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Title

Integration and testing of TEMO-IPP incineration power plant on a mobile platform

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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

عن أبي موسى رضي الله عنه قال : قال رسول الله صلى الله عليه وسلم (مثل ما بعثني الله به من الهدى والعلم كمثل غيث أصاب أرضا فكانت منها طائفة طيبه قبلت الماء فأنبتت الكلاء والعشب الكثير وكان منها أجادب أمسكت الماء فنفع الله بها الناس فشربوا منها وسقوا وزرعوا وأصاب طائفة منها أخرى إنما هي قيعان لا تمسك ماء ولا تنبت كلاء فذلك مثل من فقه في دين الله ونفعه ما بعثي الله به فعلم وعلم ومثل من لم يرفع بذلك رأسا ولم يقبل هدى الله الذي أرسلت به)أخرجه البخاري

اللهم انفعني بما علمتني ، وعلمني ما ينفعني ، وزدني علما

To my lovely family
Thank you for your love, support, help, and companionship.

Thanks to every doctor helped me over the past five years and wished them to be always a source of pride for the Lebanese University.

Thanks to Dr.Hamed El khatib to interest us throughout the training period lasting passion for achieving results and good positive reaction that contribute to raising the level of physics branch in faculty of sciences

NOMENCLATURE

E0 gradient disrupter V/m

E1 electric field against the V/m collector plates

f roughness factor of the small radius of curvature SD

J electrode Surface current A/m^2

R distance wire-cylinder m

R0 small electrode diameters bend radius m

Reynolds number Re SD

Reff effective radius used in wire-plate geometry m

s inter-electrode half-distance (wire-plate geometry) m

V potential difference in space between electrodes

V -V0 potential difference of appearance of the corona

Vp volume of the particlem^3

α first ionization coefficient Townsend 1/m

ε0 dielectric constant of the vacuum F/m

δ air density SD

μ_{ion} electrical mobility of the ions in the drift region m^2/V. s

ABSTRACT

Some actors propose, as appropriate, classify incineration among the renewable energy sources, associations oppose the " greening " and recalled the pollution emitted by the waste treatment mode. So due to this conflict, it is necessary to solve the pollution problem.

To attain this object, a smoke processing system is developed with each incinerator. Physical and chemical treatment of smoke in incineration power plant (at Ras-Nhach) is the essential purpose of this study.

First we described the operation of incineration, specified the incinerated waste, indicated the released gases and their effects on the environment. Afterward, we have distinguished two types of smoke treatment: physical and chemical. In this time, we have tried to create a design of the system of treatment by using FreeCAD, and testing its efficiency to minimize the rate of toxic gas in fume by using a gas analyzer. Finally, completing of integration by adding of inlet/outlet waste on mobile platform.

Keywords: alternative energy, incineration power plant, waste handling, flue gas purification, FreeCAD, environmental impact.

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INTRODUCTION

The waste produced by human activities have grown considerably with the industrial revolution of the nineteenth century and the consumer society of the twentieth century. If the word means has a negative connotation, they do not mean inevitable: they can be reduced at the time of manufacture, processing into other products, and can also be an important source of energy in an incinerator power plant.

Indeed, many factors are involved in accepting or rejected the power plants, for example, the residues after combustion. One of these residues and the most feared is fumes; gaseous compounds can be a danger to health and the environment. This is the case of acid gas and dust.

To accepted this method of waste disposal, current incineration plants must be equipped with a fumes filtration system. So the quality of the filter is subject to controversial environmentalists concerned with the issue of pollution.

Many studies have been done on the subject to get a complete and integrated system for treating fumes physically and chemically, and developed it to be available on most gases that have constituted the fumes of incineration. However, our objective is to create a simple design of system of filtration by FreeCAD and collect a data about the concentration of toxic gas in the fumes before and after treatment in order to know its efficiency. this system will be implemented at Rasnhach power plant. Many difficult occurred us during the implementation and testing.

As we said many previous study investigated this subject, but many questions remain open: What is incineration power plant (description, specification and modeling) and how does it function? How will be treated its pollutants residues? what are the mains factors that indicate the suitable process?

We guide this study to address this question and you will find the answers next in this manuscript.

Working plan

In chapter 1, we search and look for information about a power plant by incineration in general and checking to the international and national standards about emissions.

In chapter 2, we specify and model our plant, and we also use the programs FreeCAD to create the suitable system of treatment. The second part in chapter 2 is to making a covering to the plant and completed it at mobile platform.

In Chapter 3, trying to get data from a analyzer, dedicated for the explication and the discussion of all results obtained during our project.

Finally, we will end in chapter 4 by a small conclusion and presentation of our perspectives.

1. CHAPTER 1: BASICS

1.1 DEFINITION OF THE OPERATION OF INCINERATION PLANTS

An incineration plant and household waste (WTE) is a large oven for receiving household waste to be incinerated. Combustion, which takes place between 850 and 1000 ° C, reduces the waste volume by 90%. In doing so it produces pollutants residues potentially dangerous. They are of two types: solid residues, called clinker, are recovered in the furnace vessel. Depending on their nature, they may or may not be decontaminated and recycled. In all cases, they are treated according to strict standards to prevent pollution associated with their production and operation.

The second type of residues produced by waste incineration is the best known and most feared: these fumes. Because burning waste creates toxic fumes laden with dioxins, furans, heavy metals or sulfur dioxide and nitrogen. That is why the burning of waste in open air, or unfiltered smoke, is a disaster, so that ecological health. Current incineration plants are they equipped with systems to filter the fumes and recover the so-called REFIOMS (treatment residues from incineration fumes garbage), ultimate waste which are treated as such in special circuits. So the quality of the filter, and therefore the smoke pollution level which is effectively rejected by the stack, determines the level of toxicity of a given incinerator.

The incineration of one ton of garbage left after burning 2-5 kg of fly ash collected in filters and 300 kg of clinker. The REFIOM are sewage waste incineration fumes garbage (about 2-3% of the mass incinerated). They consist of dusts called fly ash and pressed sludge called filter cake. The bottom ash (bottom ash from household waste) is the solid residues from incineration, that is to say, the mineral part of the waste (about 10% of the initial volume of incinerated waste). the result of the combustion of 1 ton from household waste:

700 kg of gas,

300 kg of solid residues including 30 kg of ash (1)

1.1.1 PRODUCTS OF OXIDATION

The incineration is a decomposition of the material oxidation, with five types of programs:

- Water.
- Gas: CO, CO_2, NO_x, SO_2.
- Mineral Dust (ashes).
- Heavy metals: lead, copper, mercury, cadmium, nickel, arsenic.
- Organic Molecules: carbon, chlorinated organic compounds (dioxins and furans ...).

