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# Retention of Powders from Flue Gases Resulted from the Combustion of Lignite in High Energy Boilers in Thermal Power Stations

Energy is essential for the economic and social welfare, for the smooth operation of most industrial and commercial activities. However, energy production and consumption exerts considerable pressures on the environment, which include contributions to climate changes, damage to natural ecosystems, damage to the environment built and generation of adverse effects on human health.
The solutions to be implemented to make mechanical and electrical cyclones with high level of retention of powders from combustion gases are presented, taking into account the optimisation of gas flow through the active area of the electrostatic precipitator and the removal of dust re-drives from the collectors.

Keywords: powders, electrostatic precipitators, voltage

## 1. Introduction

Starting from the desideratum of attenuating the negative impact of environmental pollution by one of the main pollutants, steam boilers from thermal power plants, various primary or secondary filtering techniques have been developed.

One of these modern technologies to retain the dust from flue gases consists in the electrical cyclones, which are usually also called electrostatic or electrical filters.

The operating efficiency of these plants is influenced by many factors and parameters that are usually grouped into two categories;

- those of electrical feature (electric field distribution, density and distribution of the spatial ionic load between electrodes), which determine to a great extent another essential size that occurs in the electrostatic process and namely, the electrical charge accumulated by particles during their movement inside the electrostatic precipitator. - those which meet all the characteristics of gas flow – gasodynamic factors (the pressure difference between the electrostatic precipitator, the gas turbulence level.

## 2. Experimental Studies

### 2.1. Basics of Physical Modelling of Gas Circulation in Electrostatic Precipitators

The optimisation of gas flow has an important role among the factors influencing the ELF performance. It has been proven both theoretically and experimentally that an adequate gas flow through ELF considerably improves the dust removal level. The performance of the electrostatic process of dust removal the combustion gases is also determined, inter alia, by the cinematic spectrum of flowing in the active area of the electrostatic precipitator. It has been shown experimentally that when the non-uniformity of the velocity field in the active section increases, the yield of the electrostatic precipitators drops significantly.

The yield achieved in this case will be [2], [4], [5]:

$$\eta = \eta_{teor} - \Delta\eta , \tag{1}$$

The theoretical yield $(\eta_{teor})$ can be calculated with the Deutsch relation:

$$\eta_{teor} = 1 - e^{\frac{W \cdot L}{h \cdot V_{med}}} \tag{2}$$

The yield deduction $(\Delta\eta)$ due to non-uniformity of speeds can be determined by the relation:

$$\Delta\eta = \frac{e^{\frac{WA}{FV_{med}}} A \cdot \Delta V_{med} \cdot \ln e^{-W}}{V_{med}^2 \cdot F} \tag{3}$$

$$\Delta V_{med}^{'} = \frac{\sqrt{\sum_{i=1}^{n} (V_i - V_{med})^2}}{n} \quad : \quad n \geq 1 \tag{4}$$

### 2.2. Objective subject to physical modelling

The objective of this study was to reduce the ash content in the exhausted gases, under 50mg/ $m^3N$ by optimising the gas flow in the active area of the electrostatic precipitator.

Initially, the electrostatic precipitators related to the 1035 t / h boiler have been designed with an axial inlet provided with a single row of levelling sieves. The levelling sieves had the geometrical shape shown in figure 6.

In order to obtain high efficiency electrostatic precipitators, it was suggested to assemble some levelling systems in the inlet and outlet connections.

The configuration of these systems will be established after a study performed on the physical model.

The electrical cyclone from the 1035t / h boiler (this system was chosen as a model of study) consists of two horizontally dry electrostatic precipitators and an automation and electricity supply system.

The objective subject to physical modelling has the following technical features [14]:

Table 1.

| | |
|---|---|
| Flue gas flow for the 2 IDE's | (1 600 600 - 2 100 000) $m^3N$ /h |
| Nature of gases | Gases resulted by lignite combustion |
| Temperature of gases | (140-160) )°C |
| The ash content in the input gases | (62- 75)g/$m^3N$ |
| Symbol of the electrostatic precipitator | 60/12/3x9/0,300 |
| Number of passes | 60 |
| Active height of the fields | 12 m |
| Number of fields | 3 |
| Number of deposit electrodes in a panel | 9 |
| Size of a pass (electric filter pass) | 0.300 m |

### 2.3. Achievement of the physical model

The physical model of the electrostatic precipitator along with the related channels was built of Perspex and equipped with settling electrodes made of aluminium sheet.

