NOVA , ORIGINALNA TEHNOLOGIJA ZA SIMULTANO ČIŠĆENJE SUMPOR DIOKSIDA (SO2) i AZOTNIH OKSIDA (NOx) IZ DIMNIH GASOVA DOBIJENIH SAGOREVANJEM FOSILNIH GORIVA - ELFI TEHNOLOGIJA

Ranije se verovalo da zaštita atmosfere od sumpornih oksida (SO2) i azotnih oksida (NOx) iz dimnih gasova iz postrojenja koja sagorevaju fosilna goriva (termo elektrane, toplane, metalurški kombinati, naftna industrija i drugi...) zahtevaju velika finansijska sredstva za rešenje za zaštitu atmostfere – za ekologiju. Odstranjvanje polutanata iz dimnih gasova se rešavalo izbacivanjem dimnih gasova visoko u atmosferu (pomoću visokih dimnjaka), što je ekvivalentno razblaživanju, ali ne i otklanjanju SO2 i NOx iz dimnih gasova.

Sa porastom broja temičkih uređaja (visokih dimnjaka) su razvijane i metode – tehnologije za otklanjanje (filtriranje) SO2 i NOx.iz dimnih gasova. Međutim, postojeće metode imaju i svoje nedostatke. Kada se koristi, na primer, hemijska metoda kreč – krečnjak, sporedni proizvod filtriranja od SO2 je gips, koji ima ograničenu komercijanu vrednost, pa se jedna vrsta zagađivača pretvara u drugu, ali manje štetnu. Tada se gips odlaže na velike površine u blizini elektrane. Efikasnost ove tehnologije za SO2 nije velika, a za otklanjanje NOx se koristi druga tehnologija (selektivna katalitička redukcija).

Sledeća metoda se bazira na ozračivanju dimnog gasa elektronskim snopovima za simultano otklanjanje SO2 i NOx, u prisustvu amonijaka (u stehiometrijkom odnosu), – E-Beam tehnologija. Ova tehnologija ima visoku efikasnost – skoro 100% za SO2 i oko 70 -80 % za NOx.. Sporedni proizvod je mineralno đubrivo (amonijum sulfati i amonijum sulfo nitrati) koje ima komercijalnu vrednost, pa nema problema sa odlaganjem sporedng proizvoda. Međutim E-Beam tehnologija zahteva veći broj veoma skupih akcelatora visokog napona , preko 500 keV i velike snage – preko 100 kW. Pored veoma skupih akceleratora, E-Beam tehnologija troši znatan deo proizvedene električne energije za rad, skupo održavanje, kratak vek radnog procesa bez sevisiranja kada su postrojenja van upotrebe.Elektronski snop, usled visokog napona i velike energije, proizvodi tvrdo X zračenje pa se celo postrojenje mora da stavi u «sarkofag» od armiranog betona određene debljine, što zahteva posebne mere zaštite osoblja.

Više podataka o postojećim metodama za čiščenje dimnih gasova od SO2 i NOx su dati u članku: «Plasmas join the fight against acid rain» , Graeme Lister, Physics World, December 2002, p. 20. Prema poslednjim podacima ni jedna nova tehnologija nije razvijena.

Nova tehnologija za simultano čišćenje dimnih gasova od SO2 i NOx iz dinmih gasova, plazma hemijska tehnologija ELFI tehnologija (elektronsko filtriranje), koja nema navedene nedostatke, je razvijena u Institu za nuklearne nauke u VINČI, u Laboratoriji za atomsku fiziku, na bazi osnovnih istraživanja specijalnog tipa visoko frekventnog korona pražnjenja sa novim tipom «Teslin transformator sa trofaznim napajanjem». Sporedni proizvod je mineralno đubrivo, koje ima komercijalnu vrednost, a rešavanje ekoloških problema praktično da ne zahteva dodatna finansijska sredstva.

ELFI tehnologija je patentirana u SAD, Evropskoj patentnoj uniji (Austrija, Belgija, Švajcarska i Luksenburg, Francuska, velika Britanija, Irska, Italija, Holandija, Nemačka i Švedska), Japanu i Saveznom zavodu za intelektualnu svojinu u Beogradu.

ELFI tehnologije je prošla međunarodnu recenziju – publikovan je veći broj radova i prezentirana na većem broju međunarodnih konferencija i skupova.

1) REMOVAL OF SO_2 AND NO_x FROM FLUE GASES BY A NEW TYPE OF HIGH FREQENCY CORONA BRUSH DISCHARGE

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Abstract. Pulse corona brush discharge (CBD) can be used for cleaning of CO_2 and NO_x from flue gases. In CBD active corona occupies practically the whole volume of discharge tube, so that one may expect a great efficiency of this type of discharge in application, for flue gas cleaning from SO_2 and NO_x.

1. INTRODUCTION

With increase of Industrialization in the world, demands for production of electric energy increase, particularly in developed countries. Presently, a largest amount of electric and thermal energy is produced in fossil fuel thermal plants. Burning of fossil fuels emits info atmosphere flue gases containing sulfur dioxide (SO_2) and nitrogen oxides (NO_x). These pollutants are very harmful for environment. For example, acid rains are caused by presence of SO_2 and NO_x in atmosphere. As a movement of pollutants in atmosphere depends on winds, the problems with them is a global problem of the whole world and mainly does not depend on the location of a pollution source. More about existing methods for cleaning of flue gases, from SO_2 and NO_x is given in [1,2,3].

A now method for simultaneous removal of SO_2 and NO_x from flue gas, a plasma chemistry method called ELFI, has been developed on the basic of fundamental research of the special type of high frequency corona brush discharge (CBD).

2. CORONA BRUSH DISCHARGE

Corona Brush Discharge (CBD) is a new type of a high-frequency corona discharge, and one of the principal characteristics of this discharge is that corona occupies a whole volume between a special brush-shaped electrodes in a discharge chamber [4,5].

The results of the study of the double-sided high-frequency corona brush discharge (DSCBD) when a new type of Tesla coil is used as a power supply - the three-phase Tesla coil (3PTC) [6,7], which gives uniform output voltage in each operating pulse - are presented in this paper.

The-experimental device shown in Fig. l has five brush-shaped electrodes (BE_1-BE_5) placed sequentially in a glass tube (GT) , that is a DSCBD tube. The DSCBD tube is connected to a ventilation system of a capacity up to 150 m3/h. Inner diameter of GT and brush electrodes is 11 cm, and length of GT is also 11 cm.

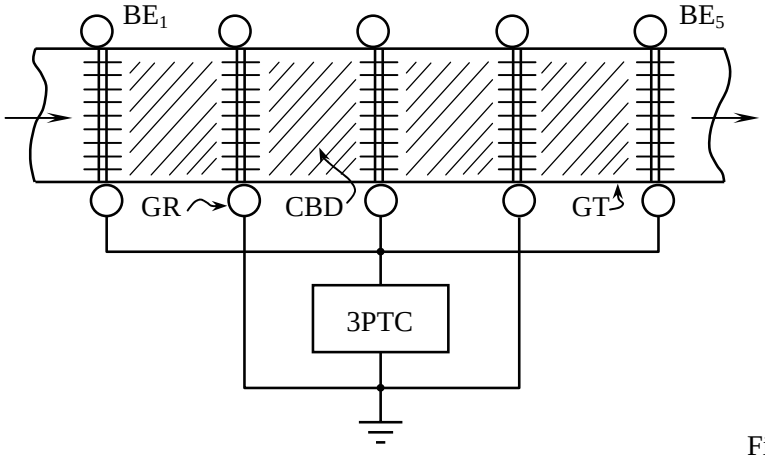

Fig. 1. Experimental device with five brush-shaped electrode.

