7. ОСТАЛИ ДОКАЗИ КАНДИДАТА ЗОРАНА МАРКОВИЋА
ЗА ИЗБОР У ЗВАЊЕ ВИШИ НАУЧНИ САРАДНИК

**ПОЗИВНО ПИСМО**

April, 2019

dr Zoran Marković
University of Belgrade
Vinča Institute of Nuclear Science,Belgrade

Dear dr Marković ,

We are pleased to invite you to the "19th International Conference on Thermal Science and Engineering of Serbia – SIMTERM 2019", scheduled from 22-27 October 2019 in Sokobanja, Serbia. This Conference will be a joint effort of the University of Niš, Faculty of Mechanical Engineering and the Society of Thermal Engineers of Serbia, with support of the Ministry of education, science and technological development of Serbia, Ministry of Mining and Energy of Serbia and City of Niš.

The representatives of Ministries, University and City government, will inaugurate the Conference. The Director of Energy Agency is expected to address the Opening Ceremony.

The Conference deliberations will be on the following themes:

- **Energy sources and potentials**
- **Technologies and plants**
- **New and renewable energy sources**
- **Energy efficiency in industry, civil engineering, communal systems and traffic**
- **Flow, heat and mass transfer, combustion**
- **Testing of operating plants**
- **Experimental investigation of processes**
- **Mathematical modeling and numerical simulation**
- **Environmental protection**
- **Reliability of processes, equipment, and plants**
- **Automatics and control of processes**
- **Water, air and soil quality management**
- **Energy management (in industry and buildings)**

It is an honor and privilege to invite you to participate in this Conference as **Invited Speaker,** with the theme of your interest. We believe that your contribution is unparalleled and will be of great benefit.

We look forward to a positive confirmation, an honor for us indeed.

Your Faithfully,

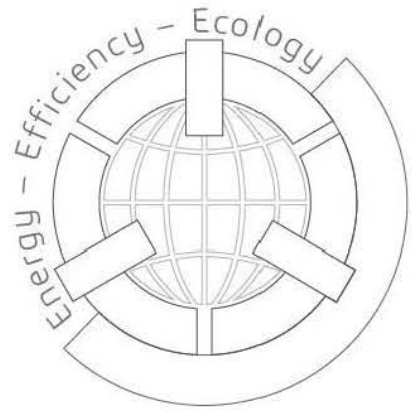
President of Organizing Program committee
***dr Mladen Stojiljković***

President of Organizing committee
***dr Mirjana Laković-Paunović***

***University of Niš, Faculty of Mechanical Engineering, Niš, Serbia***

**УЧЕШЋЕ НА МЕЂУНАРОДНИМ КОНФЕРЕНЦИЈАМА**

**Предавање по позиву са међународног скупа штампано у целини М31-(1)**




# SimTerm 2019

# PROCEEDINGS

19th International Conference on
Thermal Science and Engineering of Serbia

Sokobanja, Serbia, October 22 – 25, 2019

University of Niš, Faculty of Mechanical Engineering in Niš, Department of Thermal Engineering and Society of Thermal Engineers of Serbia

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2019

# Problem of Gas Distribution in Electrostatic Precipitators of Unit A4 in TPP Nikola Tesla

*Zoran Marković[a](CA), Predrag Stefanović,[b] Milić Erić[c], and Dejan Cvetinović[d]*

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**Abstract:** Annual reports of dust emission from unit A4 of the thermal power plant "Nikola Tesla" in Obrenovac for the period 2014-2015 showed that the emission was close to or over the limit value (ELV). Solution for the reconstruction of the electrostatic precipitator (ESP) was requested in order to increase dedusting efficiency of ESP and to reduce the emission to a level below ELV in the expected working conditions of the increased power of unit A4. The flow nonuniformity in the ESP chamber is considered an important influencing parameter on the dedusting efficiency. This paper presents results of the investigation of flue gas flow distribution through the inlet and outlet channels as well as inside of the ESP chambers. The research included measurements of the fluid velocity field in the channels and ESP chamber combined with a series of computational fluid dynamics simulations on several different numerical models of ESP. The experimental work aimed at investigating the nonuniformities of the flow in the ESP chamber. The numerical simulation tools were used to investigate the dependence of velocity distribution in the ESP chamber and pressure losses through the ESP with respect to the geometrical parameters of different proposed concepts of guiding blades. The goal was to select a concept that provides better uniformity of the gas velocity thus higher particle residence time in the ESP chamber and higher dedusting efficiency of the ESP. After ESP reconstruction, continuous measurements conducted over a period of 60 days confirmed particulate emission from unit A4 at a level much lower than ELV.

**Keywords:** electrostatic precipitator, particulate emission, computational fluid dynamics simulations, measurements.

## 1. Introduction

A particulate emission is one of the most serious environmental problems which may cause great health hazards to people, especially for the children and the elderly [1]. Electricity production in the Republic of Serbia is mainly based on the combustion of low-quality lignite from open-pit mines in thermal power plants, with a share of 70% in the power generation, therefore significantly contribute to overall particulate emission in Serbia. For particulate removal from the flue gas, Serbian thermal power plants are equipped with dry plate-type electrostatic precipitators (ESP), with a dust removal efficiency of more than 99,9%. Annual reports on periodic and continuous measurements of dust concentration from unit A4 for the period 2014- 2015 indicated that the outlet concentration was close to or over the emission limit values (ELV) of $50 mgNm^{-3}$. As a degradation of coal quality in the following years is expected, reflected in a higher content of mineral matter in the coal, it will result in a reduction of dust removal efficiency of the ESP and dust emission will exceed ELV. Therefore, the management of the PE EPS Serbia decided that upgrading of electrical equipment, as well as flue gas control equipment of the ESP of unit A4, should be carried out in order to increase dedusting efficiency of ESP and to reduce the emission to a level below ELV under the new and worsened working conditions.

