DOCTORAL THESIS
(SUMMARY)
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CONTRIBUTION TO THE PROMOTING TECHNOLOGIES WITH LOW GRADE POLLUTION TO ENERGY PRODUCTION THROUGH BURNING COAL IN A BOILER OF 1035 t / h

The main target of this thesis, was to bring a series of contributions, regarding the solutions that have to be introduced and implanted, for the caring out of some electric dusting installations, with a high degree of holding back the powder from the burning gases, in the high power energetic boilers, from the thermo-electric power stations, which function with an inferior solid fuel, with the purpose of integration in the actual and long-term standards regarding the protection of the environment.

As already known, the prevention and the struggle against polluting the environment, are considered to be the most important problems, Romanian society and humanity in general, are confronted with. Nowadays, it seems that the pollution of the environment gets closer to the "critical border", due to the uncontrolled activity of man, surpassing the defending limits of nature, jeopardizing the existence of life, on Terra.

As it is known the highest degree of the annual polluting emissions evacuated in the atmosphere, is due to the fossil fuels, used as a prime form of energy.

Because of this reason, the consumption of energy must be monitored, in relation with the polluting emissions registered annually, at a worldwide level, with disastrous effects over the surrounding environment like: air, water and soil pollution, the global warming through the greenhouse effect, acid rains, deterioration of the ozone layer, and the weather change (melting of the icebergs, hurricanes, drought, natural fires etc.)

Now and in the near future, in the field of electric and thermal energy production, by using coal as a fuel, the general objective of environmental politics, is the reduction of the impact over the environment, by reducing the quantity of dust emission in the atmosphere, up to the permissive level of international and national standards of the environment.

Romania follows closely the European Union politics, in the field of energy, with the aim of developing a competitive energetic market at a national level, integrated in the internal European market. In this context, the re-technology of electric dusting installations from the Romanian thermo-electric power stations, meant to satisfy the requirement of the EC/80/Ec Direction and the Governmental Decision no. 322/2005, is a main objective, which cannot be postponed.

The studies and the research in the present thesis, are following this line and they regard mostly the solutions that were applied but mostly the ones that have to be introduced and implanted, for the realization of electric dusting installations with a with a high degree of holding back the powder from the burning gases, *according to the actual standards and those of perspective regarding the protection of the environment.*

These dusting performances can be obtained only through a theoretical, analysis of all the fundamental processes which are at the functioning basis of the electric filters (generating the charge bearers, loading the dust particles with electric charge, moving them towards the storage electrode and collecting them), the factors which condition them, optimizing them through experiments, taking into consideration the fact that not all the existing conditions from the inside of the electric filter can be included into mathematical terms and phrases.

Regarding the structure, the thesis is divided into 6 chapters, ending with a selected bibliography and annexes.

The first chapter is dedicated to the actual stage in the dusting installation field which includes: a short history presenting the development of the electric dusting process, the technical progress performed in this field, as well as the types of electric filters, specifying the fields of activity to be applied in. Further on, the present situation in our country, is mentioned, regarding the holding back of the powder resulted from the burning of the inferior fuels with the aid of electric dusting installations, as well as the performances obtained with these installations. It is presented the scheme's position of an electro-filter in the whole, for an energetic group, the total balance of the ash resulted from the fuels burning in the energy high power boilers, devoting a special attention to the particles' granulometry. The gases dynamic parameters were determined through measurements, as well as the content of powder from the burning gases of an energy high power, functioning with an inferior solid fuel (Lignite), at a nominal charge, the results being presented in this thesis in the form of tables and charts.