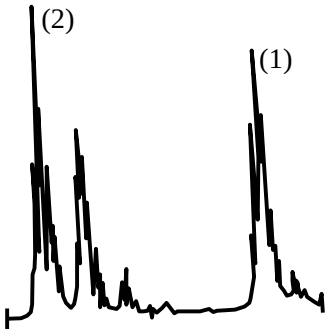

Fig. 2. Part of the CBD spectrum of the N_2 second positive system: (1) 337.1 nm and (2) 357.7 nm. Operating conditie air at atmospheric pressure, TC: U_{TC} = 250 kV, at f = 200 kHz.

Pins of the brush-shaped electrodes are fastened to the electrode mesh (1 line/cm with element wire of 1 mm in diameter). The guard rings (GR) on the electrodes, with theirs cross-sectional radius greater than a critical one, are used for electrostatic shielding to prevent edge breakdown. The electrodes of such construction does not make a considerable obstacle to a flow of operating gas through them. The electrodes BE_1, BE_3, and BE_5 are connected to one (hot) end of 3PTC, while the electrodes BE_2 and BE_4 are connected to another, grounded end of 3PTC.

When 3PTC is energized, corona discharge is established and it completely occupies the space between the all electrodes and emits uniform light from the whole volume of double-sided corona brush discharge. It is to be noted that DSCBD is very stable in the whole volume between electrodes. Characteristics of this discharge are similar to those of corona brush discharge-described earlier [4,5]. In Fig. 2 is shown a part of the DSCBD spectrum for second positive system of N_2 (337.1 nm (1) and 357.7 nm (2)) for air at atmospheric pressure and voltage of 3PTC U≈250 kV at frequency f≈200 kHz. With air-water vapor mixture as operating gas, one gets in discharge nitrogen oxides which with water vapor forms nitric acid.

Pulse brush discharge corona can be used for cleaning flue gases from SO_2 and NO_x. In, CBD active corona occupies practically the whole volume of discharge tube, so that one may expect a great efficiency of this type of discharge in application for flue gas cleaning from SO_2 and NO_x.

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Double-Sided High-Frequency Corona Brush Discharge

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Corona Brush Discharge (CBD) represents a new type of a high-frequency corona discharge. One of the principal characteristics of this discharge is that corona occupies a whole volume between a special brush-shaped electrodes in a discharge chamber [1,2,3].

The results of the study of the double-sided high-frequency corona brush discharge (DSCBD) when a new type of Tesla coil is used as a power supply - the three-phase Tesla coil (3PTC) [4], which gives uniform output voltage in each operating pulse - are presented in this paper.

The experimental device shown in Fig. 1 hae five brush-shaped electrodes (BE_1-BE_5) placed sequentially in a glass tube (GT), that is a DSCBD tube. The DSCBD tube is connected to a ventilation system of a capacity up to 150 m^3/h. Inner diameter of GT and brush electrodes is 11 cm, and length of GT is also 11 cm.

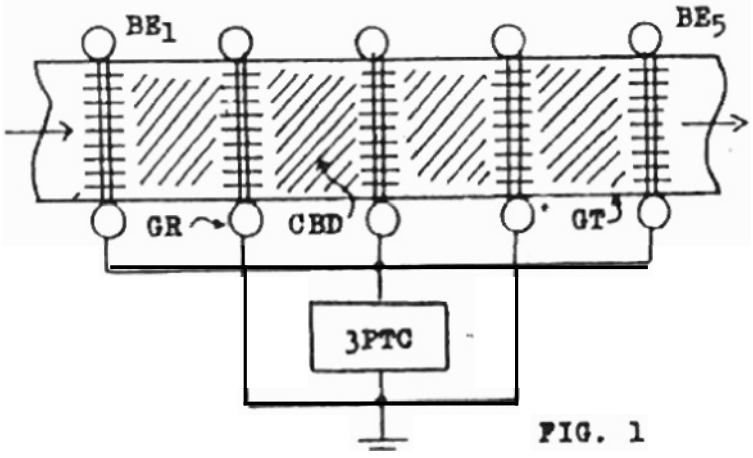
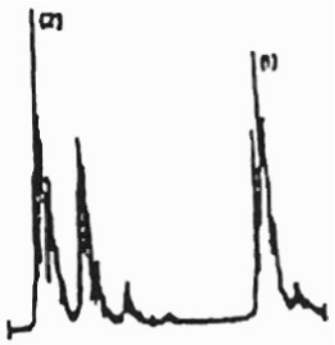


FIG. 1



PIG. 2

Pins of the brush-ehaped electrodes are fastened to the electrode mesh (1 line/cm with element wire of 1 mm in diameter). The guard rings (GR) on the electrodes, with theirs cross-sectional radius greater than a critical one, are used far electrostatic shielding to prevent edge breakdown. The electrodes of such construction does not make a considerable obetacle to a flow of operating gas

through them. The electrodes BE_1, BE_3, and BE_5 are connected to one (hot) end of 3PTC, while the electrodes BE_2 and BE_4 are connected to another, grounded end of 3PTC.

When 3PTC is energized, corona discharge is established and it completely occupies the space between the all electrodes and emits uniform light: from the whole volume of double-sided corona brush discharge (DSCBD). It is to be noted that DSCBD is *very* stable in the whole volume between electrodes. Characteristics of this discharge are similar to those of corona brush discharge described earlier [1,2]. In Pig, 2 is shown a part of the DSCBD spectrum for second positive system of N_2 (337.1 nm (1) and 357.7 nm (2)) for air at atmospheric pressure and voltage of 3PTC U=250 kV at frequency f=200 kHz. With air-watar vapor mixture as operating gas, one gets in discharge nitrogen oxides which with water vapor forms nitric acid.

Pulse corona can be used for abatement of SO, and NO_x from flue gases [5]. In DSCBD active corona occupies practically the whole volume of diecharge tube, so that one may expect a great efficiency of this type of discharge in application far flue gas cleaning from SO, and NO_x.

Studies with use of larger number of electrodes than five using 3PTC as a *power* supply with various voltages and frequencies are in progress.

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ELFI PILOT PLANT FOR REMOVAL OF SO2 AND NOx FROM FLUE GASES IN THERMAL PLANTS

1. INTRODUCTION

With increase of industrialization in the world, demands for production of electric energy increase, particularly in developed countries. Presently, a largest amount of electric and thermal energy is produced in fossil fuel thermal plants. Burning of fossil fuels emits into atmosphere flue gases containing sulfur dioxide (SO2) and nitrogen oxides (NOx). These pollutants are very harmful for environment. For example, acid rains are caused by presence of SO2 and NOx in atmosphere. As a movement of pollutants in atmosphere depends on winds, the problems with them is a global problem of the whole world and mainly does not depend on the location of a pollution source.

With the increase of numbers of thermal plants, methods for removal of SO2 and NOx from flue gas (filtering of flue gas) has been developed. However, the existing methods for filtering of flue gases have its problems and even deficiencies. When using, for example, chemical methods for filtering of flue gases, the by-product of filtering from SO2 is gypsum which has limited commercial value. As gypsum is unstable it practically means that one kind of pollutant is turned into another kind, but a less harmful one. A land is sacrificed for disposal of filtering products (gypsum) and subterranean waters are polluted. The rate of efficiency of such a technology is about 50% for SO2. The installation has to be regenerated occasionally due to its saturation. A special methods are used for removal of NOx (selective catalytic
reduction - SCR).