The precipitation process in ESP basically involves convection-diffusion transport process of particles superposed with the effect of particle drift governed by the local strength of the electric field, while drag and Coulomb force acting on the particle are of much greater magnitudes compared to particle gravity. Many

**Саопштење са међународног скупа штампано у целини М33-(9)**


# PROCEEDINGS

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2017

# Results of the Reconstruction and Modernization of theElectrostatic Precipitators at Unit B1of the TPP Kostolac B

***MilićErić[a] (CA), PredragStefanović[a], ZoranMarković[a],VukSpasojević[a], Ivan Lazović[a],DraganŽivić[b], ŽeljkoIlić[b]***

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**Abstract:**China Machinery Engineering Corporation (CMEC) has performed the rehabilitation and modernization of Electrostatic Precipitator System (ESP) of the unit B1 of Thermal Power Plant Kostolac B (TEKO B1) in 2014, according the items of the Main Contract of Phase I of Kostolac-B Package Project. The Performance– Control Test performed at the beginning of the exploitation period of the upgraded ESP proved that, under normal and guarantee working conditions of the boiler and ESP, the concentration of particulate matter in flue gases at the exit of upgraded ESP do not exceed value of 50 mg/Nm$^3$. After the control measurements and the period of ESP further testing and adjustments, the Laboratory for Thermal Engineering and Energy, Institute of Nuclear Sciences Vinča, performed five series of measurements in the frame of Acceptance Test in accordance with ISO 9096, EN 15259 and EN 13284-1 standards. This paper presents results of the investigationof particulate matter concentration, laboratory analysis of the coal samples, working parameters of the unit/upgraded ESP and results of the calculations. The averaged mean particulate concentration at the exit of Upgraded ESP of unit TEKO B1 during Acceptance Test was below guaranteed value.

**Keywords:**emission, electrostatic precipitator, particulate matter, reconstruction.

## 1. Introduction

An Electrostatic Precipitator (ESP) is one of the most efficient device to remove flying ashes from the flue gas in thermalpower plants, before passing the gas into the chimney.Maximumallowable value of dust concentration for the large power units (more than 50MW) is 50 mg/m$^3$[1]and it requires theefficiency of the ESPs better than 99%. Fulfilling this demand simultaneously calls for anincrease of active surface of the electrodes, improvement of flue gas distribution in order to obtain uniform flue gas distribution profile and to decrease the erosive effect of the dust particles, which together increase thevolume and the weight of the ESP, or evenapplication of high frequency high voltage power supply (HF HV)[2] instead of transformer and the dioderectifier (T/R) set.The performance of an ESP isusually determined by Voltage-Current (V-I) characteristics which will reflect upon the ESP collection efficiency and strongly depends on coal calorific value, content of ash in the coal and electrical resistivityof the ash, which depends of alkali and sulfur content in the ash [3] by influence on level of current when development of back corona event take place.Modernization and optimization of existing ESP TEKO B1 was a complex task assisted by the results of complex measurementsand laboratory determinations of different parameters before [4] and after [5] modernization. Although the application of modern numerical simulation methods is increasingly more frequent with the development of computing technologies, the results of Computational Fluid Dynamic (CFD) numerical simulationof the gas [6] or two-phase flow [7]in the ESP, or CFD modeling of diffusional flux of gas ions[8] and behavior ofcharged particles in turbulent gas flow in ESP [9] pointed up that numerical simulation of the fully coupled three coexisting fields of flue gas flow, ash particle dynamics and electrostatics in the ESP chamber is still very demanding task and how important a highly detailed geometry model is for a strong simulation and reliable results. The results of the numerical simulation supported by the results of the real scale measurements of the real velocity profile at the inlet boundary [10]was found to predict better the velocity distribution inside the ESP suggesting that an experimentally measured velocity profile could be used as velocity inlet boundary condition for an accurate numerical simulation of the ESP. The approach based on finite difference method has been utilized for the simulation of V-I characteristics of


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2017

# Results of the Temperature Variation in Experimental Researchof the Kolubara Lignite Drying Process in Packed Bed

***Milić Erić (CA), Rastko Jovanović, Zoran Marković, Nikola Živković, Predrag Škobalj***

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**Abstract:**Removal of moisture from low-rank coals is deemed an important quality upgrading method. Experimental research of convective drying of the Kolubara lignite was conducted. Drying process was investigated under the packed bed conditions. Experimental investigations of drying process in packed bed were performed at three different air temperatures, measured in the front of sample, for three different coal particle sizes, and for three different coal sample masses. The obtained experimental results and influence of the above mentioned parameters values variation showed that sample drying rate increased, while sample drying time decreased with temperature increase.

**Keywords:** convective drying, lignite, moisture, packed bed

## 1. Introduction

Kolubara and Kostolac open-pit mines lignite coal will continue to be the main energy source used in Serbian power plants, mainly due to the fact that it is the most abundant and cheapest fossil fuel available.Kolubara lignite is the mostly used coal in the Republic of Serbia. It belongs to low quality coals with moisture content in the range of 45 to 52%.The presence of moisture in coal reduces coal friability, negatively affecting the quality of grinding, as well as pneumatic transport of pulverized coal. Reduced moisture level in coal results in increased power plant efficiency, reduced ash disposal requirements and reduced pollutant emissions [1].

Nowadays there are several ways to reduce moisture content of low-rank coals. The methods used may be divided into two main groups: conventional evaporative drying (direct or indirect dryers, packed or fluid bed dryers, rotary kiln, etc.) and non-evaporative dewatering processes (mechanical thermal expression, hydro-thermal dewatering, etc.).

It is well known that conventional evaporative convective drying involves complex transport phenomena consisting of three consecutive processes. The first one is moisture (in liquid phase) movement in solids, occurring from the wet interior towards the gas-solid interface (internal pore, particle surface, etc.). This process is slower in larger solids and/or materials with low moisture content. The second one is evaporation facilitated by heat (energy) supplied either externally or taken from the solids and used to transform liquid into vapor. The last one is vapor movement to the surrounding gas by diffusion and convection. The slowest of the processes determines the overall drying rate. Prediction of falling-rate drying kinetics by theory alone is very difficult. Thus, accurate small-scale experiments are required instead. It is possible to estimate drying rates under different conditions by applying concepts such as the "characteristic drying curve" ([2-3], and others) or the "drying coefficient" ([4-5] etc.).

In the Vinca Institute of Nuclear Sciences, Laboratory for Thermal Engineering and Energy, a number of experiments were performed in the field of convective drying. The first step was drying in the packed bed.