The physical model shown in figure 1 contains:

- Pilot electrostatic precipitator with plates (ESP) made in two variants (of metal and plexus)
- System for the preparation and simulation of disperse environment (SPSE)
- Disperse medium transport system – Air ventilator

### 2.4. Data Measuring and Processing Methodology

The studies performed started from complex numerical simulations based on the model of two-phase gas-solid flow and were completed by experimental measurements on the model.

To obtain qualitative information on the level of filling the electrostatic precipitator chamber, the areas of gas current detachment, localisation of vortexes, circulation areas, viewing the movement of the gas flow using tracer wires was done.

Local velocities were measured using the "Bandard Tri"-type hot wire anemometer. The velocity measurements were done in a sufficient number of points that would enable a correct assessment of the gas velocity distribution. The speeds were measured in the cross sections A-A, B-B, C-C and D-D according to figure 2.

Figure 1. Diagram of the experimental plant [1]

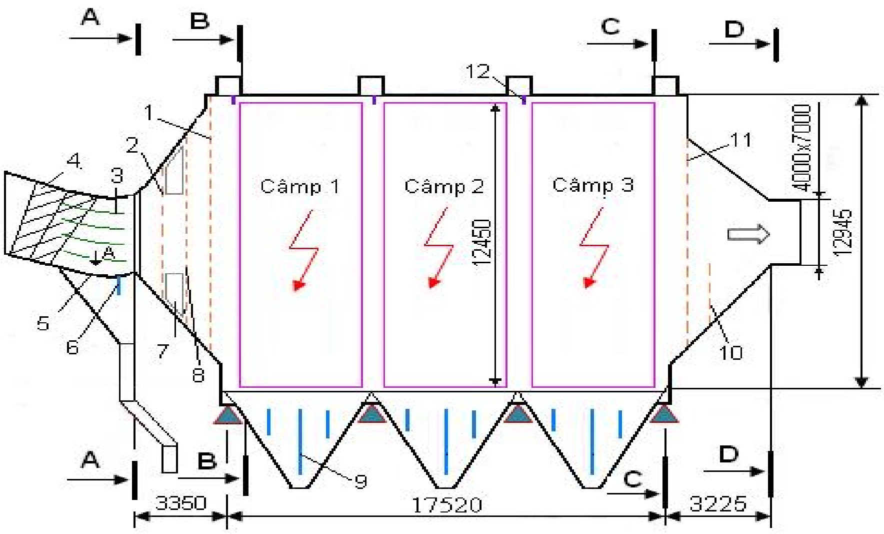


Figure 2. Electrostatic precipitator assembly – location of measurement sections

## 2.5. Modelling Conditions

The researches were done on the physical model which is based on the laws of similarity:

- Dynamic similitude
- Kinematical similitude.

The identification of the measuring points in a section is done considering that it is regarded in the direction of the flow.

The speeds are directed to the reader with the speed vector on the axis z, and the origin of the system of axes is on the left, the axis x from the top to the bottom, and axis y from the left to the right.

The criterion determined in case of modelling the flow of gases in the electrostatic precipitators is the Reynolds one [6], [7], [11]:

$$R_e = \frac{v \cdot l}{\upsilon} \tag{6}$$

where: v - the average speed of gases: l - the characteristic size, υ - kinematic viscosity,

The correlation between the modelling scales is :

$$S_v = \frac{S_\upsilon}{S_l} \tag{7}$$

where: $S_v$, $S_\upsilon$ and $S_l$ are the scale of the speeds, the scale of the kinematic viscositiy coefficients and scale of lengths. In such conditions it was worked in the field of self-modelling which is achieved at Reynolds numbers $\geq 10^4$.

The modelling conditions are shown in table 2.