Recently, method based on the electron beam irradiation of flue gas in the presence of ammonia (in stoichiometric amount) for simultaneous removal of CO and NOx has been developed - e-beam technology. This method has a high
efficiency rate; almost 100% for SO2 and about 80% - 90% for removal of NOx, and there is no saturation of the installation. The by-product is artificial fertilizer (ammonium sulfate and ammonium sulfonitrate) which has a commercial value. As it is used in agriculture there is no storage problems. One defect of this method of filtering is very expensive electron accelerator that operates in the regime of high power, i.e. 100 kW and more, as well as high consumption of electric energy for its operation. Pilot plants using this method and working under real conditions exist in the U.S.A., Japan, Germany, and Poland, with a purpose to obtain relevant data for construction of industrial installations. Thus, in Poland, using experience gained on one pilot plant, is recently made industrial 100 MW modular plant for removal of SO2 and NOx from flue gas, that operates under real conditions, and is commercialy available.

Another method for flue gas filtering is based on impulse corona discharge, and it is still in the experimental phase. Although the filter chamber is relatively simple, the impulse high power supply of rise time amounting to a few nanoseconds and of a repetition rate of 300 Hz is very expensive. The rate of efficiency of this method is about 50 to 60%, and is still in an experimental phase.

More about existing methods for cleaning of flue gases from SO2 and NOx is given in the article by G. Lister, Phisics World, December 2002, p.19. By our knowledge it is not developed a some new technology since the time the article by
G. Lister is published.

A new method for simultaneous removal of SO2 and NOx from flue gas, a plasma chemistry method called ELFI, which in great extent does not have defects of already mentioned methods, has been developed in the Atomic Physics
Laboratory of the Vinca Institute of Nuclear Sciences on the basis of fundamental research of the special type of high frequency corona discharge by the
Three Pase Tesla Coil (3PTC). The by-product of this method is also artificial fertilizer. The installation using this method costs less, consumption of energy for
its operation is lower, it is more reliable in operation, and it is simpler for servicing
than installations using previously mentioned methods. The process of cleaning of
flue gases would be completely self-contained by using such a technology: protection of human environment would be provided, and fossil fuels became also the source of other useful products besides their basic application to produce energy.

The results of fundamental research on which ELFI is based are presented on international scientific meetings. Laboratory studies completely fulfilled foreseen expectations for filtering and gave numerous data necessary to project pilot plant. The patents for ELFI technology were granted in 1998 by the European Patent Union, U.S.A., Japan, and Yugoslavia, .

2. COMPARISON OF E-BEAM AND ELFI TECHNOLOGIES

To see the advantage of the ELFI technology, let us compare it with the technology of electron beams:
- In the electron beam technology high-energy electrons (300 to 700 keV, and more) are used to produce secondary low-energy electrons in complex reactions with flue gas. Energies of secondary electrons are several thousands times smaller than energies of primary electrons. Just these secondary electrons take part in reactions which produce radicals and other constituents necessary for removal of SO2 and NOx from flue gases. That means that this is a two-

step process and a large part of energy given to flue gas by primary electrons is wasted, for instance, for heating of gas, for heating of system components (which must be cooled by forced air), and for other reactions that do not contribute to efficiency of filtering but represent a net loss of energy. That is why a filtering plant based on electron beam technology consumes even up to 15% of produced electric energy of thermo-electric power plant.
- In the case of ELFI technology primary low-energy electrons participate directly in reactions for filtering flue gases, i.e., without intermediate steps. Therefore, side effects are manifestly lower than in the case of the electron beam technology, and no additional cooling of system components is necessary. The efficiency of filtering is considerably increased in that way, and consumption of electric energy of ELFI plant is lower than for filtering by electron beam. For the same reasons ELFI plant production costs are considerably lower than those by electron beam.

The principal characteristics of ELFI technology are:
- Plasma is created in the whole volume of a plasma-chemistry reactor (PCR);
- It is possible to scale-up a plasma-chemistry reactor, so that a large flow of flue gases from thermal plants can be processed.
All this enables application of the ELFI technology to contemporary power plants.

3. ELFI PILOT PLANT

The basic aim of ELFI pilot plant is to obtain relevant data for construction of an industrial plant and its placement on the international and domestic markets. It is planned an industrial installation of modular type with basic modules of the power of 100 MW. In such a way it would be possible to ensure cleaning of flue gases from thermal plants and/or other plants of various powers emitting SO2 and NOx.

The pilot plant is designed for installation on thermal plant in VINCA Institute, of the
power of about 10 MW and with the capacity of flue gases of 10,000 m3 per hour.
A block diagram of the ELFI pilot plant is presented in attached figure. Heating plants of such characteristics are very suitable for operation of a pilot plant in realistic conditions and data obtained will be very useful for design and construction of industrial plants which will be placed on the international and domestic markets.

Eminent scientists, engineers, professionals, and technicians are engaged on the project. The project manager is Dr. V. Miljevic' who is the author of the new ELFI technology.

Completed phases of ELFI pilot plant project are as follows:
- Preliminary design.
- Complete technical documentation (contractor's design).
- All preparation for start of the construction of complete pilot plant and

choice of cooperators.

The ELFI pilot plant, as mentioned above, will give data which are going to be used for design and construction of industrial plants.

4. ECOLOGICAL EFFECTS OF ELFI PROCESS

It is usually thought that investment of financial resources is indispensable for protection of atmosphere, i.e. human environment. Therefore, a high stack is still the sole protection of atmosphere from SO2 and NOx in the majority of countries. By such "filtering" flue gases are ejected high in atmosphere - what is equivalent to dilution of harmful products but not to their removal.

The ELFI method promises a high grade of efficiency of filtering of flue gases from SO2 and NOx with addition of ammonia (NH) in stoichiometric ratio, and their conversion into artificial fertilizers of a commercial value which are deficient goods in many countries in the world. In that way, for instance, a thermo-electric power plant ceases to be a pollutant, but, besides its basic purpose of production of electric energy, becomes a "factory" of fertilizers. The simple analysis has shown that the profit from artificial fertilizer is comparable (for domestic conditions) with the profit realized by the sale of electric energy.

It means that by using the ELFI technology, by which one produces artificial fertilizers besides the primary product, for example, electric power in the case of thermo-electric plant, pure air, without SO2 and NOx,
is a "by- product" , i.e. ecological problems of contamination of atmosphere by power plants disappear.

5. SUMMARY

The principal aim of an ELFI pilot plant is collecting of relevant data for construction and production of modular industrial plants of power of 100 MW for flue gas cleaning from a contemporary large power plants emitting SO2 and NOx. The ELFI technology is granted by patents in many developed countries that eneables an exclusive placement on domestic and international markets.

The raw materials for production of artificial fertilizers by ELFI technology are just SO2 and NOx in gas phase that are obtained by scrubbing of flue gases. The only component which has to be purchased for production of artificial fertilizers is ammonia.

Application of the ELFI technology to clean flue gases from SO2 and NOx, "by-product" is the clean air (without SO2 and NOx). In such a way one solves the
fundamental problem of pollution of the atmosphere with SO2 and NOx.

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Section E- CLEAN HUMAN ENVIRONMENT *BAI2007ED007*

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Veljko D. Lucic,B.Sc.*

APLICATION OF THE THREE PHASE TESLA COIL FOR REMOVAL OF SO2 AND NOx FROM FLUE GASES BY HIGH FREQUENCY DISCHARGE

PRIMENA TROFAZNOG TESLINOG TRANSFORMATORA ZA ČIŠĆENJE SO2 I NOx IZ DIMNIH GASOVA POMOĆU VISOKOFREKVENTNOG KORONA PRAŽNJENJA

Abstract

The new original electronic filtering technology (ELFI) using a plasma chemistry method is developed in "VINCA" Institute of Nuclear Sciences, on the basis of fundamental research of the original type of high frequency corona discharge energized by the new type of high-frequency and high voltage generator - "Three-phase Tesla Coil".
The ELFI module can be added to an existing plant as a by-pass, so it does not obstruct its function. SO2 and NOx are simultaneously removed from the flue gases by the ELFI technology and are converted into a useful artificial fertilizer. Waste materials are not produced by this technology, and the problem of permanent storage of undesired products does not exist.