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# Evaluation of Kostolac Lignite Carbon Emission Characteristics

*Vuk Spasojević[a] (CA), Predrag Stefanović[a], Nikola Živković[a], Ana Marinković-Radojević[a], Milić Erić[a] and Zoran Marković[a]*

[a] *Laboratory for thermal Engineering and energy, Vinča Institute of Nuclear Sciences, University of Belgrade*

**Abstract:** Present scientific investigations provide clear evidence that human activities have caused the significant concentration rise of greenhouse gases over the past 200 years. Climate shift changes have negative effect on human health, agriculture, weather and overall effect on global economy which results in serious environmental concearns derived from the need to reduce greenhouse gases emissions from industrial sector. Carbon dioxide as main contributor to overall greenhouse gases effect and its emissions from industrial waste gases have become a major target for reduction, especially flue gases from coal power plant stations as main emitters of carbon dioxide. Before any implementation of systems for reduction of carbon dioxide emissions, thorough and comprehensive characterization of local fossil fuels must be performed on national level which is also recomendation by guidelines of Intergovermental Panel on Climate Change. This paper provides modest contribution toward these efforts. Laboratory inestigation was performed on 20 samples of low-calorific lignite recovered from the Kostolac open-pit mine. The samples of coal were carefully selected in order to cover the broad spectrum of the quality of the raw lignite supplied to the Serbian thermal power plants. Main task of this paper was to investigate correlations regarding parameters which are of great concearn such as content of moisture, content of ash, content of combustible matter, upper and lower heating values and content of total carbon and hydrogen. Emission factor for Kostolac lignite coal and dependances on investigated parameters are presented within this paper. Received results show that linear dependencies of carbon emission factor with investigated parameters can be used with high level of confidence, thus providing reliable tool for prediction and control of carbon dioxide emissions originating from combustion process in thermal power plants.

**Key words:** greenhouse gases inventory, Kostolac lignite, carbon emission factor, fuel characterization, laboratory analysis

## 1. Introduction

Recent reports of the Intergovermental Panel of Climate change (IPCC) [1] predicts an increase of average global temperature ranging from 1.1 to 6.4 °C by the end of 21th century. Such high increase of temperature will cause irreversible negative impact on agriculture, food production, water supply, diversity of ecosystems but also more importantly on economic development and global stability. The Republic of Serbia as non-Annex I member of Kyoto Protocol[2] is currently in no obligation to reduce emissions of greenhouse gases. Nevertheless, as a candidate for the EU membership Republic of Serba has commited to the international co-operation in the field of climate research. The European Union member states have realised a series of mandatory documents, all aimed at reduction of greenhouse gases such as implementation of the Directive 2003/87/EC but also the implementation of European emission trading schema (ETS). Taking into account current level of industry development and current level of GHG emissions, it is becoming clear that Serbia will have to significantly improve its capacity for full implementation of energy-climate packages[3-6]. In past two years, first steps have been performed by the Ministry of agriculture and environmental protection. The ministry have categorized over 127 main industrial emitters of carbon dioxide from field of energy, heat production, cement, petro-chemical and steel industry sectors backed-up by concomitant legislation acts. All these subjects are in obligation to perform monitoring of carbon dioxide emissions starting from 2017. This is obligatory especially in energy sector since over 40% of overall carbon dioxide emissions originate from this sector[7]. Current legislation regarding carbon dioxide emission states that all companies which in their production process use equipment with installed thermal energy output over 20MW will be in obligation to monitor and report overall carbon dioxide emissions on annual bases.

Taking into account the composition of energy sector, over 70% of total energy generation and over 50% of primary energy consumption comes from combustion of low-calorific coal-pit mine lignite which is the main

# INTERNATIONAL CONFERENCE POWER PLANTS 2018

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In the attempt to disseminate the positive practice and results of technological development concerning power generation problems, Society of Thermal Engineers of Serbia, following successful biannual International events POWER PLANTS since 2004, is organizing International Conference POWER PLANTS 2018, in cooperation with the Electric Power Industry of Serbia (EPS), under the auspices of the Ministry of Energy, Development and Environmental Protection, Ministry of Natural Resources, Mining and Spatial Planning, Ministry of Education, Science and Technology of the Republic of Serbia. The Conference POWER PLANTS 2018 is foreseen to gather energy policy makers, company managers, researchers, technical experts, environmental engineers and the other professionals actively involved in the strategic, economic, social and environmental aspects of the research, development and operation of Power Industry, mostly from the member countries signatories of the TREATY establishing ENERGY COMMUNITY of the SOUTH EASTERN EUROPE (ECSEE) and from other countries, concerned with topics and implementation of the ECSEE TREATY.

# Topics

1. Energy resources and sustainable development (integrated energy policy concerning the sustainable development; characteristics of available energy resources used for power generation by thermal /hydro/wind and other Power Plants in the following period; planning, effective consumption, perspectives of fossil fuels and renewable energy sources exploitation for Power Generation);
2. Liberalization of electricity market, impact on supply security, energy efficiency and effective operation of Power Plants (development and operation of the deregulated energy market; energy efficiency of processes and equipments used for power generation by thermal /hydro/wind and other Power Plants; research and modeling of processes in steam boilers, turbines and other equipment of thermal /hydro/wind and other Power Plants; combined production of heat and power, reliability and availability of facilities and Power Plants; effective utilization and reduction of fuel consumption; optimization of processes, equipment, facilities and whole Power Plants; economic handling of processes; rationalizations and innovations of the production processes; introduction of system of quality);
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# Lisf of Conference Papers

List of papers with abstracts, accepted for presentation at the International Conference Power Plants 2018

E2018-001 PDF

## RAZVOJ TRŽIŠTA ELEKTRIČNE ENERGIJE U SRBIJI

Aca Marković, član saveta (Agencija za energetiku Republike Srbije)

Pages 1 - 23

Session Energy resources and sustainable development

E2018-002 PDF

## CONSEQUENCES OF THE ADOPTION OF GUIDELINES ON STATE AID FOR ENVIRONMENTAL PROTECTION AND ENERGY 2014-2020 BY THE EUROPEAN PARLIAMENT ON THE SERBIAN RENEWABLE ENERGY SECTOR

Miloš J. Banjac (University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, Belgrade, Serbia), Mirjana S. Laković (Faculty of Mechanical Engineering, University of Nis, Nis, Serbia)

Pages 24 - 34

Session Liberalization of electricity market, impact on supply security, energy efficiency and effective operation of Power Plants