Table 2.

| Section | Nature | | | Model | | | |
|---|---|---|---|---|---|---|---|
| | axb | V | Re | axb | V | Re | $V_A$ |
| | mm | m/s | | | | | |
| A-A | 3700x9000 | 9.43 | $2.24 \times 10^6$ | 229x558 | 79.12 | $2.25 \times 10^6$ | 3.51 |
| B-B | 12000x18200 | 1.48 | $0.89 \times 10^6$ | 744x1097 | 12.42 | $0.89 \times 10^6$ | 1.39 |
| C-C | 11500x18200 | 1.54 | $0.90 \times 10^6$ | 713x1097 | 12.92 | $0.91 \times 10^6$ | 1.42 |
| D-D | 4000x7000 | 11.21 | $2.44 \times 10^6$ | 248x434 | 94.05 | $2.47 \times 10^6$ | 1.83 |

where: a,b - the sizes of the canal, V – gas speed,
Re - Reynolds number,
$V_A$ - self-modelling speed.

As portent media, the air was used, with the following properties [12]:

- Kinematical viscosity by model: $15.06 \times 10^{-6}$ $m^2/s$ (t = 200ºC)
- Kinematical viscosity in nature: $30.21 \times 10^{-6}$ $m^2/s$ (t = 164ºC)
- Density of gases by model: 1.208 $kg/m^3$ (t = 200ºC)
- Density of gases in nature: 0.810 $kg/m^3$ (t = 164ºC).

2.6. Analysis of Modelled Variants and Results Obtained

On the physical model achieved or modelled, 3 variants of equipping the inlet connection in order to obtain the most advantageous variant in terms of uniformity of the gas flow in the electrostatic precipitator.

The modelled variants were:

Variant V1- inlet and outlet connections not equipped with levelling system.

Variant V2 (the initial variant) - inlet connection equipped with a single row of levelling sieves (S1) having the shape in figure 6 and outlet connection equipped with two rows of levelling sieves (S4 and S5) according to figure 9, figure 10.

Variant V3 (the final variant) - inlet connection equipped with 3 rows (S1, S2, S3) (fig. 6, fig. 7, fig. 8) of sieves and guiding pallets and outlet connection equipped with 2 rows of levelling sieves (S4 and S5).

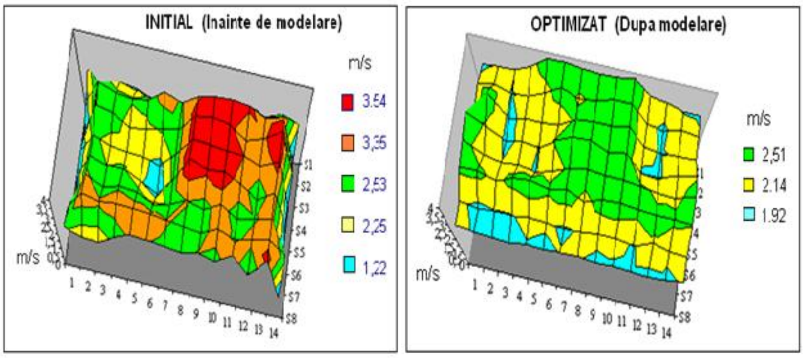


Figure 3. Size of velocities in the input section
before and after modelling

The values of the velocities in the input section before and after modelling are graphically shown in figure 3.

Based on the analysis by physical modelling, the model of the input connection equipped with guiding system consisting in levelling sieves and guiding pallets shown in figure 7 was established.

From the analysis of the modelled and measured variants, it was observed that the optimal variant to equip the inlet connections is shown in figure 4 and corresponds to variant 3.