Key words: SO2, NOx, flue gas treatment

1. INTRODUCTION

The emission of toxic gas, sulphur oxides and nitrogen oxides from industrial plants has become a serious problem in the World. SO2 and NOx are known to be converted to "acid rain" in the atmosphere and cause the environmental pollution. – Fig. 1

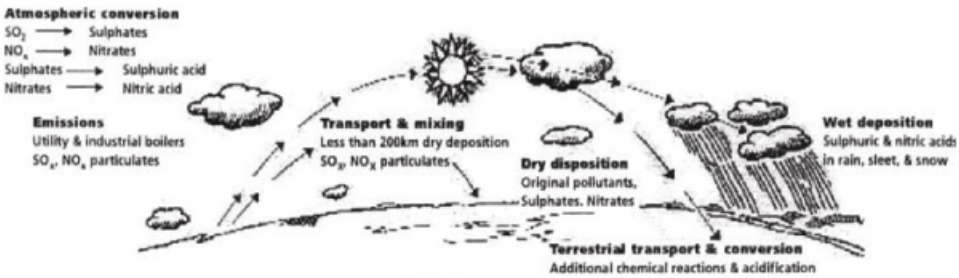

Fig. 1

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2. TECHNOLOGIES FOR CLEANING SO2 AND NOx FROM FLUE GASES

E-beam technology has the disadvantages of high capital cost and the need to shield potentially hazardous X-rays which are produced in the process. One possible alternative technology is the corona discharge, a comparatively recent entrant to the field of non-thermal waste treatment. The principle behind the corona discharge is the creation of plasma filaments – small bursts of plasma – generated when a high voltage is applied between a wire filament and a metal plate. High electric fields are created in the heads of those filaments, which produces largenumbers of free electrons, as in e-beam reactors.

Results so far have been encouraging, although the gas volumes treated to date have been considerably smaller than those using e-beams. Corona disharges have the potential advantages that fitting costs may be greatly reduced, since they use the same wire-plate electrode configuration as in the electric percipitators used in convetional "wet scrubbers" for flue gas control. If either of these methods is to replace conventional technology, they will need to use less than 3% of the total electrical power of the generator.

One of the major problems for both technologies is "scale-up" for application to the modern large power plants [1] .

3. IMPULSE CORONA DISCHARGE

Theoretical investigation of the phenomenon impulse corona energization of flue gases led to the assumption that the most suitable electron energy for producing the chemical radicals which are responsible for the oxidations of the sulphur and nitrogen oxides is in the range 5 to 20 eV and that a pulse corona discharge can provide a number of such electrons : Table 1 and Table 2 [3] .

Table I - Main reactions of the process

$e^*(5.1eV) + H_2O \longrightarrow H + OH^-$

$e^*(7eV) + O_2 \longrightarrow O + O^-$

$e^*(>15,7eV) + N_2 \longrightarrow N_2^+; e; N^+; N; N_2^*$

$e^*(>12,1eV) + O_2 \longrightarrow O_2^+; e; O^+; O; O_2^*$

$e(<5eV) + O_2 \longrightarrow O_2^-$

$O_2^+ + O_2^- \longrightarrow O_3 + O$

$O_2^+ + H_2O \longrightarrow O_2^+ H_2O$

$O_2^+ H_2O + H_2O \longrightarrow H_3O^+ OH + O_2$

$H_3O^+ OH + n\,H_2O \longrightarrow H_3O^+ (H_2O)_n + OH$

$H_3O^+ (H_2O)_n + O_2^- \longrightarrow (n+1)H_2O + HO_2$

$NO + HO_2 \longrightarrow NO_2 + OH$
$NO + O \longrightarrow NO_2$
$NO_2 + OH \longrightarrow HNO_3$

$NO_2 + O \longrightarrow NO_3$
$NO_2 + NO_3 \longrightarrow N_2O_5$
$N_2O_5 + H_2O \longrightarrow 2HNO_3$

$SO_2 + OH \longrightarrow HSO_3$
$HSO_3 + OH \longrightarrow H_2SO_4$

$SO_2 + O \longrightarrow SO_3$
$SO_3 + H_2O \longrightarrow H_2SO_4$

$HNO_3 + NH_3 \longrightarrow NH_4NO_3$

$H_2SO_4 + 2NH_3 \longrightarrow (NH_4)_2SO_4$

Table 1

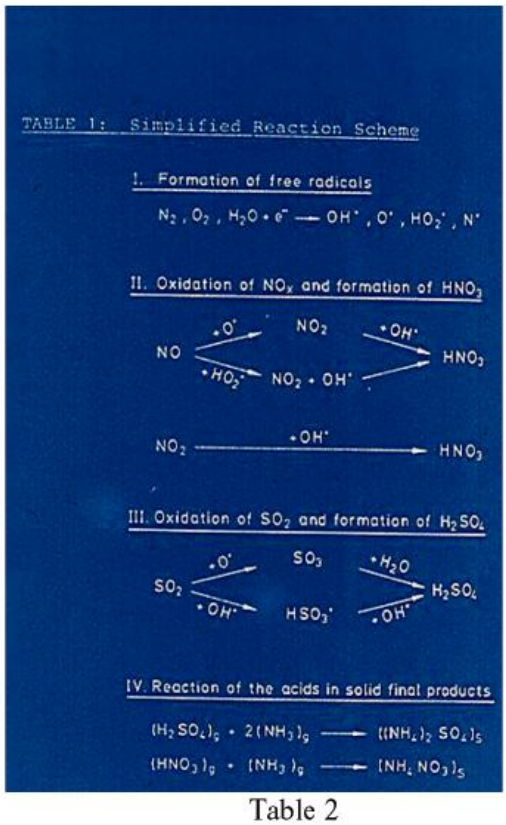


Table 2

4. HIGH FREQUENCY CORONA DISCHARGE BY THREE PHASE TESLA COIL

4.1. Double-Sided High-Frequency Corona Brush Discharge

Corona Brush Discharge (CBD) represents a new type of a high-frequency corona discharge . One of the principal characteristics of this discharge is that corona occupies a whole volume between a special brush-shaped electrodes in a discharge chamber .

The results of the study of the double-sided high-frequency corona brush discharge (DSCBD) when a new type of Tesla coil is used as a power supply – the Three-Phase Tesla coil (3PTC), which gives uniform output voltage in each operating pulse – are presented in this paper.

When 3PTC is energized, corona discharge is established and it completely occupies the space between the all electrodes and emits uniform light from the whole volume of double-sided corona brush discharge (DSCBD). So, for example, second positive system of N_2^* 337.1 nm and 357,7 nm are obtained [4] .

4.2. ELFI Technology Principal Characteristics

The ELFI technology is based on a new type of the high frequency corona discharge. As a consequence, the principal advantages of ELFI technology over other existing technologies for cleaning of flue gases (e.g. the electron beam technology) are:

- Plasma is created in the whole volume of a plasma chemical reactor (PCR);
- It is possible to scale-up a plasma chemical reactor, so that a large flow of flue gases from a thermal plant can be processed, which is significant for industrial application of the ELFI technology.