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## PARADIGM SHIFTS IN POWER GENERATION UNDER PRESSURE OF ENERGY TRANSITION

Miodrag Mesarović (Serbian WEC Member Committee, Energoprojekt Entel)

Pages 35 - 49

Session Energy resources and sustainable development

E2018-088 PDF

## REDUCTION OF PARTICULATE EMISSIONS BY MODERNIZATION OF ELECTROSTATIC PRECIPITATOR AT THERMAL POWER PLANT UGLJEVIK

Dragan Miljanović (Thermal Power Plant UGLJEVIK, Bosnia and Herzegovina, Republika Srpska), Predrag Stefanović, Milić Erić, Zoran Marković (Belgrade University, VINCA Institute of Nuclear Sciences, Laboratory for Thermal Engineering), Goran Rikić (Thermal Power Plant UGLJEVIK, Bosnia and Herzegovina, Republika Srpska)

Pages 963 - 971
Session Thermal / hydro / wind and other Power Plants exploitation problems

E2018-089 PDF

## JEDAN OD NAČINA PROVERE UTICAJA TERMOELEKTRANE NA STEPEN ZAGAĐENOSTI PM10 ČESTICAMA U PLJEVLJIMA

Vladan ivanović, Esad Tombarević (Mašinski fakultet Podgorica, Crna Gora)

Pages 972 - 980
Session Environmental and climate aspects of power generation by thermal / hydro / wind and other Power Plants

E2018-090 PDF

## APPLICATION OF UNMANNED AERIAL VEHICLES (UAVS – DRONES) AT POWER PLANTS

Radojica Graovac, Dragomir Marković (Energoprojekt Entel plc, Bulevar Mihaila Pupina 12, 11070 Beograd Serbia)

Pages 981 - 990
Session Thermal / hydro / wind and other Power Plants exploitation problems

# REDUCTION OF PARTICULATE EMISSIONS BY MODERNIZATION OF ELECTROSTATIC PRECIPITATOR OF THERMAL POWER PLANT UGLJEVIK

**Dragan Miljanović[1], Predrag Stefanović[2], Milić Erić[2], Zoran Marković[2], Goran Rikić[1]**

***Thermal Power Plant UGLJEVIK, Bosnia and Herzegovina, Republic of Srpska[1]***

***University of Belgrade, Institute of Nuclear Sciences Vinča, Belgrade, RS, milic@vinca.rs[2]***

**Abstract:** Boiler and Electrostatic precipitator system (ESP) of the unit 300 MWe of Thermal Power Plant Ugljevik started operation in 1985 and so far it has been operating over 150.000 hours. In the previous period, no significant reconstruction of ESP was carried out except replacement of emission electrodes. As a consequence, failure of certain electrical components as well as mechanical damage on the internal elements of the ESP frequently occurred while particulate matter concentration at the exit of ESP was over 1000 mg/Nm$^3$. In order to reduce particulate matter emission according to EU Directive 2001/80 and to improve availability of the facility, management of Thermal Power Plant Ugljevik decided to proceed with the reconstruction or replacement of the existing ESP with modern high-efficiency and reliably ESP. Compared to guaranteed dedusting efficiency of 99,693% and emission <150 mg/Nm$^3$ for the original ESP design, the contractual requirements for the new ESP are set to be better than 99,935%, allowing dust concentration downstream ESP to be less than 50 mg/Nm$^3$.

During the 2017 a new ESP was built by Consortium ZVVZ-Enven Engineering a.s/ZK-Thermchem s.r.o. from Czech Republik. The original ESP design, consisted of two separate ESP chambers, each with active volume of 14m x 14.6 m x 14.6 m and containing 4 separated fields in 4 dedusting zones, have been changed by new ESP to one integral chamber construction of 16,5 m x 34,5 m x 17,92 m active volume, with 15 electrical fields in 4 dedusting zones.

This paper presents the technical characteristics of old and new ESP design, results of Guarantee Tests A measurements, laboratory analysis of the coal, fly and bottom ash samples, comparatively to the guaranteed ones, working parameters of the unit and upgraded ESP during the measurements as well as results of the calculations. Based on results of measurements and calculation, it was proved that under normal and guarantee working conditions of the boiler and ESP, the concentration of particulate matter in flue gases at the exit of upgraded ESP do not exceed value of 50 mg/Nm$^3$, while ESP achieved dedusting efficiency just below guaranteed value of 99,935%.

**Keywords: emission, electrostatic precipitator, particulate matter, reconstruction.**

## 1. Introduction

Thermal power plant (TPP) ‘’Ugljevik’’ started with production in 1985. With installed power of 300 MW and projected annual production of 1,601 GWh, unit I of TPP "Ugljevik" was designed to work 200000 hours. Because of the war in Bosnia and Herzegovina the TPP was out of operation in the period April 1992 – November 1995. From the beginning of production till the end of 2006,

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## JEDAN OD NAČINA PROVERE UTICAJA TERMOELEKTRANE NA STEPEN ZAGAĐENOSTI PM10 ČESTICAMA U PLJEVLJIMA

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Nikola Živković, Predrag Stefanović (University of Belgrade, Institute for Nuclear Sciences "Vinča", Belgrade, Serbia), Emila Živković (University of Belgrade, Faculty for Technology and Metallurgy, Belgrade, Serbia), Milić Erić, Zoran Marković (University of Belgrade, Institute for Nuclear Sciences "Vinča", Belgrade, Serbia)
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# COMPARISON OF THE CLASSICAL LIME/LIMESTONE AND WET REGENERATIVE ABSORPTION PROCESS BASED ON PHYSICAL/CHEMICAL ABSORPTION IN ORGANIC SOLVENTS FOR FLUE GAS DESULPHURISATION

**Nikola Živković[*,1], Predrag Stefanović[1], Emila Živković[2], Milić Erić[1] and Zoran Marković[1]**

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**Abstract:** The multiple harmful effect of emitted Sulfur-dioxide ($SO_2$) in the atmosphere is well known. It is manifested in the form of respiratory problems in humans, and is also a source of acid rain that is harmful to the biological world and construction objects. Energy and industrial activities have the major share in $SO_2$ emissions, with the dominant role of combustion of fossil fuels (coal and oil) in thermal power and industrial plants. The first steps towards the removal of $SO_2$ from flue gases date more than a century ago, when a classic lime/limestone process is patented, which is still the most world widespread process. Since the long time significanace of flue gas desulphurisation (FGD), the aforementioned lime/limestone process with certain modifications has a significant representation.

