taking into consideration the main geometrical parameters of the precipitator: the wire diameter and the duct width, they act differently on the production of the corona discharge and on the drift of the charged particles.

Recently the so called rigid discharge electrodes (RDE) have been successfully employed [1] and the reason of their success can be ascribed to fact that they allow the separation of the two phenomena: (i) the production of the negative space charge which is accomplished by the sharp protuberances and (ii) the larger size of the overall electrode produces a higher electric field at the collecting plate. In this view the classic elicoidal electrode should be considered a pioneer.

Investigating the performances of the precipitators installed in different power plants and in particular those installed at the Marghera Power Station which are especially equipped for testing purposes, some observations and remarks have been drawn which are useful for better understanding the relevance of the various mechanisms which may affect the removal efficiency. The present contribution aims to report such observations.

Tests on industrial precipitators

The precipitators object of the tests have the characteristics reported in Table I: the unit named PE8 was arranged with a duct width of 400 mm while the unit named PE9 was arranged with a duct width of 300 mm.

TABLE I: MAIN DESIGN CHARACTERISTICS OF THE ELECTROSTATIC PRECIPITATOR USED FOR THE TESTS

Gas flow rate	175.000		Nm3/h
Gas temperature	155		°C
Gas pressure at inlet	-150		mm H2O
Inlet particle concentration	10 ÷ 16		g/Nm3
Collection efficiency	99.6		%
Casing length	20.9		m
Casing width	9.5		m
Casing height	15		m
Hopper height	6		m
Electric fields in series	3		
Electric sections	3		
Active length	15		m
Length over height ratio	1.15		
Residence time	21		s
Collection electrodes height	13		m
Collection electrodes width	0.5	0.29	m
Collection area per section	3640	2730	m2
Specific collection area	145	109	m2/(m3/s)
Gas passages per channel	28	21	
Gas passage width	300	400	mm

The emitting electrodes of both units were 5mm wires assembled into frames. Both units were conventionally energised and the control system was also very similar.

The two units were downstream of two similar boilers of 35 MWe supplied with the same type of coal. During each test, samples of coal were collected and analysed; the results are reported in Table II. The fly ash collected at the inlet of the two precipitators was also analysed and the results are reported in Table III. The resistivities of the ashes of the three coals used during the tests were: $5.2 \cdot 10^{12}$ Ω·cm for the AMCOAL of first supply; $5.5 \cdot 10^{12}$ Ω·cm for the AMCOAL of second supply and $3.0 \cdot 10^{12}$ Ω·cm for the SHELL.

TABLE II: CHEMICAL ANALYSIS OF COALS USED DURING THE TESTS ON THE INDUSTRIAL PRECIPITATORS

	AMCOAL I	AMCOAL II	SHELL
Specific heat value (kC/kg)(2)	5849	5991	5796
S content (%)	0.74(1)	0.60(1)	0.51
C content (%)	65.1	71.8	65.1
H content (%)	3.55	4.0	3.87
N content (%)	1.46	1.82	1.39
volatile matter (%)	27.0	27.7	29.07
ashes (%)	16.4	15.5	15.68
total humidity (%)	7.77	6.69(1)	7.62

All values are referred on dry samples but the specific heat value which refers to the sample as it is

(1) These figures exhibited a significance variance (about 10%)

TABLE III: ANALYSIS OF THE ASH COLLECTED AT THE INLET OF THE INDUSTRIAL PRECIPITATORS

	SiO_2	Al_2O_3	CaO	Fe_2O_3	MgO	Na_2O	K_2O	TiO_2	unburnt
AMCOAL I	50.4	36.2	5.4	3.7	0.68	0.11	0.63	1.83	7.8
SHELL	55.0	31.6	5.8	3.1	1.5	0.15	0.46	1.68	4.3
AMCOAL II	49.6	36.4	5.7	2.6	0.99	0.15	0.71	1.77	4.8

NOTE: All the standard deviations were in the range of few percent but for MgO, K2O and Na2O for which were about 10%

In Table IV the results of three subsequent test campaigns are summarised. The dust concentrations at the input were quite constant (between 10 and 12 g/Nm3) but there was no complete confidence on the absolute value. Thus the outlet dust concentrations are thought to be more meaningful.