One may find about other existing methods for cleaning of flue gases from SO2 and NOx in the article: "Plasmas join the fight against acid rain "by Graeme Lister, Physics World, December 1992, p. 19.

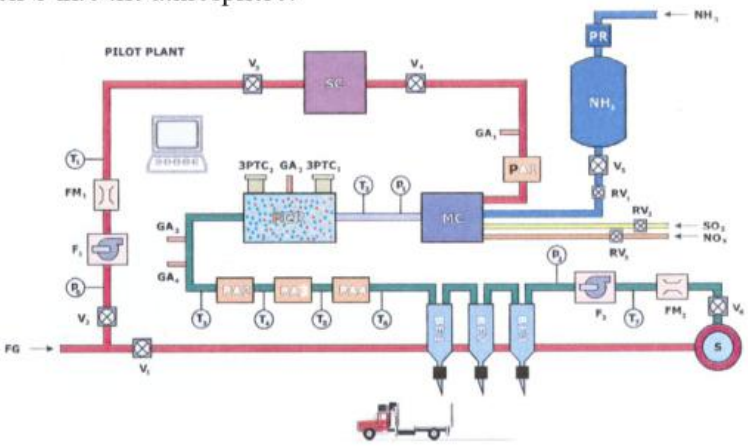
Some properties of the ELFI technology:

- this new, original technology using a plasma chemistry method is developed in the "VINCA" Institute of Nuclear Sciences on the basis of fundamental research of the original type of high frequency corona discharge.
- it is realized in the form of a special ELFI module which makes a part of a plant that burns fossil fuel.
- ELFI modules can be added to existing plants as a by-pass, so that it does not obstruct their function.
- SO2 and NOx are simultaneously removed from flue gas and by ammonia addition, converted into a useful, high quality and commercially valuable artificial fertilizer.
- waste materials are not produced by this technology, and the problem of permanent storage of undesired products does not exist.
- it consumes less electric energy for its functioning than other technologies.
- it is the only commercially efficient technology of this kind in the world.
- Removal of SO2 and NOx from flue gases contributes to the protection of human environment from these pollutants, and therefore directly improves health of human population ; it also prevents creation of acid rains, and protects buildings and metal constructions

- It can be used (installed) in all plants that burn fossil fuels: electric power plants, mills, chemical industry, oil industry, thermal plants, and other plants.

Principle of operation

A flue gas of known characteristics (temperature, gas flow rate, humidity) enters the plasma chemical reactor PCR, in which SO2 and NOx are being removed with addition of ammonia (NH3) in stoichiometric ratio and converted into artificial fertilizer.
Fertilizer is collected in bag filters BF1 – BF3, and flue gas without SO2 and NOx is passed through the stack S into the atmosphere.



S	– stack	MC	– gasmixing chamber
FG	– flue gas	PCR	– plasma chemical reactor
V	– valve	GA	– gas analyzer
F	– fan	PA	– particle analyzer
P	– pressure gauge	3PTC	– 3 Phase Tesla coil
T	– thermometer	BF	– bag filter
SC	– spray cooler	RV	– regulation valve
FM	– flow meter	PR	– pressure regulator

Results achieved:

- New technology is the result of fundamental research on which ELFI is based and is presented on international scientific meetings.
- Laboratory studies show completely fulfilled foreseen expectations for flue gas filtering and gave numerous data necessary to project a pilot plant [6] .
- The patents for ELFI technology were granted in : United States of America [7], following countries of the European Patent Union - Austria, Belgium, Switzerland and Luxemburg, France, Great Britain, Ireland, Italy, Holland, Germany and Sweden.[8] , Japan [9], and Serbia [10].

4.3. V. Miljevic, ELFI – New original technology for simultaneous removal of sulphur dioxide (SO2) and nitrogen oxides (NOx) from flue gases in plants which burn fossil fuel - Fig. 3

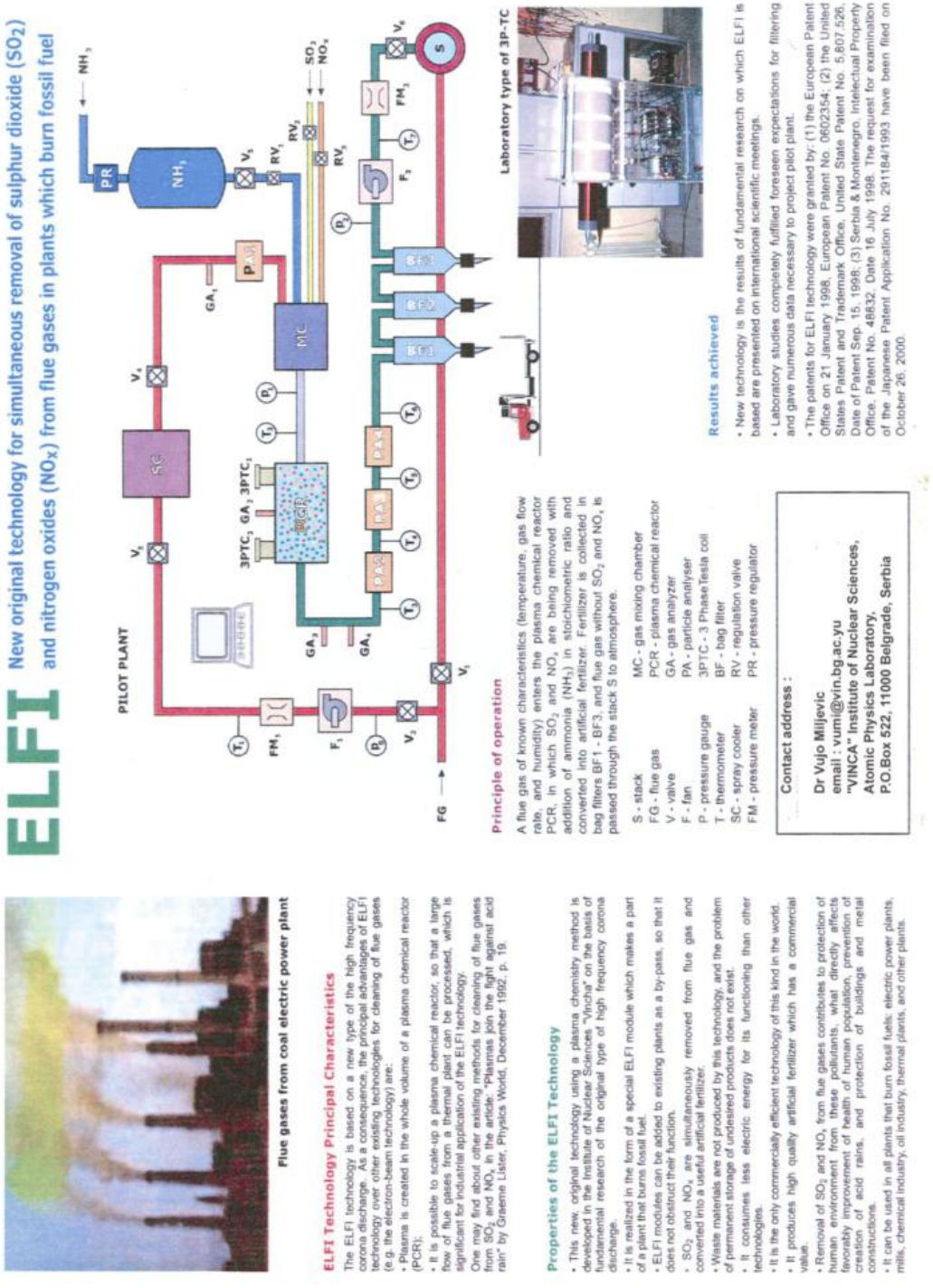


Fig. 3

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Conferences:

[3] L. Civitanno, G. Dinelli, F. Bussi, M. Angelantonio, I. Galamberti, M. Rea, Flue Gases Simultaneous DeNOx/DeSOx by Impulse Corona Energization, IAEA – TECDOC – 428, (1986) p.55 – 84.