Elements	
Dust	1500-5000 mg/Nm^3
CO	20-50 mg/Nm^3
HCl	800-2000 mg/Nm^3
SO_2	20-200 mg/Nm^3
NO_x	200-300 mg/Nm^3

Table 1: composition of fumes produced by 1 ton of waste by incineration (5000-6000 Nm^3)

oxidising	**NO**	**SO_2**
Coal	**6**	13
Natural gas	**0.1**	1.7
Petroleum	**12**	4
Burning waste	**5.4**	0.8

Table 2:Comparison of emissions to product 1 MWh.

1.1.1.1 DIVISION OF EMISSIONS

Emissions are divided into three groups depending on their size and the degree of severity:

1* Non-harmful to the environment: nitrogen (N_2), oxygen (O_2), and water vapor (H_2O)

2* Harmful to the environment because they cause acid rain (Acid gases): nitrogen dioxide (NO_2), nitrogen oxide, (NO), Sulfur dioxide (SO_2), carbon dioxide (CO_2)

3* Toxic gases: Furans, dioxins, heavy metals (Hg (from batteries), cadmium, plumb, zinc)

However, almost 95% of emissions are gazes from the first group which mean that they are not harmful to the environment and non-toxic.

For example, at temperature of 850 ℃ and with amount of oxygen 6% of the air, we obtain:

Carbon dioxide (CO_2) between: 186 mg/m^3 and 96mg/m^3.

Nitrogen dioxide (NO_2) between: 320 $mg/m^3$and 140 mg/m^3

Furans, dioxins, between: 21 $mg/m^3$and 5 mg/m^3

Sulfur dioxide (SO_2): 67 mg/m^3. (2)

1.1.1.2THE NEW STANDARDS ABOUT EMISSIONS

EU directives on emissions from various boilers, dependent the type of fuel and the size of plants. The following list is a short summary of the requirements on emission to atmosphere for waste burning plants from the two EU directives 2001/80/EG and 2000/76/EG. (3)

Dust**:** 10 mg/m^3.

SO_2: 50 mg/m^3.

NO_x: 200 mg/m^3.

HCl: 10 mg/m^3.

HF: 1 mg/m^3.

Cd,Tl: 0,005 mg/m^3.

Hg: 0,005 mg/m^3.

Other trace metals (Pb+Cu+Mn+Ni+Sb+As+Co+Cr+V): 0,5 mg/m^3.

Dioxins : 0,1 ng/m^3.

With 1 ng = 1/$10^9$of gram

parameter	**half-hour mean value**	**European Directive 2000/76 / EC of 04/12/2000 and French Decrees of 20/09/2002 and 03/08/2010**	**refectural stopped operating permit Flamoval of 17/06/2009**
Total dust	1-20	10	3
Hydrochloric acid (HCl)	1-50	10	7
Hydrofluoric acid (HF)	10	1	0.7
Sulphur dioxide (SO_2)	1-150	50	15
Carbon monoxide(CO)	5-100	50	30
total organic carbon (COT)	1-20	10	8
Mercury (Hg)	0.001-0.03	0.05	0.04
Cadmium + Thallium (Cd + Tl)	-	0.05	0.04
Other heavy metals (Sb + As + Pb + Cr + Cu + Co + Mn + Ni + V)	-	0.5	0.4
Oxides of Nitrogen (NOx)	40-300	200	50
Ammonia (NH_3)	-	30	10
Dioxins and furans	0.01-0.1	0.1	

Table 3: Emission limit values in mg / Nm^3 to 11% O_2 dry gas According to EC 20/09/2010 to an incinerator >6 ton/h

In Lebanon:

	<1 ton/h	1-3 ton/h	>3 ton/h
Elements (polluants)	Maximum value(mg/m^3)	Maximum value(mg/m^3)	Maximum value(mg/m^3)
Dust	200	100	30
Pb+Cr+Cu+Mn	-	5	5
Ni+As	-	1	1
Cd+Hg	-	0.2	0.2
Cl (HCl)	250	100	50
F (HF)	-	4	2
SO_2	-	300	300

Table 4: Emission limit values in mg /m^3 to respected (Lebanese environmental ministry

1.1.1.3THE EFFECTS OF SOME EMISSIONS

- DIOXINS:

High stability, slow elimination, fat soluble (ease of accumulation in fat) and very slightly soluble in water, very persistent in the environment. They are deposited on soil, grass and fodder consumed by animals, are fixed in their fat and accumulate in humans through the food chain. (Dairy products, meat, eggs, fish and breast milk for example (4)

- FURANS

polychlorinated or PCDF are a family of cyclic chemical molecules (aromatic heterocyclic) emitted during incineration of PCBs. They differ from dioxins by the presence of a single oxygen atom in the central ring. Some of them are toxic to humans and the environment. Like almost fireproof electrical insulation and excellent dielectric and thermal conduction properties, PCBs were used extensively from in: electrical transformers ;capacitors ; power switches on. (5) (1)

- NITROGEN OXIDE (NO_x) AND NITROGEN DIOXIDE (NO_2)

Contribute to the formation of acid rain, degrading the soil and vegetation. They increase nitrate concentration in soils and surface waters (eutrophication). They also contribute to the formation of ozone.

- THE OZONE

The ozone is harmful to a variety of commercial crops and natural plant species. It is a powerful oxidant that degrades the quality of the rubber, textiles ... Even at low levels, it also contributes to global warming.

- SULPHUR DIOXIDE (SO_2)

Contributes to acid rain, degrading soils and vegetation. It also threatens certain types of stones used in construction. (6)

- CARBON MONOXIDE (CO)

Carbon monoxide contributes to the formation of ozone. It also changes to carbon dioxide, which is also directly emitted during combustion. CO2 has no direct impact on health, but this is the most abundant anthropogenic greenhouse gas. (7)

1.2 TREATMENT BY INCINERATION

The pollutants covered are the acid gas and dust, heavy metals, nitrogen oxides and dioxins, treated with additional processes. The neutralizing reagent can be injected dry as a powder (lime or sodium bicarbonate), by semi-wet (sprayed lime milk), or in a wet scrubber with sodium hydroxide. These processes generate waste products, mainly composed of fly ash dust). The REFIOM stabilized before being stored in class CSD 1. These methods allow purifying more than 98 incinerations of household waste fumes.

(Note: REFIDI are the fumes purification of residues from industrial waste incineration).