In Table V the electrical parameters of the energization are detailed. The voltages applied to the second and third field during the first and second campaigns couldn't be measured because of the failure of the voltage divider. It was however evident that this failure didn't affect the applied voltage level. All the reported values are mean values and the standard deviation was less than 5% unless differently stated.

TABLE IV:SUMMARY OF TESTS ON INDUSTRIAL PRECIPITATORS				
Campaign	Coal	Flue gas temperature	PE9 w=300 mm; d=5 mm	PE8 w=400 mm; d=5 mm
#1 Feb. 20 (3 runs)	AMCOAL first supply	146 °C	**85.6 ± 13%** **mg/Nm^3**	**36 ± 15%** **mg/Nm^3**
#2a Mar. 16 (2 runs)	SHELL	147 °C	**136 ± 2%** **mg/Nm^3**	**22 ± 7%** **mg/Nm^3**
#2b Mar 20 (2 runs)		151 °C	**270 ±1%** **mg/Nm^3**	**24 ± 7%** **mg/Nm^3**
cleaning of both precipitators				
#3 May 27-29 (6 runs)	AMCOAL second supply	156 °C	**114 ± 6%** **mg/Nm^3**	**136 ± 7%** **mg/Nm^3**

TABLE V: ELECTRICAL OPERATING CHARACTERISTICS OF INDUSTRIAL PRECIPITATORS DURING TESTS									
		PE9 (w=300 mm)				PE8 (w=400 mm)			
test camp. date	field	V (kV)	I (mA)	P (kW)	N..of spark	V (kV)	I (mA)	P (kW)	N. of spark
# 1 Feb 20	first	38.3	116	7.5	5	53.5	296	19.3	17
	second		80	5	7	68.9	218	16.5	5
	third		162	8.5	7	55.5	795	56	4
# 2a Mar 16	first	37	154	9.2	7	51	354	22.5	16
	second		106	6.3	13	69.4	152	11.5	10
	third		150	8.1	8	56.5	803	57.5	4
# 2b Mar 20	first	34.6	193	10.5	8	51	343	22	16
	second		204	11	10	70.4	148	11	9
	third		221	11.4	8	57.5	751	54	4
# 3 May 27-29	first	40.5	337	16.7	10	40.6	699	39.6	11
	second	45.3	510	24.3	7	42.2	630	35	7
	third	37	523	21.5	10	35	656	31.5	3

During the first two tests campaigns, aimed to verify the influence of the duct spacing on the precipitator performance, we got the persuasion that something was going wrong and that it was probably because of an abnormal dust accumulation caused by the fact that, before the starting of the test campaign, the precipitators were interested by the residual products of fuel oil combustion. Moreover the analysis of the V/I characteristics indicated that the rapping of the emitting electrodes of the second field of precipitator PE8 was probably bad working since before the beginning of the test campaign.

The visual inspection following the second test campaign showed that (i) both precipitators were affected by a large dust accumulation, (ii) in the precipitator PE9 protrusion of the dust layer on the collecting plates and on the baffles in the hoppers suggested abnormal sparking, (iii) in the second field of precipitator PE8 the emitting wires were covered by a very large dust layer up to 4 cm in diameter. The presence of a large dust layer on the emitting electrodes of precipitator PE8 can be explained by the temporary failure of the rapping system. The presence in the precipitator PE9 and not in the precipitator PE8 of remarkable protrusions of the dust layer must be explained by the previous operating conditions of the two precipitators. In fact both precipitators were interested by the residual products of fuel oil combustion before the test campaign but precipitator PE9 was also interested by a previous experience of lime injection in the boiler. The collected fly ash, however, didn't show any difference in calcium content.