In the **second chapter**, a bibliography study is presented, regarding the construction and functionality of the electric dusting installations. To understand the complexity of the phenomenon, different problems that appear in the functioning of electric dusting installations, were presented. The efficiency of these installations was analyzed, by defining the notion of efficiency-speed migration, as well as the limitative factors that affect the performances of the electric dusting installations. A model for the efficiency of separation, for a turbulent flow, was presented, in details. The equation of dusting output-efficiency according to the presented model is given by the following equation:

It was distinguished, the fact that the most important effects that influence the collecting of efficiency are: the distribution of gasses in the entrance coupling-inlet, the laying down of the particles on the sediment electrodes, the re-stimulating/re-circulating of the dust laid/set down on the sediment electrodes, the re-stimulating of the dust from the collecting storage bunkers, the gas slinking through un-electrified zones and the high resistivity of the dust that had to be filtered. The main sources of turbulence from the interior of the electric filter were identified and the main means of prevention were distinguished.

The phenomenon corona upside down is extremely noxious for the performances of the electric filter. It appears when a particle migrates towards the collecting surface, but it does not succeed in discharging the electrical charge, provoking this way a gradient of high potential in the dust layer on the surface of the plate, phenomenon that appears in the case of resistive high spread environment. This layer negatively highly charged, interrupts the electric field, which provokes the migration of the ash particles negatively charged to the sediment electrode and rejects the particles with such a charge, which try to migrate towards the collecting surface. The upside down *corona*, in the incipient phase, reduces the tension of appearance of the arc, while the upside down intense *corona* represents a positive ions discharge at the collecting electrode, which tends to neutralize the negative ions of the *corona* electrode. In this last situation, the electric charge of the particles is greatly reduced, the positive or neutral particles being present in a large number, surpassing even the negative ones.

This "upside down corona", phenomenon, affects badly the efficiency of the dusting installations. In the thesis, the solution for removing of the appearance of the "upside down corona", phenomena is presented, through energizing the electric filters with high tension impulses .

Further on, in the thesis, are presented comparatively, the effects obtained through energizing with conventional equipments which function at the net frequency and a new generation of equipments which deliver/furnish energy, using the classic rectifier converter technology, combined with the technology of the feeding source in a commutation regime, having a tension frequency of tens of kHz (between 20 and 30 kHz). A special attention, in this chapter, is given to the principles of equipment choosing and equipment sizing for high tension, as well as to the manner of choosing the dusting fields.

Chapter 4 regarding the fundamental processes that the place inside the electric filters: the generation of the *corona* discharge and the formation of the gas ions, the loading of the particles inside the electric filter, the laying down of the particles on the sediment electrodes, and the evacuation of the collected material. There were identified the main forces which action on the dust particles, inside the electric filters.

Chapter 4 is dedicated also to the experimental studies presented in detail in the thesis.

Considering the national and international tendency, of generalizing the 400 mm step, the target of this study was one of making researches, in order to turn to steps between 300 mm and 400 mm, for certain sediment electrodes and the optimum placing of the emission electrodes in the structure of the frame with emission electrodes, so that the entire space from the active zone of the electric filter to be occupied by an efficient electric field.

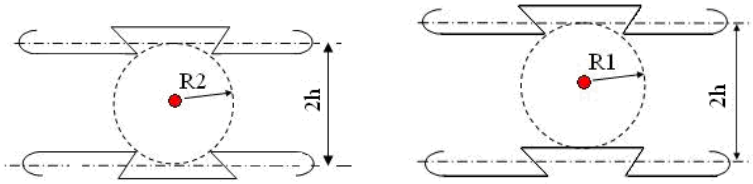
To put into practice the above mentioned objective, it was necessary the determination and fixing of the characteristic, tension-current for all the types of emission electrodes, used in the practice of electrostatic dusting, used by the big companies and specialized institutes from the electric filters field.

This characteristic, called the variation law of *the corona* discharge current, depending on the applied tension (Towched characteristic), is very important for the sizing of the high tension aggregates, which supply the electric filter. *By abducting this characteristic it can be recommended, at a certain distance between the different polarity electrodes and certain sediment electrodes, the type of emission electrodes which should assure an efficient corona discharge.* On the other hand, from the current –tension curves, one can get information regarding the tension of striking *corona* (limit tension) and a field of a certain and economic functioning of the electric filter. These characteristics necessary for measuring the dusting installation are especially difficult to be determined through calculation, from Mathematical relations, simplifying hypothesis that should be introduced leading to severe mistakes. For instance, it is very difficult to point, through simple Mathematical relations, the influence of electrodes angles and edges on the distribution of electric field and current density, and many times the simplifying hypothesis introduced are leading to big errors.