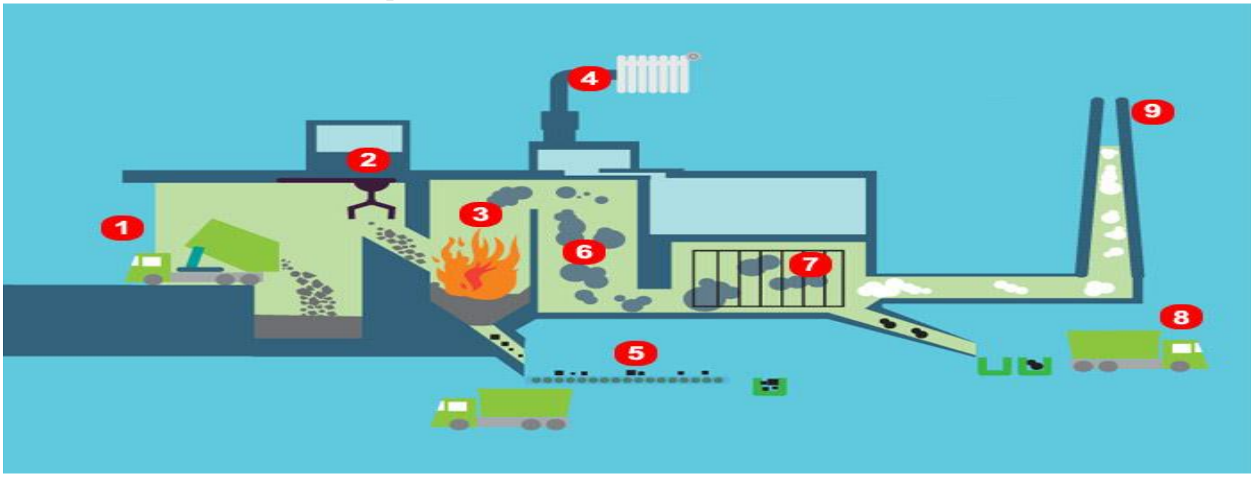


Figure 1: steps of treatment by incineration

- 1 / trucks emptying garbage into the pit
- 2 / gripper transports the waste to the furnace
- 3 / the furnace is fed continuously at more than 1000 °C
- 4 / the exchange of heat between the hot air of the oven and the water circulating in the pipes will produce steam that is sold to nearby industrial plant
- 5 / metals are extracted from bottom ash to be recycled. Clinkers are valued under road layer
- . 6 / the fumes are treated by injection of lime and activated carbon
- 7 / the fumes are dusted after passing through filters
- 8 / Fume Treatment Residues of Household Waste Incineration (REFIOM) are sent to landfill

• 9 / the chimney are equipped with analyzers for measuring the quality of air emissions continuously.

1.2.1 FUMES FACTORS

The following is a list (not exhaustive) of general elements to consider when choosing the flue gas treatment system: waste type, temperature of the flue gas, composition of the combustion gases and ranges of variation emission limit values to respect restrictions on discharges of aqueous effluent vis-a-vis requirements of the visibility of the field plume and available space availability and cost of outlets for the residues / recycled compatibility with the components of the existing process (in the case of existing installations) availability and cost of water and other reagents possibilities of energy supply (e.g. providing the heat recovered by the laveurs-condenseurs) allocation of incentives / subsidies for energy exported acceptable waste treatment cost (both according to market criteria policies) reduced emissions by primary processes noise if possible, arrange the various components of the flue gas treatment system such that, proceeding from the boiler to the chimney, they require temperatures of becoming weaker gas. (8)

1.3 OVERVIEW OF FILTERING

*** Electrostatic**

20 kg of dust and ash per ton of waste in electrostatic precipitators, ash fly are electrified (ionized) and stick into electrodes of plate-shaped. These plates are hit automatically to recover the ashes into hoppers. In electrostatic precipitators, it captures 99.9% of fly ash (REFIOM). Once retrieved, they are stored in silos and then transported in landfills for final waste to be stabilized (mixed with "cement") and buried in watertight compartments.

*** The flue gas scrubbing**

The fumes then pass through two washing columns, one the other basic acid, which will trap the pollutants residual dust, heavy metals, chlorine, fluorine, sulfur oxides.

*** Dioxins**

It only remains to destroy dioxins and nitrogen oxides. The gases pass through a catalyst. It functions as the catalytic converter of a car. These pollutants are completely broken (their molecules are broken).

In contact with catalysts, the molecules of dioxins and nitrogen oxides are broken. The reactor is filled with several shaped catalyst layers of the "honeycomb" so that the contact surface with the flue gases to be as large as possible.

*** The output**

The plant discharges its chimney 68% air, 23% water vapor and 9% carbon dioxide. Other substances in trace amounts are monitored very closely.

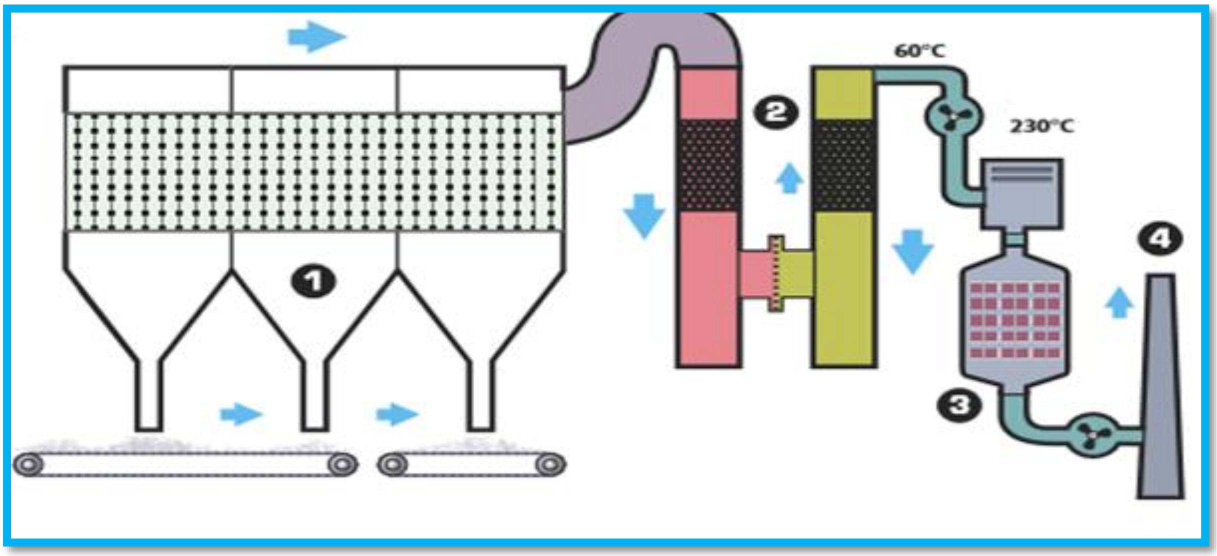


Figure 2: main steps of filtering (9)

Whitewash is widely used in industrial wastewater treatment as acid water neutralization reagent thereby precipitate **heavy metals** present in the effluent.

Dissociates into OH^- ions bind to metals to give insoluble metal hydroxides largely. Ca^{2+}can bind to phosphate or fluoride ions may be present in the effluent to produce calcium phosphate or calcium fluoride.