However, in recent times, a new group of regenerative absorption processes based on physical/chemical absorption of $SO_2$ in organic solvents are present with the increasing rate. These processes are gaining importance because of their main advantage, avoiding the accumulation of large quantities of solid by-products, such as gypsum in lime/limestone process.

The paper presents a comparison of the two groups of procedures. Comparison is carried out according to several aspects: their general representation in operational use, applicability for certain types of plants (thermal, industrial and other), in terms of capital and annular costs, process efficiency, flexibility of process parameters, market usability of the final product from the process and environmental aspects.

**Key words:** Sulfur-dioxide, Flue gas desulphurisation, Regenerative absorption, Lime/Limestone process.

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# A critical review of the research of the low-rank coal, biomass, and coal-biomass blends devolatilization: experimental research and mathematical modeling

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## ABSTRACT

The Western Balkans produce about 60% of electricity burning low-quality coals, which causes high GHG emissions. Co-firing of coal and biomass is among the most attractive approaches for decreasing these emissions. The present work aims to offer an in-depth critical review of the current status of low-quality coal, biomass, and coal/biomass devolatilization research to serve as a good base for future research in the field. Paper provides a thorough analysis of experimental methods and critical analysis of achieved experimental results, together with the basic set of computational models, models' accuracy, and applicability for coal/biomass devolatilization modeling. Biomass compared to coal devolatilization occurs at lower temperatures and produces more light gases and tar. Interactions between coal and biomass during coal/biomass blends devolatilization is not completely understood. Complex network devolatilization models offer the possibility to derive input parameters for simpler kinetic devolatilization models that are suitable for implementation in CFD codes.

KEYWORDS
Coal, Biomass, Devolatilization, Co-fuel, Volatiles, Tar, Mathematical Modelling.

## INTRODUCTION

Primary energy consumption continues to increase, with 2.2% in 2017, which is rise from 1.2% in 2016 and the highest growth since 2013. Global coal production increased by 3.2%, at the highest rate from 2011. Coal still has a dominant position in global power generation, with a share of 44%, in 2017 alone coal generation increased by 3%, which is the first time in four years [1]. However, coal reserves are being spent rapidly. It is expected that, at the current consumption rate, proven coal reserves will last for another 150 years [2]. Another alarming issue is $CO_2$ emitted from power plants firing coal. $CO_2$ is the main source of GHG emissions with a share of 73%. About 40% of the total $CO_2$ emitted to the atmosphere comes from coal combustion [3]. Worldwide concerns of climate change and global warming intensified the need for alternate, carbon neutral, energy resources.

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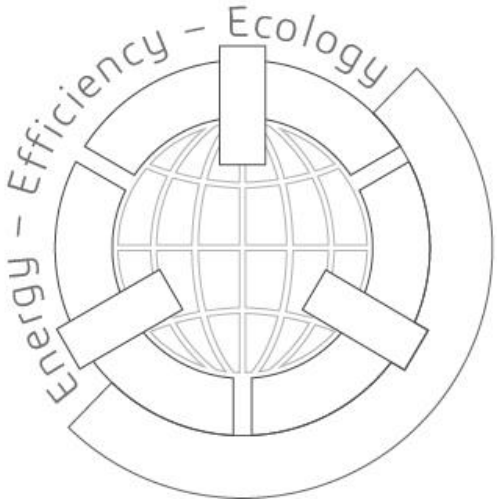


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# Development of Pre-drying Procedures of Low-rank Coals to Increase Efficiency of Coal Fired Power Plant

***Milić D. Erić[a] (CA), Zoran J. Marković[b], Predrag Stefanović[c], Rastko D. Jovanović[d], Nikola Živković[e]***

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**Abstract:** Carbon dioxide participates in the total greenhouse gasses emissions by around 75%. Majority of carbon dioxide emitted to the atmosphere comes from power plants burning coal. It is expected that coal will remain the dominant energy source due to its large reserves, world-wide availability, and stable and relatively low price in the international market. Thus, one of the biggest challenges is development of low carbon dioxide technologies for coal utilization. Clean coal technologies are group of measures aiming to reduce carbon dioxide emissions by increasing energy efficiency of coal power plants. Special attention is given to low quality coals with high moisture content, among which lignite coals have dominate position. One of the most promising technologies for increasing the rank from lignite coals is coal pre-drying using thermal energy from the power plant. This work aims to present the major advances in development and state-of-art utilization of coal pre-drying technology. Examples of the pre-drying technology advancements are given for all countries in which this technology is under major development, including: US, EU, Japan, Canada, and Australia. Special attention is given to the experimental and numerical results of investigation of coal pre-drying process of Serbian Kolubara lignite coals.

**Keywords: Energy efficiency, Fluidized bed, Low-rank coals, Pre-drying procedures**

## 1. Introduction

Low-rank high-moisture coals around the world are vast constitute and a major energy source for the future as reserves of such. High moisture content entails high transportation costs, potential safety hazards in transportation and storage. In the combustion of such coals the thermal efficiency is reduced and increased $CO_2$ emissions that contribute to the greenhouse effect. This is because in conventional coal-fired power plants a part of the fuel's heat is consumed in the boiler during combustion and mill drying to evaporate coal moisture. The coal moisture leaves the power plant as steam together with the flue gas, so that this heat cannot be used in the plant process and is lost. Also, the presence of moisture in coal reduces coal friability, negatively affecting the quality of grinding, as well as pneumatic transport of pulverized coal.

US low-rank coals have typical values of moisture content range in the range 15-30% for sub-bituminous coal and 25-40% for lignite [1]. The ash content of American lignite varies depending on the moisture content, *e.g.* ash content of lignite (North Dakota) with 40% moisture is 12% [1]. In the work of Levi and others [2] it was stated that the coal-drying experiments in the fluidized bed were carried out with coals of the following moisture content: about 37% for sub-bituminous coal (Power River Basin) and 54-58% for lignite (North Dakota).