[4] V. Miljevic, Double-Sided High-Frequency Corona Brush Discharge, XVth Europhysics Conference on Atomic and Molecular Physics of Ionized Gases, Europhysics Conference Abstracts, Volume 24F, p.436 – 437.

[5] V. Miljevic and Veljko Lucic, The Technology for Removal of SO2 and NOx from Flue Gases by High Frequency Discharge by Tesla Coil, Proceedings, POWER PLANT 2006, Serbia, Vrnjacka Banja (2006), 48 – 52.

[6] V. Miljevic, ELFI – New original technology for simultaneous removal of sulphur dioxide (SO2) and nitrogen oxides (NOx) from flue gases in plants which burn fossil fuel

Patents :

[7] V.Miljević, Device for Simultaneous Removal of SO2 and NOx from Flue Gases by High - Frequency discharge, USA Pat. Office, Grant March (1998), USA pat. No. 5,807,526

[8] V. Miljević, Device for simultaneous removal of SO2 and NOx from flue gases by high frequency discharge, European Patent Specification EP 0 602 354 Bl, Certificate 0602354, 21.01.1998. In Europe: Austria, Belgium, Switzerland and Luxemburg, France, Great Britain Ireland, Italy, The Nederlands, Germany and Sweden.

[9] V. Miljević, Device for simultaneous removal of SO2 and NOx from flue gases by high frequency discharge, Japanese Patent Application no. 291184 / 1993.

[10] V.Miljević, Uređaj za simultano čišćenje dimnih gasova od SO2 i NOx pomoću visokofrekventnog pražnjenja sa Teslinim transformatorom ili drugim generatorom visokog napona i visoke frekvencije, Rešenje Saveznog zavoda za intelektualnu svojinu, No. 48463, Beograd, 16. jul 1998.

5)

Flue gases from coal electric power plant

ELFI Technology Principal Characteristics

The ELFI technology is based on a new type of the high frequency corona discharge. As a consequence, the principal advantages of ELFI technology over other existing technologies for cleaning of flue gases (e.g. the electron-beam technology) are:

- Plasma is created in the whole volume of a plasma chemical reactor (PCR);
- It is possible to scale-up a plasma chemical reactor, so that a large flow of flue gases from a thermal plant can be processed, which is significant for industrial application of the ELFI technology.

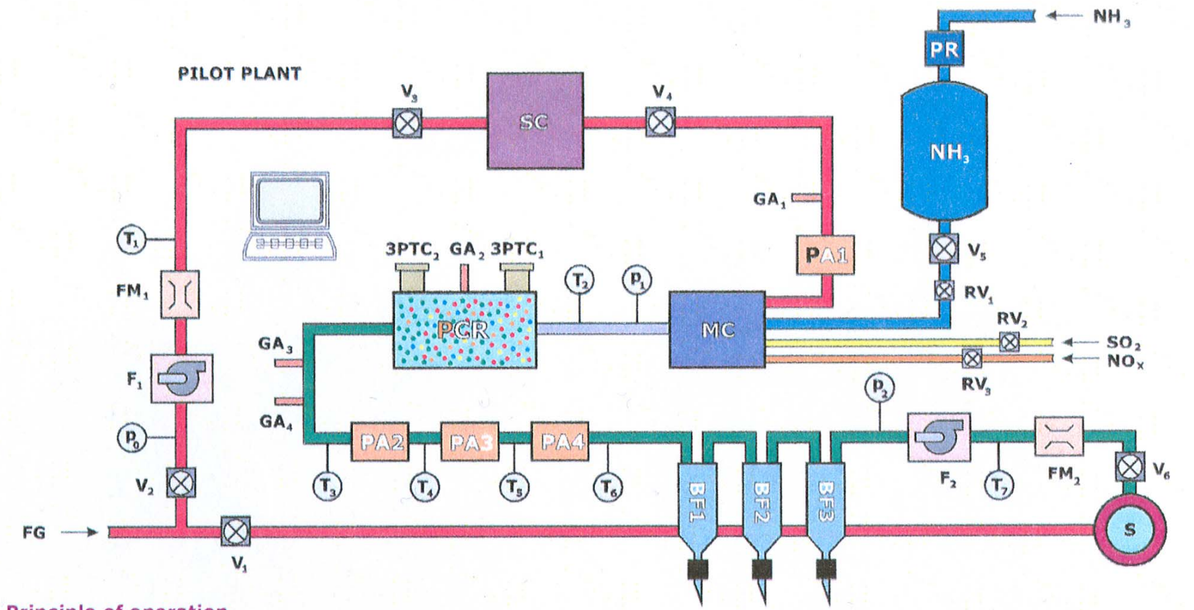
One may find about other existing methods for cleaning of flue gases from SO_2 and NO_x in the article: "Plasmas join the fight against acid rain" by Graeme Lister, Physics World, December 1992, p. 19. By our knowledge no new technologies, except the ELFI technology, has been developed since the time the article by G. Lister was published.

Properties of the ELFI Technology

- This new, original technology using a plasma chemistry method is developed in the Institute of Nuclear Sciences "Vincha" on the basis of fundamental research of the original type of high frequency corona discharge.
- It is realized in the form of a special ELFI module which makes a part of a plant that burns fossil fuel.
- ELFI modules can be added to existing plants as a by-pass, so that it does not obstruct their function.
- SO_2 and NO_x are simultaneously removed from flue gas and converted into a useful artificial fertilizer.
- Waste materials are not produced by this technology, and the problem of permanent storage of undesired products does not exist.
- It consumes less electric energy for its functioning than other technologies.
- It is the only commercially efficient technology of this kind in the world.
- It produces high quality artificial fertilizer which has a commercial value.
- Removal of SO_2 and NO_x from flue gases contributes to protection of human environment from these pollutants, what directly affects favorably improvement of health of human population, prevention of creation of acid rains, and protection of buildings and metal constructions.
- It can be used in all plants that burn fossil fuels: electric power plants, mills, chemical industry, oil industry, thermal plants, and other plants.

ELFI

New original technology for simultaneous removal of sulphur dioxide (SO_2) and nitrogen oxides (NO_X) from flue gases in plants which burn fossil fuel



Principle of operation

A flue gas of known characteristics (temperature, gas flow rate, and humidity) enters the plasma chemical reactor PCR, in which SO_2 and NO_x are being removed with addition of ammonia (NH_3) in stoichiometric ratio and converted into artificial fertilizer. Fertilizer is collected in bag filters BF1 - BF3, and flue gas without SO_2 and NO_x is passed through the stack S to atmosphere.