These considerations, together the ones presented in the thesis, have leaded to the necessity of experimental investigations, a current-tension characteristic, for different emission, deposition electrodes configuration, regarding the right point of functioning, from the point of view of electric parameters and high tension ad measurement equipment. As it is known the emission electrode is the electrode around which the corona discharge is produced. In this thesis the emission types of electrodes are presented used in tests that are:

-electrode with edges and continuous active surfaces: round wire electrode (Φ = 1,5 mm; Φ = 2 mm; Φ = 2,5 mm, spiral electrode, electrode type Fe-Stern, lamella type electrode with rectangular section and lamella type electrode with square section.

-electrodes with sharp edges having concentrated emission points: electrode Isodyn B5, Isodyn B5M, electrode Isodyn W22, electrode with spikes, electrode barbed wire type, electrode with drifts.



a. b.

The disposal of the deposition panel before the emission electrodes: a- optimum disposal, b- classic disposal

On the experimental installation presented in the thesis all types of emission electrodes used in the electrostatic undusting technique were tested, in the following variants:

Variant 1 for the disposal of deposition electrodes at step 2h = 300 mm, in conformity with the disposal from figure 1 a).

Variant 2 for the disposal of deposition electrodes at 2h = 380 mm (according to figure1.a).Variant 3 for 2h = 400 mm (in conformity with the disposal from figure 1 b).

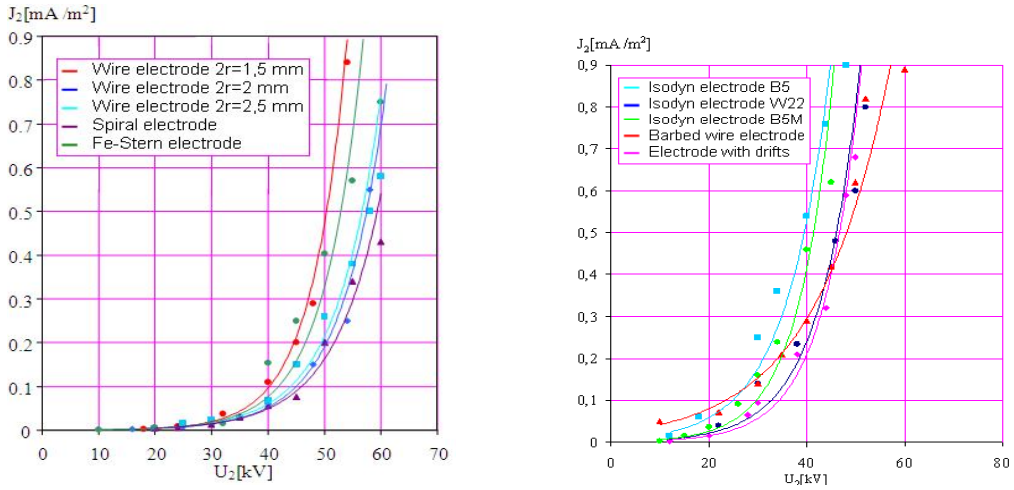
The disposal electrodes (type CSV) used in tests had a disposal surface of 0.5 m^2 and was connected to a mass through a Milliamp meter. The length of the emission electrodes is 0,7 m. In this thesis are presented just the first two variants of testes, as the results obtained in the third variant are identical with the results obtained in variant two.

From the analyzes of the experimental data, one can note that the electrodes with edges present stronger emissions than the electrodes with continuous active surfaces. The emission concentration in different points of the electrode makes that the penetration of the space between the electrodes to appear at applied tension values, between 40kV and 53 kV, while for the electrodes with continuous active surfaces, the penetrating tension is between 49 kV and 57 kV.

In the case of the electrodes with edges the characteristics are more arduous than those of neat electrodes (with continuous active surfaces).