***Manufacturing**

One can make in small quantities quickly by heating a piece of chalk with a flame and then dilute the resulting powder in water. Then filtering the resulting mixture using a coffee filter, or through several thicknesses of absorbent paper in a funnel. The flame heating decomposed limestone chalk $CaCO_3$ (limestone or calcium carbonate, solid) CO_2 (carbon dioxide or carbon dioxide gas) + CaO (quicklime or calcium oxide, solid).

Hydration of quicklime gives the slaked lime according to the following equation:

$CaO + H_2O$ (water) → $Ca(OH)_2$, or calcium hydroxide (slaked lime, solid).

Calcium hydroxide is diluted in water, where it dissolves only very little, giving a true solution $Ca^{2+} + 2(OH^-)$, and an excess of undissolved hydroxide remaining in suspension in the water. This first step results in a whitish mixture known as milk of lime. To eliminate fraction undissolved suspended, the next filter whitewash. Finally reaches clear lime water.

But do not put too much carbon dioxide. It may be that, if we really introduced a large excess of carbon dioxide, the precipitate just dissolves $CaCO_3$ later, and that happens then the reaction: $\mathbf{CaCO_3 + CO_2 + H_2O \longrightarrow Ca2^+ + 2\,HCO_3}$, and solution cleared.

1.4 DUST

The black smoke (determined as such according to the associated sampling method) are carbonaceous particles of diameter less than 5 microns to about 0.1 microns' dust that are made of solid particles less than 75 microns, the largest emission source falling meadows.

1.4.1 ELECTROSTATIC

The operating principle of the simplest electrostatic filters, wire concentric cylinder, a high electric potential is applied to the wire, called emitter electrode. It is placed in the axis of the vertical cylinder, called the collecting electrode, which is connected there to ground. The gas carrying the particles to be removed enters through an opening located at the bottom of the cylinder, the particulate laden gas passes through the inter-electrode space

1.4.1.1 OPERATION

The operation of an electrostatic precipitator is relatively simple, but the description and understanding of all phenomena that come into play in the filtration is still largely a treaty study subject. Basically an electrostatic generates ions in the vicinity of a high voltage electrode of small radius of curvature. The gas is ionized by collisions between electrons accelerated by the electric field and by photoionization of the excited species. These ions are ejected from the surroundings of the electrode and are broadcast to the surface of particles to be filtered and to the collector electrode. By repelling the high voltage electrode of the same charge and attraction of the wall of the device connected to the ground, the particles migrate to it and settle permanently until a critical thickness. They then fall by mass effect or by vibration of the header plate. Commercially, two types of electrostatic precipitators are used: wire-cylinder electrostatic and electrostatic plate's wire. The wire-cylinder electrostatic precipitators are rather used when the recovered particles tend to form a liquid film to flow naturally and electrostatic wire-plate in the case of dust. Two classes are distinguished from electrostatic wire-plate, namely wire-plate one or two floors. When there is a single stage, the gas ionization and particles are at the same time in the whole volume of the facility, and when there are two stages, the particles are charged in a small area containing one or more discharge electrodes, and then deflected in a long plate-plate system. In the case of a cylinder thread, there is always one floor.