The model of equipping the outlet connection has the shape shown in figure 5

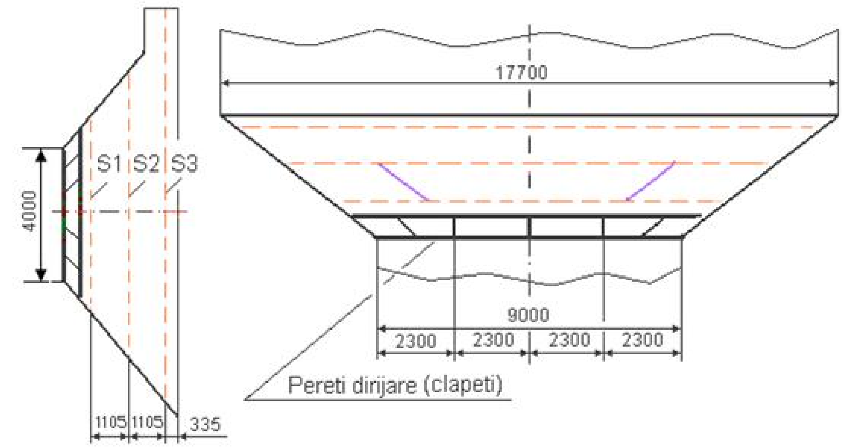


Figure 4. Model of equipping the inlet connection after modelling

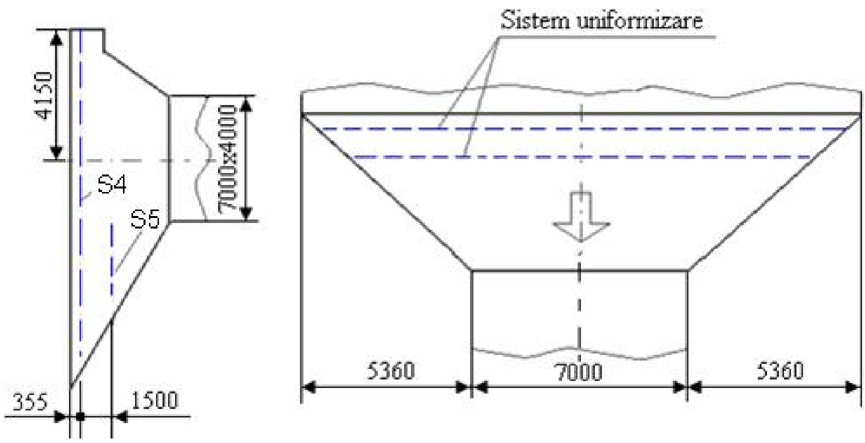


Figure 5. Model of equipping the outlet connection

Pas = Step

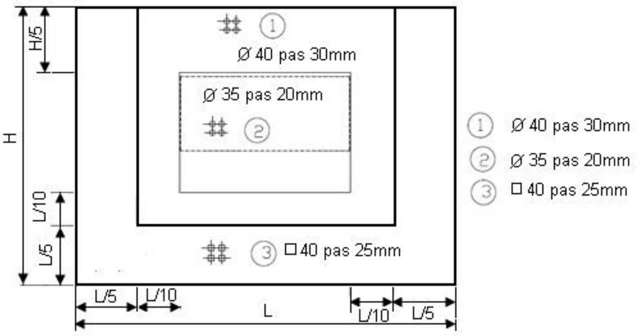


Figure 6. The levelling sieve S1

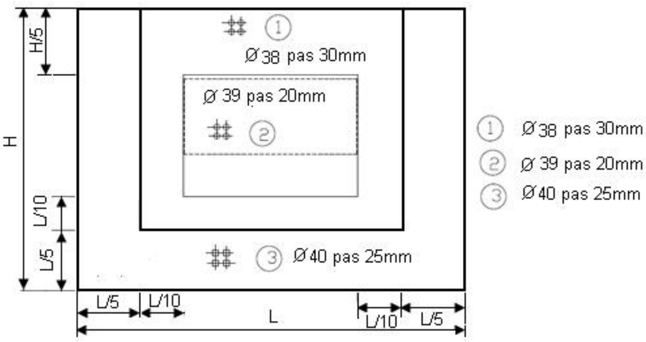


Figure 7. The levelling sieve S2

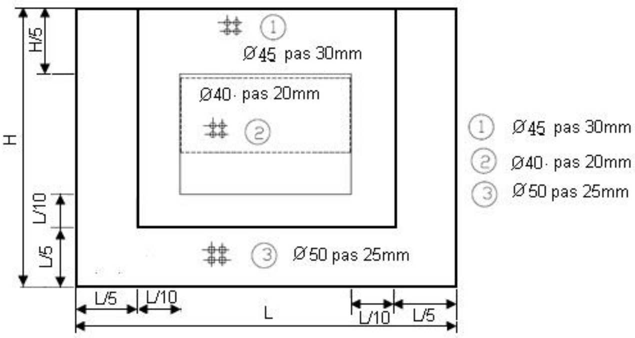


Figure 8. The levelling sieve S3

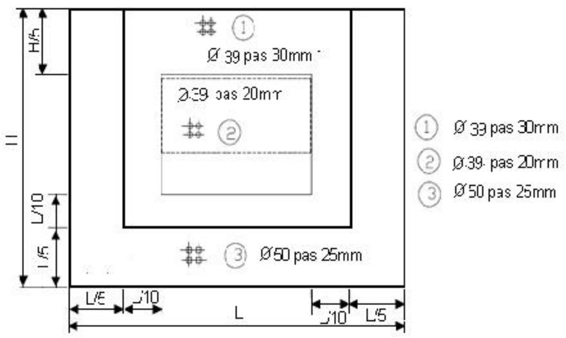


Figure 9. The levelling sieve S4

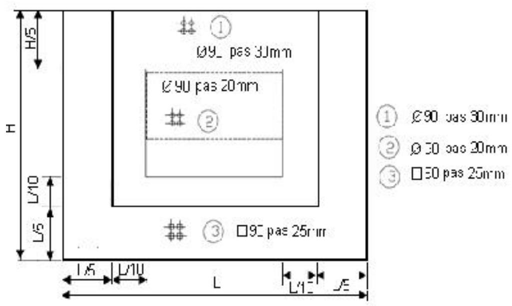


Figure 10. The levelling sieve S5

## 3. Technical solutions suggested to upgrade IDE

This section will present the solutions that should be implemented to reduce the dust emissions from a high energy group in thermal power plants (at the maximum value of 30 mg/$m^3{}_N$).

Layout of the inner plant at a 380mm step according to figure 11

Use of a new type of a settling electrode with the shape shown in figure 11

Use of a new type of an Isodyn BMO type emission electrode

Replacement of the systems supporting the emission and settling system

Replacement of the systems shaking the emission and settling system

Equipping the housing of the electrostatic precipitator with gas flow guiding and control systems

Energising the electrostatic precipitators with high frequency equipment

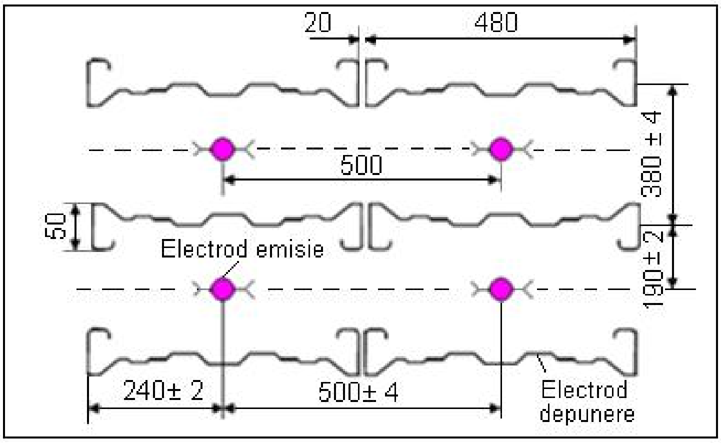


Figure 11. Model of layout of the deposit electrodes against the emission electrodes - variant 3

## 4. Conclusions

The suggested equipping model and technical solutions shown in this paper can provide a database for further researched in the field of electrostatic dust removal and a starting point to size and make some electrical cyclones with a high level of retaining the dust from combustion gases, in compliance with the current and future environmental rules, with the adaptations specific to each technological process and thorough assessment of the technical standards of design.

By the equipping model suggested, the authors estimate a reduction of dust emissions from combustion gases of maximum 30mg/Nm$^3$ at the output from the electrostatic precipitators.

In this case, the symbol of the electrostatic precipitator will be:

43 / 15 / 3 x + 9 / 0.380

where: 43 – the number of passes

15 - active height of the field

3 – the number of fields on an electrostatic precipitator

0.380 – the step between the electrodes or the electrostatic precipitator step.

Compliance with the limit emission values provided by the new Directive 2010/75/EU regarding industrial emissions, which enters into force in 2016, respectively 20mg/ m$^3_N$, will be done by means of the desulphurisation plant which, by spraying the limestone suspension into the combustion gases and washing the gases will provide the reduction of dust emissions from 30 mg/m$^3$N to 20 mg/m$^3_N$. [10].

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