The phenomena *corona* primes at tensions between 6 and 16 kV, while at neat electrodes of striking of the phenomena corona is placed between 22 and 30 kV.

Regarding the electrodes with continuous surfaces, it has to point the fact that the electrode with stellar section (Fe-Stern), although it has sharp edges, gives a smaller current than a circular wire with the diameter of 2 mm. More, the initial tension of discharging, through corona effect, has for the stellar electrode a smaller value, which constitutes a positive important characteristic.



a). b).

Tension current characteristics for the emission electrodes with a continuous active surface (a) and with edges (b) at step 2h = 380 mm

Spiral electrodes have a greater capacity of emission, fact due to un-uniformity of electrical field and his concentration in the curvature zones. In the case of electrodes with edges, the strongest emission has the electrode Isodin B5M and the lowest the electrode Isodyn W22.

In practice, the apparition of inverse emission manifests through a sudden raise of corona current, till the discharge under the shape of arc. This way, the separation of dusts with great resistance is the electrodes with continuous active surfaces, because the electric field has a constant intensity on the length of the whole path of the gas.

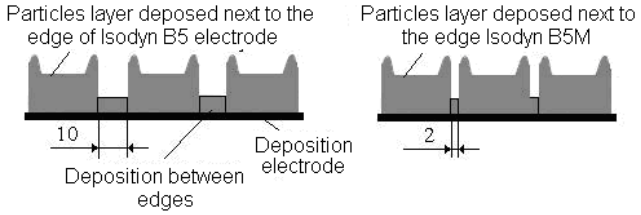
On the installation pilot was analyzed the layer of dust deposed on the deposition electrode, in the situation that the electric filter was equipped with electrodes type Isodyn B5M and the layer of dust deposed on the deposition electrode, in the situation that the electric filter was equipped with electrodes type Isodyn B5. From the quantitative analyze of the two layers one can notice that, through the use of electrodes Isodin B5M where the edges of emission are disposed at a step of 30 mm, the quantity of dust deposed on the deposition electrode is much bigger comparing with the quantity of dust deposed on the deposition electrode, by using the Isodin B5 which has the edges placed at a distance of 50 mm (the dunes of dust are denser in the situation of using the electrodes Isodyn B5M). After this analyze, on can note that the use of the emission electrode type Isodyn B5M in the place of Isodyn B5 leads to the improvement efficiency of separation of the electric filter.

This type of electrode can be used successfully in the energetic industry on the field no. 1 and field no. 2 and in the field of cement, because it realizes big currents, at a relative low tension, and in a field of resistance between $10^4 \div 10^{11}$ Ω·cm.

Use of the new type of emission electrode in the interior equipment structure constitutes o novelty element of equipage solution of electric filters which un dust a great number of gases flows.

a). b).

The deposition of dust on the deposition electrode next to the emission electrode Isodyn B5 (a) and IsodynB5M (b)



The comparison between the layer of dust deposed on the deposition electrode next to the emission electrode Isodyn B5 and next to the electrode Isodyn B 5M.

Tests on stall effectuated showed that there are no big differences between tension-intensity characteristics, determined with air circulation and without air circulation.

The tension interval, between initial appearance of discharging *corona* and the penetration tension, is the working interval of the electric filter which grows together with the grow of the step.

It is remarkable the fact that the emission electrodes were tested at step as well 2h = 400 mm mm with an orientation of the deposition electrodes according to the figures 1.b. from the thesis. The results after the measurements were the same like in the deposition case at step 380 mm, which indicates an equipage solution more favorable of the industrial electric filters (this solution constituting an element of novelty proposed by the author).

The equipage solution of an electric filter, proposed by the author, is: field no. 1 and field no. 2 will be equipped with electrodes Isodyn B5M (new solution of equipage), field no. 3 will be equipped with electrodes type Fe-Stern.

The manner in which the loading process of particles is unfolding, the size of the electric field in the ionization space, influences through the speed of migration the process of electric purification.