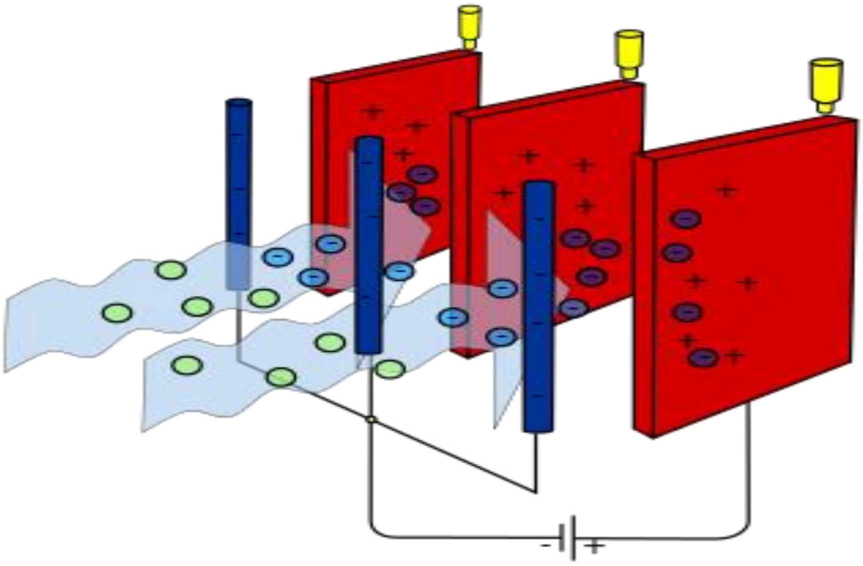


Figure 3: electrostatic precipitator

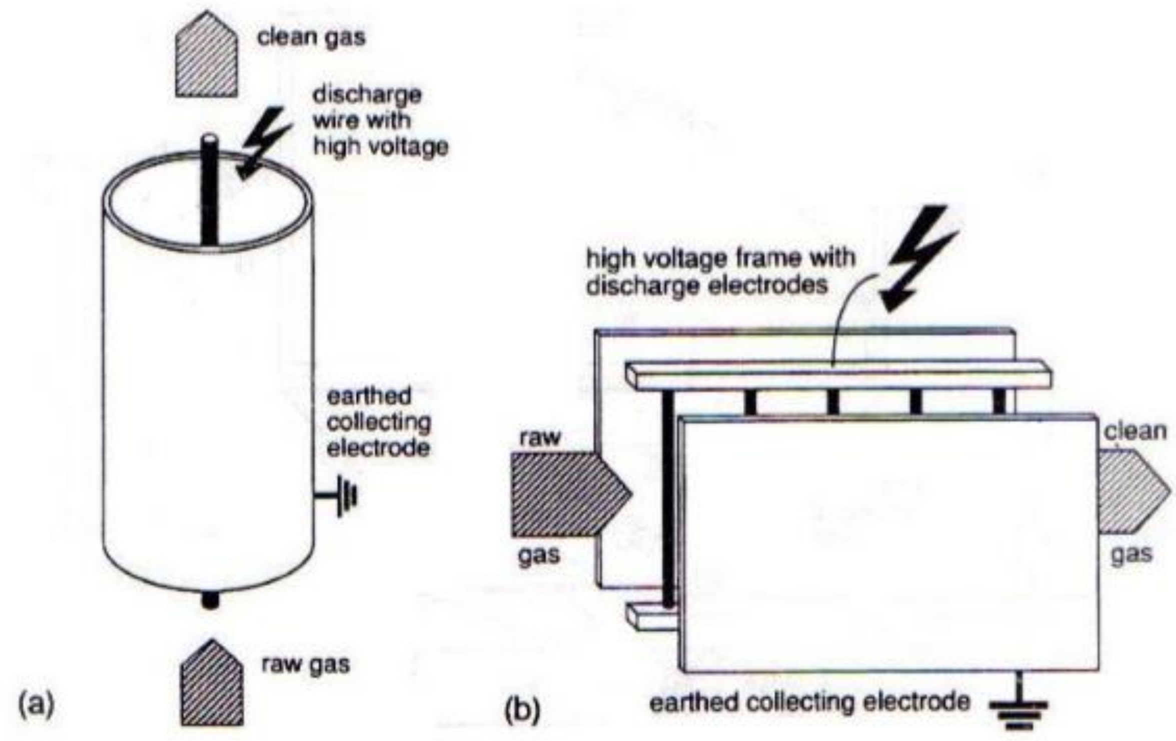


Figure 3a and 3b: the two main types of electrostatic precipitators: in (a) the wire cylinder, and (b) wire-plate 1 stage.

The parameters influencing the filtering particles are numerous and complicated to relate. The nature of the gas, its temperature and pressure influence the discharge phenomena and the minimum ionization voltage. The ionization of the gas causes a flow of ions in the vicinity of the high voltage electrode which disrupts the gas velocity field. The gas itself is more or less subjected to turbulence, and in the case of highly particle-laden gas, the movement thereof. The electric field is totally disrupted by the particulate and ionic space charge. The particles entrained by the carrier gas and the electric field, charge over time in an electric field and a payload field nonhomogeneous space. Finally, the space charge is partially driven by the carrier gas.

Electro-filtration treating the problem, beyond the simplified analytical approaches demand the resolution of a large number of differential equations highly nonlinear and coupled. Fortunately, in most cases it is possible to decouple the resolution electrostatic, fluid dynamics and particle dynamics, without much influence the final outcome.

1.4.1.2 OVERALL EFFICIENCY MODELS

The first design method electrostatic proposed by Deutsch and Anderson ignored the understanding of electrostatic phenomena, such as the structure and operation of the corona discharge or the kinetics of charge particles. This model is still widely used and gives very good estimates of the filtration efficiency of various geometries. This theory assumes that the particles are loaded instantly upon entering the electrostatic their saturation charge, the electric field is constant, and therefore the velocity of a particle to the wall collection is the electrostatic constant. Deutsch hypothesized that the radial particle dispersion coefficient is infinite and zero longitudinal. Cooperman (1984) improves the model taking into account a finite longitudinal dispersion coefficient and a possible re-entrainment of particles. The resolution by Cooperman is often considered perilous to use because of the very high turbulent dispersion coefficients used by the author. Leonard et al. (1980) use a finite and constant radial diffusion coefficient and derive their effectiveness from the convection diffusion equation with a flat radial velocity profile, which seems not to be appropriate near the walls. Zhibin and Guoquan (1992) use a global turbulent diffusion coefficient taking into account the electric and a wind profile Non regular speed in the flow. All global models, however, have a limitation, which is that each relationship giving the efficiency of the electrostatic filter is valid only for a certain particle size. In order to calculate directly the mass efficiency, Bai et al. (1995) develop a model assuming a lognormal distribution of the particles. This approach allows with minimal calculations have very good estimates efficiencies on polydipsersés aerosols. It appears that turbulent dispersion of the particles is critical phenomenon in modeling the efficiency of electrostatic precipitators.

The overall filtration efficiency may be calculated from the particle diffusion equation (x is in the flow direction, longitudinal direction y perpendicular to the wall of the electrostatic transverse direction Dp ,i coefficient dispersion in the direction considered)

$$D_{p,y}\frac{\partial^2 C}{\partial y^2} + D_{p,x}\frac{\partial^2 C}{\partial x^2} + v_e\frac{\partial C}{\partial y} - u\frac{\partial C}{\partial x} = 0$$

The theoretical efficiencies of Deutsch models Cooperman, Leonard, and Zhiblin are synthesized by Kim and are more or less simplified analytical solutions of this equation

$$De = \frac{v_e.L}{u.b}$$

$$Pe = \frac{v_e.b}{D_p}$$

$$R = 2.b \quad \textbf{wire-cylinder}$$

$$\eta_{Deutsch} = 1 - \exp(-De)$$

$$\eta_{Cooperman} = 1 - \frac{2.\exp(v_e.b/(4.D_{p,y}))}{\pi.(v_e.b/(4.D_{p,y}))}.\exp\left(-\frac{v_e^2.L}{4.u.D_{p,y}}\right)$$

$$\eta_{Leonard} = 1 - \int_0^1 P\left(\frac{\xi - De}{\sqrt{2.De/Pe}}\right).d\xi$$

$$\eta_{Zhibin} = 1 - \sqrt{\frac{Pe}{4.\pi.De}}.\int_0^1 \exp\left[-\frac{Pe}{4.De}(\xi - De)^2\right].d\xi$$

With v_e particle migration rate that takes into account the average electric field and the charge of the particles (which will be explained later in the physical part of the particles), b distance wire-plate,

R distance wire-cylinder,

L the electrostatic precipitator length,

u the average velocity of the gas,

and P is the absolute pressure.

Xiangrong (2002, [14]) offers an analytical solution of the turbulent diffusion equation charged particles in wire-plate geometry (Cartesian coordinate system), assuming zero flow to the high voltage son (symmetry condition. The efficiency is given by

the following relationship:

$$\eta_{Xiangrong} = 1 - \exp\left(-F\frac{v_e.L}{u.b}\right)$$

$$F = \frac{u}{v_e}.\frac{Pe_x}{2}\left\{\left\{1 + \frac{v_e}{u}\frac{Pe_y}{Pe_x}\left[1 + \left(\frac{2\theta}{Pe_y}\right)^2\right]\right\}^{\frac{1}{2}} - 1\right\}$$

$$\tan\theta = \frac{4(\theta/Pe_y)(F-1)}{(2.\theta/Pe_y)^2 + 2.F - 1}$$

The values of F and θ are found iteratively by successive approaches. The difference from the Deutsch equation is the inclusion of a longitudinal and radial diffusion.

Finally, Kittelson cites Hinds for a filtration efficiency in geometry wire-cylinder and in laminar flow of the type:

$$\eta_{Hinds} = \frac{2.\pi.\mu_{p,e}.V.L}{Q_v.\ln(R/R_0)}$$

These overall efficiency models are all assuming that the speed of particle migration (for a given size) is constant, which means that the electric field is constant and the charge of the particles is instantaneous. This is far from the case most of the time. In addition to these approximations are added all the hydrodynamic phenomena begin in the actual geometries and not taken into account (not homogeneous turbulence, wind power, etc.).