S - stack	MC - gas mixing chamber
FG - flue gas	PCR - plasma chemical reactor
V - valve	GA - gas analyzer
F - fan	PA - particle analyser
P - pressure gauge	3PTC - 3 PhaseTesla coil
T - thermometer	BF - bag filter
SC - spray cooler	RV - regulation valve
FM - pressure meter	PR - pressure regulator

The sole owner of the patents and pattent application as well as the sole author of the ELFI technology is

- **Dr. Vujo Miljević, Research Professor of the Vincha Institute of Nuclear Sciences**
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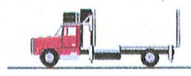
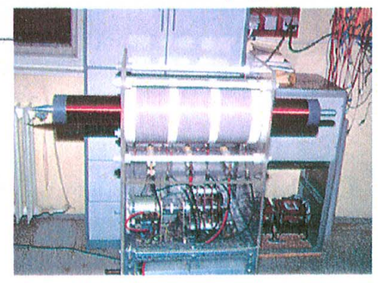


Laboratory type of 3P-TC



Results achieved

- New technology is the results of fundamental research on which ELFI is based are presented on international scientific meetings.
- Laboratory studies completely fulfilled foreseen expectations for filtering and gave numerous data necessary to project pilot plant.
- The patents for ELFI technology were granted by: (1) the European Patent Office on 21 January 1998, European Patent No. 0602354; (2) the United States Patent and Trademark Office, United State Patent No. 5,807,526, Date of Patent Sep. 15, 1998; (3) Serbia & Montenegro, Intelectual Property Office, Patent No. 48832, Date 16 July 1998. The request for examination of the Japanese Patent Application No. 291184/1993 have been filed on October 26, 2000.

6)

ИНОВАЦИОНИ ПРОЈЕКАТ 2005

Подаци о пројекту:

Руководилац пројекта: Др Вујо Миљевић
Област пројекта: 1
Број пројекта: 8004
Извештај: ИП 2005

НИО реализатор: ИНН "ВИНЧА"

ТЕ "Никола Тесла", Обреновац, Корисник итражинања

Министрарство науке и заштите животне средине је прихватило пројекат и високо га оценила, на првом месту из екологије. Пошто није била затворена финансијска конструкција - Термо електрана "Никола Тесла" Обреновац, једина није уплатила партиципацију за израду пилот постројења, пројекат није у целини прихваћен, али је прихваћен истраживачки део пројекта-истраживачи и опрема

Medjutim, United State Steel Corporation, Pitsburgh, U.S.A. se interesuje za ELFI tehnologiju, sa kojima sam u kontaktu.

Главни делови пројекта ће бити овде изложени, због информисаности али и због чињенице да у лабораторији за атомску физику уу Институту у Винчи се већ дуже времена ради на екологији.

ЦИЉ ИСТРАЖИВАЊА

- Главни циљ истраживања је освајање производње постројења за чишћење димних гасова од CO2 и HOx на бази резултата добијених истраживањима на ЕЛФИ пилот постројењу**,** које ће да ради у реалним условима на термо електрани.

- Освајање технологије производње индустријских постројења – модула од 100 MW омогућиће њихов пласман на домаћем и иностраном тржишту обзиром да је ЕЛФИ технологија патентима заштићена у У.С.А., Јапану и у десет земаља европске патентне уније и СЦГ.

- Поред тога минерално ђубриво, које се добија као споредни производ применом ЕЛФИ технологије, пошто је дефицитарно и код нас и у свету, може да се пласира у већини земаља.

- Од значаја је и образовање кадрова у области екологије.

О отклањању угљлен диоксида (CO_2)из димних гасова Елфи технологијом

Познато је да угљен диоксид и водоник у гасној фази под високим притиском и на високој температури може да се конвертује у метанол (Токуо Gas Co., LTD Public Relation Section, Section1-5-20 Kaigan, Minato -ku105, Japan). Међутим, то је класична метода са малом ефикасности, па изгледа да није индустријски применљива. Угљен диоксид је гас чије присуство у атмосфери производи "ефекат стаклене баште", тако да је његово уклањање из атмосфере корисно, а конверзија у метанол је врло корисна. Метанол има велику примену у хемијској индустрији а такође се користи као извор енергије, тј. у многим земљама се меша са бензином, као гориво за аутомобиле.

Елфи технологија је ново истраживачко решење проблема заштите човекове животне средине у складу са Кјото протоколом. На редукцији емисије штетних гасова посебно са "ефектом стаклене баште".Пројекат се базира на плазма хемији.То је релативно нова област из физике и хемије која има многе корисне примене.На пример, могуће је добити дијамант у плазма хемијском реактору, на ниском притиску и практично на собној темпепатури, што у природи није случај Елфи пројекат за чишћење гасова од сумпор диоксида (SO_2 и азотних оксида (NO_x) се може проширити и на угљен диоксид (CO_2), на бази нових примењених и развојних истраживања ЕЛФИ технологије.

ПОСЛОВНИ ПЛАН СА ЕКОЛОШКЕ ТАЧКЕ ГЛЕДИШТА САМО ЗА SO_2 И NO_x

Пословни план се базира на чињеници да се помоћу ЕЛФИ технологије димни гасови чисте од SO_2 и NO_x. Применом ЕЛФИ технологије постижу се следећи резултати:

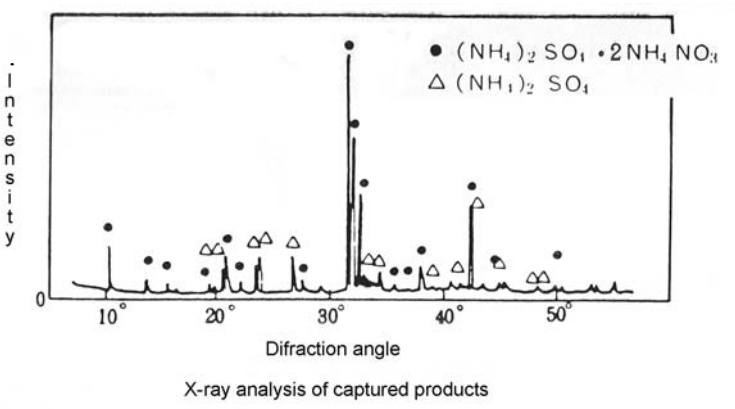
1. Добија се димни гас без SO_2 и NO_x,
2. споредни производ филтрирања је минерално ђубриво,
3. побољшава се здравље становништва,
4. заштита шума од киселих киша,
5. заштита металних конструкција и грађевинских објеката,
6. повећава се комфор животних услова,
7. осваја се производња уређаја за чишћење димних гасова од SO_2 и NO_x,
8. школовање кадрова.

1) ЧИШЋЕЊЕ ДИМНИХ ГАСОВА ОД SO_2 И NO_x.

У Институту за нуклеарне науке ВИНЧА у Винчи развијена је нова технологија за симултано чишћење димних гасова од сумпор диоксида (SO_2) и азотних оксида (NO_x) из постројења која сагоревају фосилна горива, као што термоелектране, топлане, нафтна и хемијска индустрија, металуршки комбинати и слично. ЕЛФИ технологијом се SO_2 и NO_x, уз додатак

амонијака, преводе у МИНЕРАЛНА ЂУБРИВА одличног квалитета која могу директно да се користе у пољопривреди, посебно за житарице. Ови подаци су добијени вишегодишњим истраживањима у различитим лабораторијама у свету, посебно у У.С.А. и Јапану.

Сл.1 Ренгенска анализа минералног ђубрива



X-ray analysis of captured products

2) ПРОИЗВОДЊА МИНЕРАЛНОГ ЂУБРИВА

Примера ради, само на термоелектрани ТЕНТ - Обреновац може се добити око 300.000 тона минералног ђубрива годишње мимо нормалне производњ струје. Значајне количине минералног ђубрива могу се добити и из других постројења која емитују димне гасове, тј. из постројења металске индустрије, хемијске индустрије, прераде нафте и слично, па се може очекивати да би проблем снабдевања пољопривреде минераним ђубривом применом ове технологије био решен а земља ослобођена увоза, а можда би преостало и за извоз – видети слику у прилогу.
Финансијски гледано термоелектране, металска индустрија и друга слична постројења, поред добити остватене продајом основних производа, остварују добит продајом минералног ђубрива без улагања у сировине за производњу јер, у овом случају, сировине су CO2 и HOx, који су иначе отрови и стварају еколошке проблеме. Једина компонента која се додаје је амонијак у стехиометријском односу.
Постоји погрешно убеђење да је за смањење загађења атмосфере полутантима (SO2 и NOx) неопходно инвестирати неповратно велика финансијска средства, па је са економске тачке гледишта нерентабилно чишћење димних гасова. Међутим, савремене технологије чишћења димних гасова то демантују.