For the rigorous dimension of electric filters, the energetic industry, at the step of 380 mm and the step of 400 mm, were necessary works of research, which consisted of tests on pilot electric filter, regarding the establishment of gas-dynamic parameters influence on the migration speed and its determination.

For the effectuation of the tests on the pilot installation ash probes were collected from thermal centrals functioning on lignite and pit.

Probe 1: C.E. Turceni and C.E. Rovinari – Ash resulted from the burning of lignite from the mines of Oltenia basin (calorific power 1600-1700Kcal/Kg)

Probe 2: Ash of mixtures of pits C.E.T. Paroşeni – resulted from burning of mixtures of pit from Valea Jiului (caloric power 2992-3044 Kcal/Kg).

For the admeasurements of the electric undusting installation is absolutely necessary to be known the resistance of the dust that has to be kept.

For the medium tests with lignite ash and pit mixtures, it was determined that the variation curves of electrical resistance with the temperature at point of constant dew water the results being presented in this thesis under the shape of tables and graphics.

For establishing the dependence of the migration speed of gas-dynamic parameters which cannot be included in Mathematical equations to be molded, measurements were made on the pilot installation.

For the lignite ashes having a granulometric distribution, the medium diameter being between 30 ÷ 35 μm, the optimum speed of gases flow through the electric filter is of 1, 2 m/s, and the results of the tests are presented in the thesis .

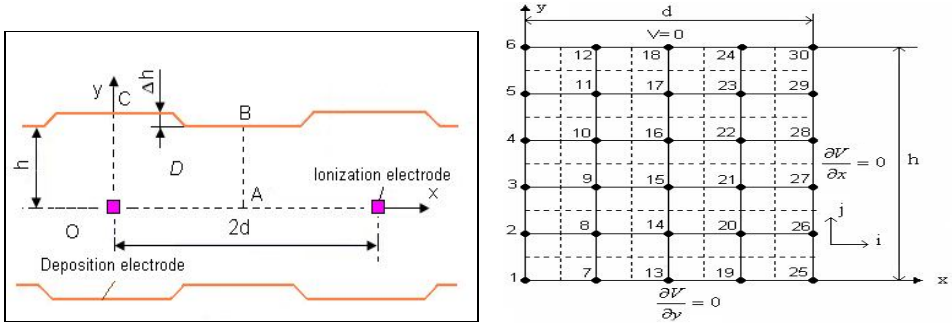
For the dispersed environment of burning gases - mixed pit ash, in which the environment diameter is between 20 ÷ 25 μm, results an optimum speed of gases flow in the electric filter of 1 m/s.

This parameter is very important for the function in good conditions of electric filters because, in the industrial practice many time it is neglected this parameter in the favor of others and it functions at speeds over the limit resulted from this thesis, which leads to an important raise of the content of dust in the gases of burning at the way out the electric filters.

Chapter 4 is dedicated to the analyze of the electric field from the active zone of electric filter.

The physical problem proposed to be studied in this chapter, is that of determined the repartition of the potential and the electric field, which distribution is influenced by the spatial ionic task. The target of this study is that of obtaining precious information regarding the manner of optimum disposal of the emission system and the deposition system and implicitly the realization of a maximum efficiency of undusting, keeping the same dimensions of gauge of the carcass.

The physical real model is represented by an industrial electric filter composed from plates parallel disposed, which forms ways for the burning gases to flow. These plates form the panel with depositation electrodes, being tight up at the ground. In the middle of the distance between the collecting plates it can be found the electrodes of ionization more often supplied with continuous tension of negative polarity. These electrodes present under the form of wire nets of different shapes. Between emission and deposition electrodes it generate an electric field very strong produced through corona emission.



The simplified representation of the real physical model and that of the calculation field D

The electric phenomena are characterized by the non-uniformity of electrostatic field in the space in between the electrodes.

The physical model is characterized by the physical properties in the thesis.

The general study of the electromagnetic field is made with the help of Maxwell equations , equations with partial coefficients derivative of grade 2 cu, completed with material. In this thesis there are presented some simplifying hypothesis imposed by the practical utilization of the equations system and those of dispersed environment from the electric filter.