The turbulent diffusion equation of the particles is based on the Eulerian method called resolution of particle migration in electrostatic precipitators, which will be developed further.

A simplified method of calculation of the turbulent diffusion coefficient of the particles will be presented.

It is therefore dangerous to rely on overall efficiency models when we want to tackle the physical description of an electrostatic precipitator with a rather special geometry and industrial another, or that we are to respect all electrostatic aspects, which are not nearly as simple as do suggest hypotheses on the electric field and the charge of the particles of these models. We will now proceed to a detailed study of electrostatic phenomena encountered in electrostatic precipitators.

1.4.1.3 THE CORONA DISCHARGE

The corona discharge is a stable ionization of the surrounding gas of a small radius of curvature electrode connected to the high voltage. The ionization of the gas is due to the strong electric field surrounding the electrode surface. The corona discharge can be established by negative or positive polarity according to the needs. It is generally found that small units working in confined spaces and cold gases using a positive voltage, which although not very stable, generates little ozone, while larger installations for hot gas working negative voltage because the ozone is not stable at high temperature, and the discharge is more stable.

1.4.1.4 THE CORONA DISCHARGE: QUALITATIVE DESCRIPTION

Conduction in the gas is very different from the conduction in liquids or metals, where loads of travel is under a minimal difference of potential. Air naturally contains a small number of charged species due to cosmic rays and low ambient radioactivity. The resistivity is then about 1014 Ω-m. From a certain potential difference applied to the air, naturally enough electrons are accelerated between two molecular collisions to cause ionization of the gas, followed by electron avalanches. The resistivity of the air then decreases sharply to values of the order of 103 Ω-m. The onset of conduction in the air begins to fields of the order of 30 kV / cm. In a planar configuration, the establishment of conduction current causes immediately the occurrence of an arc.

if the thermal discharge current can be maintained, the effect itself crown is not observed. As the field is constant, any electronic avalanche is growing exponentially until breakdown. Using electrodes with very different radii of curvature, the electric field is very inhomogeneous and only a small volume of air around the electrode connected to the high voltage is ionized, it is the corona. The field called "disruptive" is achieved only in a very small sheath around the electrode small radius of curvature.

If the electric field is sufficiently intense and if the distance between two electron-molecule shock is sufficiently large, the kinetic energy of the accelerated primary electrons enables to remove an electron impact on neutral atoms of the gas. The kinetic energy of impingement of the electrons is measured in eV (1 eV = 1602.10 to 19 J). In between each clash, there is therefore release of one or more electrons and an exponential increase in their number: it is the electron avalanche. A portion of the shock also leads to the passage of neutral molecules electrons to higher roughly stable orbital. The relaxation of the excited state to the neutral state occurs by releasing a photon, which in the case of nitrogen is enough energy to ionize itself other molecules. This permanent-excitation is also responsible for the violet glow of the corona discharge. In the case of a corona, the kinetic energy of the electrons averaged a few electron volts, sufficient to ionize the nitrogen, oxygen and the vapor from the air to water. Parallel to this avalanche of negative charges to the anode, positive ions created migrate towards the cathode. Mass generally very high compared to that of the electrons, and having free course means very low, positive ions are only slightly accelerated and do not participate in the ionization of the gas. By against their low mobility locally created a very high load of space, disrupting the overall electric field.

1.4.1.5 NEGATIVE DISCHARGE

If discharge is easiest to describe, because the electron avalanche takes place in all or part of the inter-electrode space. The avalanche propagates from the cathode (small radius of curvature, connected to the negative high voltage) to the anode (large radius of curvature). The primary electrons in the vicinity of the cathode initiate an electron avalanche until the electric field, which has a very inhomogeneous become low enough so that the electron energy becomes insufficient. Ionization then stops and recombination events between neutral species and electrons take place during the migration of the electron cloud toward the anode. The arrival of negative charges is therefore in the form of an electronic cloud that follows a cloud of negative ions. The electronics then avalanche leaves behind a very strong positive load space, which will slowly migrate to the cathode. The strong polarity of the cloud will lead extracting secondary electrons from the surface of the cathode (Malter effect) and thereby renew the amount of electrons necessary for the corona discharge. The cathode surface condition affects many electronics extraction. The higher the field will be intense in the inter-electrode space, more landfills will be spread far and negative voltage discharge therefore ensures high ionization of the inter-electrode space. Because of the individual aspect of the electronic avalanche, we see that the current measured in a negative crown is pulsed, and the frequency increases with the applied potential. Electron recombination and thus the electronegativity of the gas goes much influence the stability of the discharge. In the case of a very little electronegative gas, any avalanche breakdown leads to, since no phenomenon diminishes the amount of electrons in the discharge (recombination). When the avalanche manages to connect the cathode and the anode, an ionized channel very low resistivity is formed, and allows the passage of a very high current. The gas in the channel is heated by Joule effect, the charges are redistributed to form a polarity medium at about neutral but highly ionized, the voltage abruptly drops: what is the thermal arc.