Following the visual examination this explanation of the results of the first two tests campaigns may be suggested. The performance of the precipitator PE9 deteriorated because of the presence of a severe dust accumulation which reduced the maximum applicable voltage. The dust accumulation did not deteriorate the performances of precipitator PE8 because (i) the precipitator PE8 had a wider duct spacing, (ii) the presence of the large dust layer on the emitting wires, especially those of the second field, probably acted positively on the precipitator performances.

It is supposed that partial discharges occurred in the dust layer on the emitting wires, the produced positive ions being collected by the wire while the negative ions being moved first through the dust layer and then through the interelettrode spacing to the collecting plate. The different mobility of the negative ions inside the dust layer and the average mobility of the space charge in the interelectrodic space produced an increase of the electric field close to the collecting plate and this was responsible of the increase of collecting performances. The lack of knowledge of the boundary conditions prevent the simulation of the phenomenon; it is hoped that laboratory experiments may confirm this interpretation of the experimental results.

The comparison of the outlet dust concentrations measured during the first and the third campaign on precipitator PE8 may give an indication of the influence of the large dust layer on the emitting wires of field 2 on the collecting performances of the whole precipitator. The analysis of the electrical parameters shows that the current absorbed by the second field increases 5 times when the efficiency of the precipitator decreases; it is supposed that this is due to the fact that almost all the current is transported by ions and only a small fraction is transported by dust.

The outlet particle emission of the two precipitators during the third test campaign is not significantly different and it would suggest that the duct width doesn't influence the collecting performance, at least under these operating conditions.

Tests on the pilot plant

At the Marghera power station is also available a 10.000 Nm^3/h pilot precipitator which can be supplied with the flue gas coming from a 35 MWe boiler. The main characteristics of the pilot are reported in Table VI.

Using the flue gas produced by the combustion of coal type AMCOAL, tests have been carried out with two different emitting electrode diameters: 5 and 6 mm. The results are reported in Table VII.

TABLE VI: MAIN CHARACTERISTICS OF THE PILOT PRECIPITATOR		
Nominal gas flow	12,000	Nm^3/h
Actual gas flow	18,306	m^3/h
Duct width	400	mm
Number of ducts	3	
Height of collecting plates	3.75	m
Height of wires	3.14	m
Total collecting surface	218	m2
SCA	43	$m^2/(m^3/s)$
Number of fields	2	
Length of each field (m)	4.84	m
Number of wires for each duct	17	
Total wire length for each field (m)	160	m

It appears evident the great increase of efficiency due to the increase of the emitting wire diameter. The fact that the gas temperature during the test with the 5 mm diameter was lower than that in the case of 6 mm suggests even a larger increase at constant temperature. Although the large variability of the inlet concentrations the efficiency is very constant from test to test.

TABLE VII: RESULTS OF THE TESTS CARRIED OUT ON THE PILOT		
Diameter of the wire	5 mm	6 mm
numbero of tests	4	5
inlet temperature (°C)	133 ± 0.7%	138 ± 1.4%
outlet temperature (°C)	117.5 ± 0.8%	125 ± 1.6%
first field voltage (kV)	48.2 ± 5%	57.7 ± 1.2%
first field current (mA)	11.1 ± 0.9%	10.6 ± 2.8%
second field voltage (kV)	48.3 ± 1%	57.2 ± 2.6%
second field current (mA)	12.5 ± 1.6%	12.1 ± 0.8%
inlet concentration (mg/Nm3)	12191 ± 4.7%	13669 ± 15.6%
outlet concentration (mg/Nm3)	480 ± 10%	269 ± 8.2%
efficiency (%)	**96.03 ± 0.57**	**97.98 ± 0.31**

The increase of the efficiency is related to the increase of the applied voltage and of the electric field. In fact, assuming the same charge mobility of $1.8 \cdot 10^{-4}$ m^2/Vs, the electric fields have been computed, simulating a corona discharge producing the measured currents with the measured applied voltages, in the two geometric conditions. The ratio between the computed electric field E_6, with the 6 mm wire , and the computed electric field E_5, with the 5 mm wire, is represented in fig. 1. The electric field with the 6 mm wire is about 10% greater on the collecting plate and it increases up to 40% at 4 cm from the emitting wire.