In the specified conditions the equations get the following form:

$$\begin{cases} \Delta V = -\dfrac{\rho_v}{\varepsilon_0} \\ \vec{E} = -gradV \\ div(\rho \cdot k_i \cdot \vec{E}) = 0 \end{cases}$$

The calculation field chosen D is discredited in a finite no. of points which approximates the operators from derivate of equations through development in series Taylor at a précised chosen order. For this we a discredited uniform net in the D calculation field, having 5 nodes on the direction of axis Ox and 6 nodes on the direction of axis Oy, as the step of the net of discrediting to be constant along the two axis. It is mentioned with Δx on the direction of axis Ox, respectively Δy on the direction of axis Oy. The discrestization of the field is Cartesian and each node is represented through clues (I). The variable values which interfere in the equations system are calculated in each node of the net. For each node of the discretization net it was obtained an equation which expresses the potential in the respective node as is $V_{i,j}$.

The limit conditions imposed by the symmetry from the electric filter for the first two equations in the systems :

For the electrical potential there are two types of conditions:

a). on symmetric axis (OA, OC şi AB) Newmann type

$$\frac{\partial V}{\partial x} = 0 \text{ on OC and AB} \quad \text{and} \quad \frac{\partial V}{\partial y} = 0 \text{ and OA}$$

b). on the surfaces of the corona electrodes and on the surface of the deposition electrodes limit conditions type Dirichlet:

$V=V_0$, $\rho=\rho_0$ - at corona electrode

$V=0$ - at deposition electrode

For getting the solution it was opted for a classic method of numerical calculation, which assures a calculation precisions de sufficient in this case.

For developing the Poisson equation from the system, as a method of discretization was chosen the method of finite differences, through which approximates the equations with partial derivatives with finite differences concentrated on semi intervals. These approximations are introduced in the equations with partial derivates and a system with linear algebraically system is obtained.

The matrix of this equation system is a tri-diagonal matrix and can be solved with the aid of Thomas algorithm o TDMA (Tri-Diagonal- Matrix Algorithm).

This way it was formed the 24 equation system which has to be solved.

To solve the equation Poisson (under his discreet form), it is necessary to know the spatial ionic load density $\rho_{i,j}$ in each node. The electric field intensity calculation necessitates the discretization of the gradient operator in the equation (2) of the system equations. This thing equalizes with establishing a calculation relationship for the first order of the electric potential.

It gets to the following expressions:

$$E_{x_{(i,j)}} = \frac{V_{i-1,j} - V_{i+1,j}}{2 \cdot \Delta x} \qquad E_{y_{(i,j)}} = \frac{V_{i,j-1} - V_{i,j+1}}{2 \cdot \Delta y}$$

For solving with accuracy the systems it is necessary to know the intensity of the electric field density and the special electric load at the initial stage.

The size of the limit load accumulated on the particle is given by professor Pouthenier on which bases was calculated the value of special initial load density taking into consideration the initial electric field, the concentration of particles in the tested and the specific surface of the particles.

The initial load density ρ_0 will be calculated after an interactive process respecting the condition $E = E_0$. It was supposed that the electric field density E_0 in the initial moment is the one given by the applied tension of the emission electrode (in the molded case the applicable tension of the emission electrode is U = 50kV). With these explanations we can pass to the initial electric load density value ρ_0 in the point O.

The solution of the problem is made through the application of the Thomas algorithm for the problems 2D (o line by line) described in the annex. We combine the direct method of the Thomas algorithm in a direction with Gauss-Seidel iterative method in the other direction.

Considering the chosen initial data, this supplies the solution of discretization algebraically equations system.

Taking into consideration the emission rod electrodes of the square section having the side of 4 mm and the ionic load injected equably along the electrode it was determined the influence of the distance between deposition electrodes (2h) and between the emission electrodes on the same frame on the electric sizes which characterizes the functionality of the electric filter.