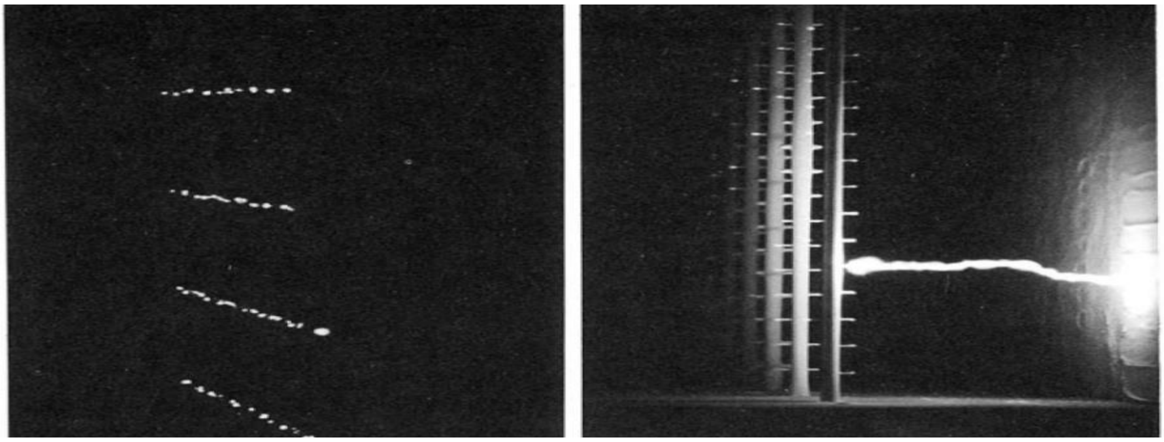


Figure 4:the corona discharge

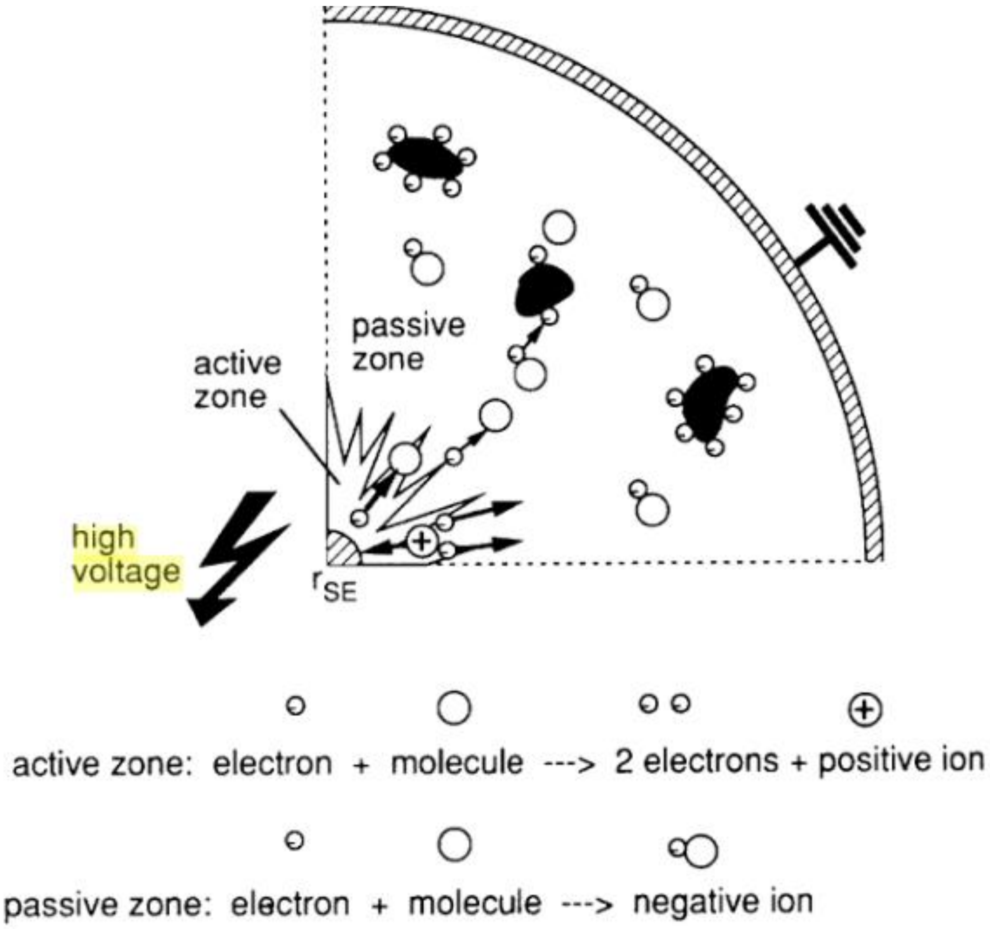


Figure 5: mechanism of discharge

1.4.1.6 POSITIVE DISCHARGE

In the positive discharge, the anode is the small radius electrode. The anode attracts to it the primary electrons and avalanche occurs the inter-electrode space towards the center of the device, in fact a very small volume (due to the considered cylindrical geometry). The crown is much better defined than in negative voltage, and the discharge current is almost continuous. The positive charges created then slowly migrate towards the cathode. The regeneration of the primary electrons takes place mainly by excitation of an unstable form of nitrogen in the form of a high energy UV photon which allows this phenomenon. The de-excitation is not instantaneous; the phenomenon of positive discharge is relatively steady over time. A lot of edge, the positive discharge seems much more stable. However, the positive charges created in the crown have very low electrical mobility and profoundly disrupt the electric field of the interelectrode space. From a certain load space, the field generated by it is of the same order of magnitude as the field generated by the high voltage, and the crown can self-propagate by electronic darts or streamers. These darts have a very high probability of spread to the cathode and an electric arc. It is found experimentally that the inter-electrode medium is very quickly saturated with positive ions and the breakdown occurs at relatively low currents. The positive discharge is more unstable equivalent current and low electric mobility of the positive ions that for the same potential, the positive discharge current is lower than negative voltage. In the positive discharge finally, the region of strong electric field contains few ions, chemical reactivity within this ring is reduced.

1.4.1.7 CURVES CURRENT-POTENTIAL

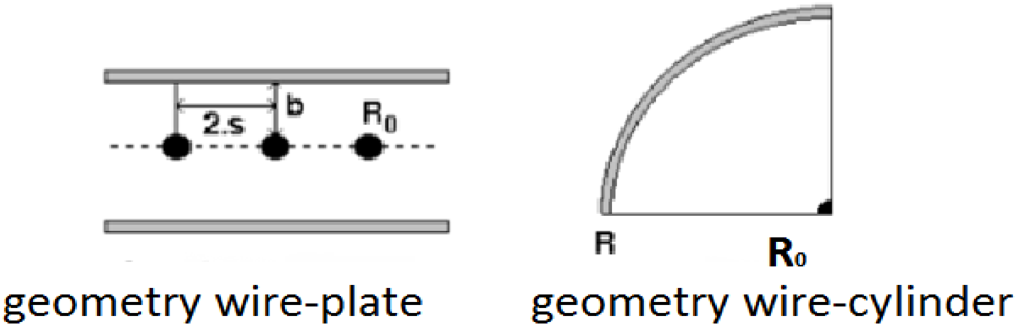
Gradient disrupter

The foregoing description of the corona is valid from the time the kinetic energy of electrons in the air is sufficient to cause ionization of the gas molecules, i.e. the reduced scope is sufficient. Peek offers a semi-empirical equation for giving the minimum air ionization field as a function of the geometry of the system (peek cited by Kaptzov):

$$E_0 = 3{,}1.10^6.\delta.f.\left(1+\frac{0{,}0308}{\sqrt{0{,}5.\delta.R_0}}\right) \textbf{spherical geometry}$$

$$E_0 = 3{,}1.10^6.\delta.f.\left[1+0{,}0308\left(\frac{1}{\delta.R_0}\right)^{\frac{1}{2}}\right] \textbf{for a cylindrical wire}$$

The figure recalls the geometric conventions used.



geometry wire-plate geometry wire-cylinder

Figure 6:geometry of wire

Geometry current wire cylinder

Townsend gives linear relations between the voltages applied to the current geometry wire cylinder for low currents in the air:

$$I_{linéique} = \frac{8.\pi.\mu_{ion}.\varepsilon_0}{R^2 \ln\frac{R}{R_0}}.V(V-V_0)$$

$$V_0 = E_0.R_0.\ln\frac{R}{R_0}$$

This relation is valid until a current criterion given by Townsend:

$$C_I = \left(\frac{R}{E_0.R_0} \right)^2 . \frac{J.R}{\varepsilon_0 . \mu_{ion}} << 1$$

Beyond this limit, Townsend proposes to make the following relation:

$$\sqrt{1 + C_I} - 1 - \ln \frac{1 + \sqrt{1 + C_I}}{2} - \frac{V - V_0}{V} . \ln \frac{R}{R_0}$$

This is much less obvious to use. In the case of our ESP, switching from one relation to another occurs to 1 mA discharge current (for a matrix of 20 cm), but results in very small differences in fine, which does not justify its routine use.