The moisture content of German low-quality coal exceeds 50%, while the ash content is 5-15%, depending on the moisture content [3]. Open pits of lignites, *i.e.* brown coals are: Rhineland, Lusatian, Central German and Helmstedt.


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# Review of Particulate Matter Emission Reduction at the TPP Nikola Tesla A after Reconstruction and Modernization all Six Units

*Milić Erić[a], Zoran Marković[b], Predrag Stefanović[c], Aleksandar Milićević[d] and Ivan Lazović[e]*

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**Abstract:** Public Enterprise "Electric Power Industry of Serbia" has harmonized their operation in accordance with regulations with EU requirements related to the limitation of the emission of certain pollutants into the air from large combustion plants until 2016. Among other measures, electrostatic precipitators reconstructions of the intended units were completed until 2015. Reduction of the outlet concentration of particulate matter was mainly achieved by increasing of height and number of collecting electrodes of electrostatic precipitators. Additional measures were adding one additional field of electrodes and enhancement of current and voltage characteristics of electrostatic precipitator sections. Suppliers of electrostatic precipitators guaranteed the outlet concentration of particulate matter ≤ 50 mg/m$^3$ and it was also confirmed by the guarantee investigations in accordance with standard ISO 9096. Thermal Power plant Nikola Tesla A, as the largest power plant in Serbia, consist of six units which electrostatic precipitators were reconstructed and modernized. This paper present results of guarantee, periodic-intermittent and automatic measuring system (AMS) tests of particulate matter concentration after the reconstruction and several years later and indicate problems in power plant operation.

**Keywords:** particulate matter, emission, electrostatic precipitator, reconstruction, modernization.

## 1. Introduction

In order to preserve the environment, thermal power plants, as one of the biggest polluters, invest significant funds in the construction of new facilities to reduce the emission of dust, sulfur and nitrogen oxides.

The long-term investigations of the particulate matter emission by authorized and accredited institutions, before the reconstruction of electrostatic precipitators, determined that the highest level of emissions of 2000 mg/Nm$^3$ for units A1 and A2, while for units A3 to A6, the emission were in the range from 80 to 400 mg/Nm$^3$. The oldest units A1 and A2, with the lowest degree of dedusting before reconstruction, had in the total particulate matter emission share of 66% in TPP Nikola Tesla A, and producing only 15% of the TPP total electricity production [1].

The Electric Power Industry of Serbia has adopted a long-term modernization program to reduce environmental pollution. In order to reduce particulate matter concentration to the level of below 50 mg/Nm³, the reconstructions and modernizations of the existing electrostatic precipitators were carried out between 2004-2014 at all six units of the TPP "Nikola Tesla".

Electrostatic precipitators of the thermal power plant Nikola Tesla were reconstructed and modernized by a consortium of companies from Poland RAFAKO S.A., ELWO S.A. and companies from Serbia Energoprojekt-Oprema and Energoprojekt-Entel [2-7].

The aim of this paper is to analyze all six units operations after reconstruction and modernization, in terms of the particulate matter emission into the air and to indicate the problems that need to be fixed.


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# Homogeneity Assessment of the Velocity Distribution in the Chamber of Electrostatic Precipitator of Unit A1 in TPP Nikola Tesla

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**Abstract:** To obtain the optimum dedusting efficiency of an electrostatic precipitator, the flue gas should be uniformly distributed over the precipitator's vertical cross-section. This paper presents the results of the homogeneity assessment of the velocity distribution in vertical cross-sections of the electrostatic precipitator of unit A1 in the thermal power plant Nikola Tesla in Obrenovac. Velocity measurements were conducted in the front of the first and after the last electrical field of the precipitator. The coefficient of variation, momentum correction coefficient, energy correction coefficient, and linear and quadratic norm-based metrics of flow uniformity were calculated based on the values of velocities measured in the vertical cross-sections of interest and compared. In addition, a percent of the total area of the cross-section that exhibits velocities less than 85%, greater than 115%·and greater than 140% of the average velocity in the cross-section were calculated. The analysis indicated unfavorable velocity distribution resulting in poor homogeneity of the flow field through the chamber of the precipitator regarding all calculated parameters, therefore in a decrease in the precipitator's efficiency and an increase in particulate matter emission.

**Keywords:** electrostatic precipitator, velocity measurements, flow homogeneity assessment

## 1. Introduction

For the removal of particulate matter (PM) from the flue gas, the low-rank lignite-fired unit A1 of the thermal power plant Nikola Tesla in Obrenovac is equipped with two-chamber dry plate-type electrostatic precipitators (ESP). According to the results of periodic measurements carried out in 2016 and 2018, i.e. continuous measurements in 2017, the PM emission from unit A1 exceeded the emission limit value (ELV) of 50 mg/Nm3. The major overhaul of the unit is planned for 2022/2023 and it is expected that the unit will be at a longer standstill (12 months). During that overhaul, the primary measures for the nitrogen oxide emission reduction from unit A1 are planned to be introduced. At the same time, the appropriate refurbishment of the ESP could be done in order to increase their efficiency. For this purpose, during the overhaul of unit A1 in 2020, certain reconstructions were made only on ductwork of the left chamber of the ESP. An comprehensive analysis was necessary in order to check the effects of the implemented reconstructions and to determine the limitations for achieving the required high efficiency of the ESP as well as to propose the measures that could be implemented during the overhaul in order to improve their efficiency and to reduce PM emission. It was demanded to determine the velocity distribution in the chambers of ESP of unit A1 and to assess the uniformity of the flow through the ESP as one of the main influencing factors on the ESP efficiency [1]. This paper presents the results of the velocity measurements in the chamber of the ESP of unit A1 conducted on 2.11.2020. The goal was to assess the homogeneity of the velocity distribution in the vertical cross-sections of the ESP chamber. Measurement of the velocity distribution in the ESP chamber is a demanding task. In such a test, the gas velocity is measured over the entire cross-section of the ESP. This test is conducted''offline'', with the unit and ESP out of operation and a flue gas fan (FGF) in operation, generating the necessary airflow through the ESP chamber and ductwork for the measurement. Particle Image Velocimetry (PIV) [2,3] and Laser Doppler Velocimetry (LDV) [4] are primarily applicable in laboratory conditions for the cases of small measuring domains and low gas velocities. For on-site measurements of the air velocity distribution in the large vertical