These determinations were executed on the same supplying tension (U = 55 kV) and it is noticed the electric field density and the volume density of special ionic load are developing together with the decrease of the step between the deposition electrodes.

So, it is necessary that together with the increase of the distance between the deposition electrodes, the high tension equipment to have the possibility of supplying electric potential to the great emission electrodes, the electric filter to energize with an increased tension level, balanced with the increase of the step. Contrary, the dust particles will be charged with a smaller electric load and the electric nature forces will be smaller, so the electric filter undusting performances will worsen.

As we can notice in the above figures, the distribution of the electric field intensity presents high values around the corona electrode and low values in the majority of the interval.

As a follow up of this paper, present the solutions proposed by the author, for an electrical dusting installation equipment, which will lead to a high degree of dust retention produced by and after the burning of the gases and of course the presentation of the author's personal contributions.

As a result of the theoretical studies and of all the experiments done in a life span of 20 years, by the author in the field of the dusting installations, a definite real model of equipping and fitting an electric filter, is presented here.

The description of the optimum solution for the placement of the emission system regarding the sediment system is done, together with the advantages obtained by the passing and staining from the pace of 2h = 4 mm towards a pace of 2h = 380 mm.

Through this solution of redistributing of the interior equipment at a pace of 2h = 380 mm (this representing a personal contribution), results a plus in the depositing or

sediment surface of 1178 mp. The increasing of the sediment surface in the same electrical conditions imposes a superior output in the separation of the dust from the burning gases. These performances can be justified by the introduction in the efficiency model of the obtained data, by this paper.

An other new element in the solution is represented by the rise of the dust collecting efficiency in the electrodes pockets. Through modeling and visualization, a better flow of the gases can be emphasized in the sense that the dust particles are better oriented towards the sediment electrodes.

The tests and the studies regarding the dust layer deposited on the sediment electrode, underlined the fact that in practice the necessity of using of a new type of emission electrode is necessary, which is the Isodyn B5M electrode. It proved to be superior to the Isodyn B5 electrode, which is frequently used by many specialized companies in this field of activity in the country and outside.

This new type of electrode, Isodyn B5M, is proposed by the author to be implemented in the structure 1 and 2 of the electric filter. This implementation has never been done up to the present in the practice of electric dusting. It resulted out of the analysis of the electrical characteristics and out of the analysis of the dust layer settled down on the sediment electrodes.

The introduction of the new type of emission electrode in the structure of the inside equipment in order to optimize the electric field from the active zone of the electric filter, represents an other personal contribution of the author.

Another important contribution is the acomplishment of a numeric calculation, which permitted the calculation of the bidimensional repartition of the electric field from the lectric filter.

Regarding the real evaluation of the electric field from the active zone of the electric filter, it is influenced by elements of distorsion which appear in the functioning of the installation and which can be introduced and comprised in mathematical expressions or phrases that can be processed on the computer.

Using the proposed model, the disposition and placement of the inside equipment can be optimised (correlation between h and d), so that maximum electric parameters with major economic effects can be obtained.

An other important contribution is represented by the study carried out on the pilot installation, having in view the optimum, the most favorable values of the measurements for the flowing speed of the gases through the electric filter for two scattered mediums, frequently met in the practice of electrostatic dusting in Romania, as well as the speed migration depending upon the temperature.

The theoretical results obtained, together with the results obtained in the experimental study, lead to the ideea that the placement of the sediment electrodesat a pace of 2h = 380 mm and of the emission electrode sat a pace of 2d = 300 mm represent the best solution for the placement of the inside equipment of the electric filter so that an efficient electric field is obtained.

The proposed equipment model, the theoretical and the experimental results obtained and presented in the PhD thesis, can represent a data basis for future researches in the field of electrostatic dusting and a starting point for the sizing, dimensioning and acomplishing of some electric dusting insatallations with a high degree of dust retention for the burning gases, according to the actual up to date norms and the perspective ones, concerning the protection of the environment, with the adaptations specific to each technological process and the minute evaluation of the technical norms of planning and designing.