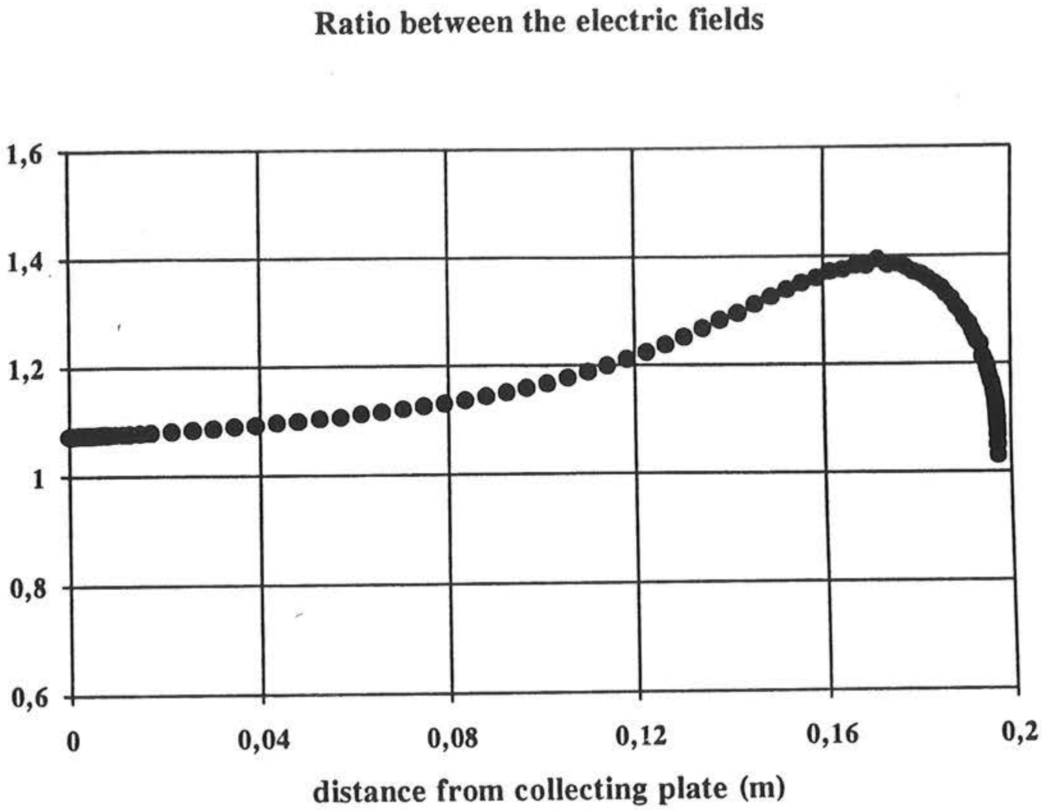

Fig. 1 Ratio between the electric field E_6 computed with a wire diameter of 6 mm and the electric field E_5 computed with a wire diameter of 5 mm

Concluding remarks

It has been reported a significant increase of precipitation efficiency when using the novel type Rigid Discharge Electrodes (RDE) which are characterized by the production of a high mean electric field still conserving a local field high enough for allowing corona discharge.

The reported observations and investigations confirm that a significant increase of the precipitation efficiency can be obtained when the mean electric field is increased. This may be achieved by an increase of the diameter of the emitting electrode provided the duct width is large enough to prevent the evolution of corona into spark. It can also be achieved by a special design of the emitting electrode such as the RDE type or by the formation of a dust layer around the emitting electrode.

References

[1] Crynack R. ***Discharge electrodes for electrostatic precipitators - A perpective***
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