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## 11.15 NUMERICAL SIMULATION OF GAS FLOW THROUGH PERFORATED PLATES INCLINED TO THE MAIN FLOW

**Z. Marković (1), R. Jovanović (1), M. Erić (1) and I. Lazović (1)**
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**Background and Aims**: The new, restrictive best available technology requirements posed by EU Decision 2017/1442 clearly define the need to take measures to improve existing flue gas treatment installations. The process of removing particulate matter from the flue gas generated in coal-fired boilers of thermal power plants, by electrostatic precipitators (ESP), or by using filter bags, is significantly affected by uniformity of flue gas flow through the dedusting zone (Bäck, 2017). In order to improve the flue gas flow distribution through the ESP, perforated plates are used to establish as uniform as possible flow over the cross-section of the wide-angle diffuser exit. A computational Fluid Dynamics (CFD) method with source terms in the momentum equation defined according to the porous medium model is widely used for numerical simulation of flow through the perforated plate. Permeability and internal resistance per unit thickness of the perforated plate, considered as homogenous porous material, are usually calculated based on results of experiments. With these parameters defined for the streamwise direction, the porous medium model is useful in cases where the incoming velocity is almost perpendicular to the perforated plate. But this model loses prediction accuracy for the velocity distribution behind the perforated plate, as well as for the pressure drop through the plate, when the direction of the incoming fluid velocity deviates from the perpendicular (Guo et al, 2013), which is always the case for the wide-angle diffuser of one ESP. The aim of the present work is to add to the existing porous medium model when used in modelling a perforated plate by introducing a new approach for determination of the momentum losses regarding both streamwise and transverse directions for wide range of yaw and pitch angles of incoming flow.

**Methods**: The permeabilities and loss coefficients are calculated based on the results of CFD numerical simulations for different angles of incoming flow. The numerical calculations were performed by using ANSYS CFX finite-volume-based software to resolve the RANS equation for the solution domain. The key simulation properties are defined to be parameters representing one design point. The output parameters for all design points are solved by using Design of Experiments (DOE) technique. The permeability and loss coefficient algebraic dependencies on the angle are defined and implemented in the porous medium model. The proposed procedure is applied on the case of a plate of thickness 5mm, with face porosity 0.3 formed of circular openings in quadrilateral pitch.

**Key results of the study**: The results obtained for several pitch and yaw angles by applying the proposed approach are compared to the results of the full-scale CFD numerical simulations as well as to the CFD simulations relying on the standard porous medium model with permeability and loss coefficient defined in the direction orthogonal to the perforated plate An acceptable correlation was obtained and directions for future work highlighted (influence of the wall and other structural elements).

**Conclusions**: The study shows that the proposed approach is suited to predict pressure drop and velocity distribution behind the perforated plate for a wide range of yaw and pitch angles of incoming flow. More reliable prediction of the flow distribution in the exit of the wide-angle diffuser allows optimization of the flow through the ESP, and therefore a decrease in particulate matter emission.

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**Keywords:** perforated plate, porous medium model, CFD, DOE.

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ЕЛЕКТРОТЕХНИКУ И ОПШТУ ТЕХНИКУ
990 број 2022/10939-МП-2022/0043
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Завод за интелектуалну својину у Београду, Кнегиње Љубице 5, и то овлашћено службено лице Мирјана Јелић, на основу члана 36. Закона о министарствима („Службени гласник РС", бр. 128/20 и 116/22), чл. 67, 69, 70. 109, 111, 164. и 167. Закона о патентима („Службени гласник РС", бр. 99/11, 113/17 - др. закон, 95/18, 66/19 и 123/21) и Решења о преносу овлашћења за доношење и потписивање управних и других аката Завода за интелектуалну својину 990 број 021-18245/2021-01 од 1.12.2021. године, у управном поступку по пријави малог патента број МП-2022/0043 од 25.3.2022. године, подносиоца Институт за нуклеарне науке Винча - Институт од националног значаја, Универзитет у Београду, Мике Петровића Аласа 12-14, 11351 Београд-Винча, ради признања малог патента, донео је 1.11.2022. године

# Р Е Ш Е Њ Е

1. ПРИЗНАЈЕ СЕ правном лицу Институт за нуклеарне науке Винча - Институт од националног значаја, Универзитет у Београду, Мике Петровића Аласа 12-14, 11351 Београд-Винча, мали патент по пријави број МП-2022/0043 од 25.3.2022. године, за проналазак под називом: „ТРАНСПОРТНА КОЛИЦА ЗА ИСПИТИВАЊЕ ПРОФИЛА БРЗИНА ОТПАДНОГ ГАСА У КОМОРАМА ЕЛЕКТРОФИЛТЕРСКИХ ПОСТРОЈЕЊА ВЕЛИКИХ ЕМИТЕРА", према опису, патентним захтевима и цртежима из патентног списа.

2. УПИСУЈЕ СЕ у Регистар малих патената Завода за интелектуалну својину признато право из тачке 1. диспозитива овог решења под бројем

1775

3. Податке о признатом праву објавити у „Гласнику интелектуалне својине", број 11/2022.

О б р а з л о ж е њ е

Правно лице Институт за нуклеарне науке Винча - Институт од националног значаја, Универзитет у Београду, Мике Петровића Аласа 12-14, 11351 Београд-Винча, подносилац је пријаве малог патента број МП-2022/0043 од 25.3.2022. године, за проналазак под називом наведеним у диспозитиву решења.

У спроведеном поступку за признање малог патента утврђено је да су испуњени услови из члана 164. став 1. Закона о патентима.

Имајући у виду наведено, Завод за интелектуалну својину је, на основу чл. 164, 167, 109. и 111. Закона о патентима, одлучио као у диспозитиву овог решења.

Подносилац пријаве ослобођен је плаћања републичких административних такси на основу одредбе члана 18. став 1. тачка 4) Закона о републичким административним таксама („Службени гласник РС", бр. 43/03, 51/03 – исправка, 53/04, 42/05, 61/05, 101/05 – др. закон, 42/06, 47/07, 54/08, 5/09, 54/09, 35/10, 50/11, 70/11, 55/12, 93/12, 47/13, 65/13 – др. закон, 57/14, 45/15, 83/15, 112/15, 50/16, 61/17, 113/17, 3/18 – исправка, 50/18, 95/18, 38/19, 86/19, 90/19 – исправка, 98/20, 144/20 и 62/21 – усклађени дин. износи).