(nastavlja se)

Подаци за ТЕНТ су следећи :
- Производна цена струје на прагу ТЕ : 1 кWh = 1,25 дин. , што за годишњу производњу износи:

2.062.500.000,00 динара

- Минерално ђубриво – подаци су добијени на основу јапанске донације за минерално ђубриво 2001. године.
300.000 тона минералног ђубрива годишње:
цена за 1 тону = 153.8 УС$, или
укупно **46.140.000,00** УС$,
по садашњем курсу за 1 УС$ = 62 динара добија се
бруто: 3.976.680.000,00 динара ,

3) ПОБОЉШАЊЕ ЗДРАВЉА СТАНОВНИШТВА

Загађење ваздуха емисијом SO2 и NOx постројењима која сагоревају фосилна горива представља врло озбиљан проблем са далекосежним негативним последицама по човечанство.

Емисија SO2 из термоелектрана у свету износи око 100.000.000 тона годишње, а укупна емисија NOx износи преко 50.000.000 тона годишње (подаци из 1995. године).
Озбиљност проблема загађивања ваздуха овим полутантима може се илустровати еквивалентом сумпорне киселине од 125.000.000 тона годишње, која се добија конверзијом емитованог SO2, и еквивалентом азотне киселине од 40.000.000 тона годишње коју даје емитовани NOx, што у средњем износи око 30 килограма годишње киселина по глави становника земљине кугле само из загађивача које емитују термоелектране.

Угаљ у производњи електричне енергије учествује са преко 50% и представља око 70% светских резерви фосилних горива, тако да ће остати још дуго главни извор енергије. Процењени трошкови оштећења изазваних дејством SO2 и NOx износе око 80 US$ по становнику годишње који се састоје од трошкова лечења и губитака услед отсуствовања са посла, трошкова оштећења флоре и фауне и материјалних добара.
Процењени трошкови оштећења у U.S.A. износе 80 US$ годишње по становнику. Ако се у нашем случају узме да има 10.000.000 становника, добија се сума од 800.000.000 US$ годишње.

4) ЗАШТИТА ШУМА ОД КИСЕЛИХ КИША

Угаљ који сагорева у термоелектранама даје око 80% емисије CO2, који је главни узрочник киселих киша, и 46% емисије HOx, који је такође чинилац киселих киша али и урбаног смога.

(nastavlja se)

Услед деловања киселих киша, данас поједини делови земљине кугле личе на "месечев пејзаж". Такође и у нашој земљи је огољено на хиљаде хектара шуме са тенденцијом повећања уништавања шума.

5) ЗАШТИТА МЕТАЛНИХ КОНСТРУКЦИЈА И ГРАЂЕВИНСКИХ ОБЈЕКАТА

Погубно деловање SO2 и NOx, односно киселих киша одражава се и на материјална, културна и друга цивилизацијска добра. Од дејства киселих киша пропадају металне конструкције, грађевински објекти, флора и фауна и други разни објекти за које је нанету штету тешко проценити.

6) ПОВЕЋАВА СЕ КОМФОР ЖИВОТА СТАНОВНИШТВА

Коришћењем ЕЛФИ технологије у постројењима која сагоревају фосилна горива се затвара природни циклус: из земље се добија угаљ, сагоревањем угља, на пример, у термоелектранама, се добија најквалитетнија и најкомформнија електрична енергија а штетни састојци се преводе у минерална ђубрива која се поново враћају у земљу и повећавају производњу хране. При томе се поред добити остварене продајом електричне енергије остварује и добит од продаје минералног ђубрива а димни гас без SO2 и NOx је сада »споредни производ« или, са тачке гледишта екологије, ово је практично самофинансирајућа заштита човекове околине.

7) ОСВАЈА СЕ ПРОИЗВОДЊА УРЕЂАЈА ЗА ЧИШЋЕЊЕ ДИМНИХ ГАСОВА ОД SO2 И NOx

Овај пројекат, поред супституције увоза минералног ђубрива, ствара могућности домаћој индустрији отварањем великог броја нових радних места и отвара могућности извоза индустријских постројења на домаће и иностранo тржиште, као и образовање кадрова у тим областима.

Примера ради, модул индустријског постројења од 100 MW на бази постојеће, лошије "e-beam" технологије, кошта око 20 милиона US$ (подаци од Међународне Атомске Агенције).
У развијеном делу света потребно је бар 12.500 индустријских модула од 100 MW. У нашем случају, предпоставимо да извеземо 100 модула, по цени од 10.000.000 US$ (50% од предходне цене) добија се око 1.000.000.000 US$.

8) ОБРАЗОВАЊЕ КАДРОВА ИЗ ОБЛАСТИ ЕКОЛОГИЈЕ

У организацији Уједињених Нација у Кјоту, у Јапану, од 1. до 10. децембра 1997 године одржан је Самит на коме је учестовало око 150 држава из целог света који је био посвећен глобалној заштити природне околине на целој

земаљској кугли, посебно од гасова са ефектом “стаклене баште”, јер је садашње стање екологије веома критично.
За решење ових еколошких проблема предвиђа се сума од 150 милијарди долара Наравно, један део проблема које треба решавати се односи и на нашу земљу. Школовањем кадрова из области екологије омогућило би да се спремно укључимо у решавање тих проблема.

За ставке 4) , 5) и 8) нема података .

ЗАКЉУЧАК

- ЕЛФИ технологија је нова, оригинална технологија за симултано одстрањивање сумпор диоксида (SO2) и азотних оксида (NOx) из димних гасова добијених сагоревањем фосилних горива.

- ЕЛФИ технологија се базира на новом типу високофреквентног корона пражњења када се као извор за напајање користи Теслин трансформатор.

- У светској литератури овај тип пражњења је први пут публикован у радовима аутора ЕЛФИ технологије, као и у патентима које је аутор заштитио у земљи и иностранству.

- Истраживања у области високофреквентног корона пражњења са Теслиним трансформатором представљају оригинални допринос аутора повећању фонда светског знања.

- Високофреквентно корона пражњење испуњава целокупну запремину плазмахемијског реактора, тако да се велики протоци димног гаса могу обрађивати ЕЛФИ технологијом.

- Да би се добили репродуцибилни резултати у плазма хемијском реактору развијен је нови тип Теслиног трансформатора са трофазним напајањем.

- Главни циљ иновационог пројекта је освајање производње индустријских постројења за чишћење димних гасова од SO2 и NOx на бази резултата добијених истраживањима на ЕЛФИ пилот постројењу које ће да ради у реалним условима на термоелектрани.

- Комплетан лабораторијски уређај на коме је изучавана ЕЛФИ технологија је урађен у Институту ВИНЧА од домаћег материјала, што значи да је наша индустрија способна да производи и ЕЛФИ индустријска постројења.

- Стечена знања мултидисциплинарног тима истраживача из Института ВИНЧА на изградњи пилот постројења могу да представљају и почетну

фазу у правцу формирања еколошке лабораторије у Винчи, за експериментална и теоријска истраживања заштите човекове околине, као и других примена овог новог типа високофреквентног пражњења кој се напаја помоћу Теслиног трансформатора.

- Од посебног значаја је и образовање кадрова у области екологије.

7)

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