Упутство о правном средству:

Против овог решења може се изјавити жалба Влади Републике Србије у року од 15 дана од дана његовог пријема, а преко овог завода. Уз жалбу треба доставити доказ о уплати административне таксе у износу од 490,00 динара.

Решење доставити:
- подносиоцу пријаве

Институт за нуклеарне науке Винча
Институт од националног значаја
Универзитет у Београду
Мике Петровића Аласа 12-14
11351 Београд-Винча
- у спис

Саветник

Мирјана Јелић

# *Информативни подаци о малом патенту/пријави малог патента*

| | |
|---|---|
| Регистарски број (Registration number) | 1775 |
| Број и датум решења о признању права (Number and date of decision to grant the right) | 2022/10939 01.11.2022 |
| Број пријаве (Application number) | МП-2022/0043 |
| Датум пријема пријаве (Reception date) | 25.03.2022 |
| Признати датум подношења пријаве (Filing date) | 25.03.2022 |
| Статус (Legal status) | Регистрован (Registered) |
| Међународна класификација патената (IPC) | B03C 3/36 |
| Назив проналаска (Title of invention) | TRANSPORTNA KOLICA ZA ISPITIVANJE PROFILA BRZINA OTPADNOG GASA U KOMORAMA ELEKTROFILTERSKIH POSTROJENJA VELIKIH EMITERA<br><br>TRANSPORT TROLLEYS FOR ANEMOMETERS FOR TESTING THE AIR VELOCITY PROFILE IN THE CHAMBERS OF ELECTROSTATIC PRECIPITATORS OF LARGE EMITTERS |
| Подаци о проналазачу (Inventor) | LAZOVIĆ, Ivan<br><br>MARKOVIĆ, Zoran<br><br>ERIĆ, Milić<br><br>JOVANOVIĆ, Rastko<br><br>TASIĆ, Viša |
| Подаци о носиоцу права (Owner) | INSTITUT ZA NUKLEARNE NAUKE VINČA-INSTITUT OD NACIONALNOG ZNAČAJA, UNIVERZITET U BEOGRADU, Mike Petrovića Alasa 12-14, 11351 Beograd-Vinča, RS |

## Акција (Action): Priznaj mali patent

| | |
|---|---|
| Датум акције (Action date) | 01.11.2022 |

РЕПУБЛИКА СРБИЈА
ЗАВОД ЗА ИНТЕЛЕКТУАЛНУ СВОЈИНУ

REPUBLIC OF SERBIA
INTELLECTUAL PROPERTY OFFICE

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# ГЛАСНИК ИНТЕЛЕКТУАЛНЕ СВОЈИНЕ

# INTELLECTUAL PROPERTY GAZETTE

Београд / Belgrade **2022/11**

Завод за интелектуалну својину Републике Србије
The Intellectual Property Office of the Republic of Serbia

# ГЛАСНИК ИНТЕЛЕКТУАЛНЕ СВОЈИНЕ

## INTELLECTUAL PROPERTY GAZETTE


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|---|---|---|---|---|---|
| ГЛАСНИК ИНТЕЛЕКТУАЛНЕ СВОЈИНЕ | Година излажења CII | 2022 | број 11 | P 63646 - 63720<br>U 1774 - 1775<br>Ж 83393 - 83580<br>Д 11661 - 11665 | Датум објављивања:<br>30.11.2022.<br>Београд |

Издаје и штампа: **Завод за интелектуалну својину,** Београд, Кнегиње Љубице 5, Београд, Србија
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# САДРЖАЈ / Contents

# МАЛИ ПАТЕНТИ / Petty Patents

**(51)** ***A01G 23/099*** (2006.01) **(11) 1774 U1**
***B25F 1/02*** (2006.01)
(21) **MP-2022/0065** (22) 20.09.2022.
**(54) OBELEŽIVAČ STABALA SA SEČIVOM**
TREE MARKER WITH A HEWING KNIFE
(73) INSTITUT ZA ŠUMARSTVO, Kneza Višeslava 3, 11030 Beograd, RS
(72) HADROVIĆ, Sabahudin, dr, Rajka Ackovića 101, 36300, Novi Pazar, RS; JOVANOVIĆ, Filip,dr, Zadrugarska 14b, 11080, Beograd, RS; BRAUNOVIĆ, Sonja, dr, Stanoja Glavaša 31, 11060, Beograd, RS; ĆIRKOVIĆ-MITROVIĆ, Tatjana, dr, Belo vrelo 21/1, 11030, Beograd, RS; MLADENOVIĆ, Katarina, dr, Stevana Sremca 3, 11000, Beograd, RS; JOVIĆ, Đorđe, dr, Nedeljka Čabrinovića 64, 11030, Beograd, RS; MARKOVIĆ, Miroslava, dr, Milorada Draškovića 46, 11090, Beograd, RS

**(51)** ***B03C 3/36*** (2006.01) **(11) 1775 U1**
(21) **MP-2022/0043** (22) 25.03.2022.
**(54) TRANSPORTNA KOLICA ZA ISPITIVANJE PROFILA BRZINA OTPADNOG GASA U KOMORAMA ELEKTROFILTERSKIH POSTROJENJA VELIKIH EMITERA**
TRANSPORT TROLLEYS FOR ANEMOMETERS FOR TESTING THE AIR VELOCITY PROFILE IN THE CHAMBERS OF ELECTROSTATIC PRECIPITATORS OF LARGE EMITTERS
(73) INSTITUT ZA NUKLEARNE NAUKE VINČA-INSTITUT OD NACIONALNOG ZNAČAJA, UNIVERZITET U BEOGRADU, Mike Petrovića Alasa 12-14, 11351 Beograd-Vinča, RS
(72) LAZOVIĆ, Ivan, Ljubomira Stojanovića 34/21, 11060, Beograd, RS; MARKOVIĆ, Zoran, Jovanke Radaković 68a/11, 11160, Beograd, RS; ERIĆ, Milić, Živanićeva 22, 11253, Beograd, RS; JOVANOVIĆ, Rastko, Homoljska 1/5, 11060, Beograd, RS; TASIĆ, Viša, Đorđa Andrejevića Kuna 19/5, 19210, Bor, RS