Current wire-plate geometry:

In wire-plate geometry for low discharge currents, Cooperman offers an alternative to wire-cylinder

$$J = \frac{\varepsilon_0 . \mu_{ion}}{s.b^2 . \ln \frac{R_{eff}}{R_0}} . V(V - V_0)$$

$$V_0 = E_0.R_0 . \ln \frac{R_{eff}}{R_0}$$

$$R_{eff} = \frac{4.b}{\pi} \qquad \frac{b}{2.s} \leq 0{,}3$$

$$R_{eff} = 0{,}36.s.\exp^{\left(\frac{2{,}96.b}{2.b}\right)} \qquad 0{,}3 < \frac{b}{2s} < 1{,}0$$

$$R_{eff} = \frac{s}{\pi}.\exp^{\left(\frac{\pi.b}{2.b}\right)} \qquad 1{,}0 < \frac{b}{2s}$$

The relation is valid until a current criterion:

$$C_I = \left(\frac{b}{E_0.R_0}\right)^2 . \frac{1}{\ln\frac{R_{eff}}{R_0}} . \frac{s.J}{\pi.\varepsilon_0.\mu_{ion}} << 1$$

Cooperman (1981, cited by Goo and Parker) provides a meaningful relation to the strong currents in wire-plate geometry:

$$J = \frac{\varepsilon_0.\mu}{16.b^3}\left(\alpha_J + \sqrt{\alpha_J^2 + 192(V - V_0)(b.E_1)^3}\right)$$

$$\alpha_j = 9(V - V_0 + b.E_1)^2 - 12(b.E_1)^2$$

$$E_1 = \frac{\pi.V_0}{2.s.\ln\left(\frac{R_{eff}}{R_0}\right)}$$

E1 is the maximum electric field on the collector plates, s half-space between two high voltage electrodes, the b wire-plate distance and J current per unit area of collector plates.

White (cited by Ducret) states that for low inter-electrode distances and negative voltage (of the order of cm), there may be a sharp divergence between the calculated current and the actual current, because the occurrence of a stream of free electrons. This can lead to abnormally high measures of ion electric mobility in negative discharges. Townsend takes the relation rather than a form of the type ILINEAR = k. (V-V0).

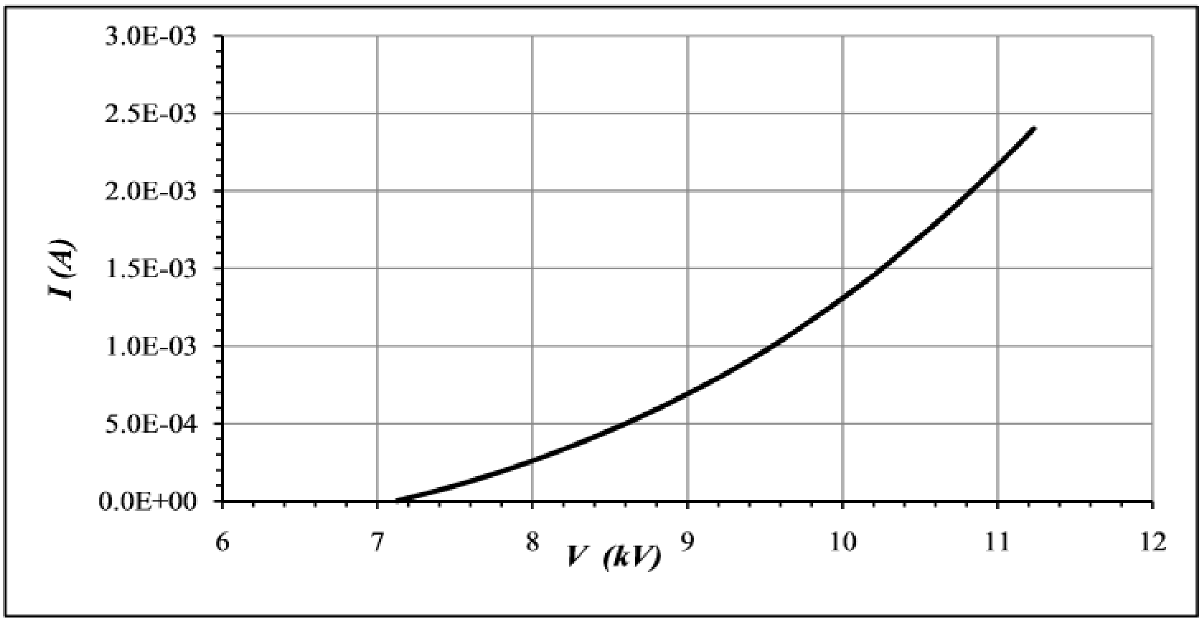


Figure 7: current-potential of electro-filter

1.4.1.8 RESISTIVITY

Resistivity, which is a characteristic of particles in an electric field, is a measure of a particle's resistance to transferring charge (both accepting and giving up charges). Resistivity is a function of a particle's chemical composition as well as flue gas operating conditions such as temperature and moisture. Particles can have high, moderate (normal), or low resistivity.

Bulk resistivity is defined using a more general version of Ohm’s Law, as given in Equation below: $\vec{E} = \rho \vec{j}$

Where:

E is the Electric field strength (V/cm);

j is the Current density (A/cm^2); and

ρ is the Resistivity (Ohm-cm)

A better way of displaying this would be to solve for resistivity as a function of applied voltage and current, as given in next Equation below:

$$\rho = \frac{AV}{Il}$$

Where:

ρ = Resistivity (Ohm-cm)

V = The applied DC potential, (Volts);

I = The measured current, (Amperes);

l = The ash layer thickness, (cm); and

A = The current measuring electrode face area, (cm^2).

Resistivity is the electrical resistance of a dust sample 1.0 cm^2 in cross-sectional area, 1.0 cm thick, and is recorded in units of ohm-cm. The table below, gives value ranges for low, normal, and high resistivity.

Resistivity	**Range of Measurement**
Low	between 10^4 and 10^7 ohm-cm
Normal	between 10^7 and 2×10^{10} ohm-cm
High	above 2×10^{10} ohm-cm

Table 5: types of resistivity

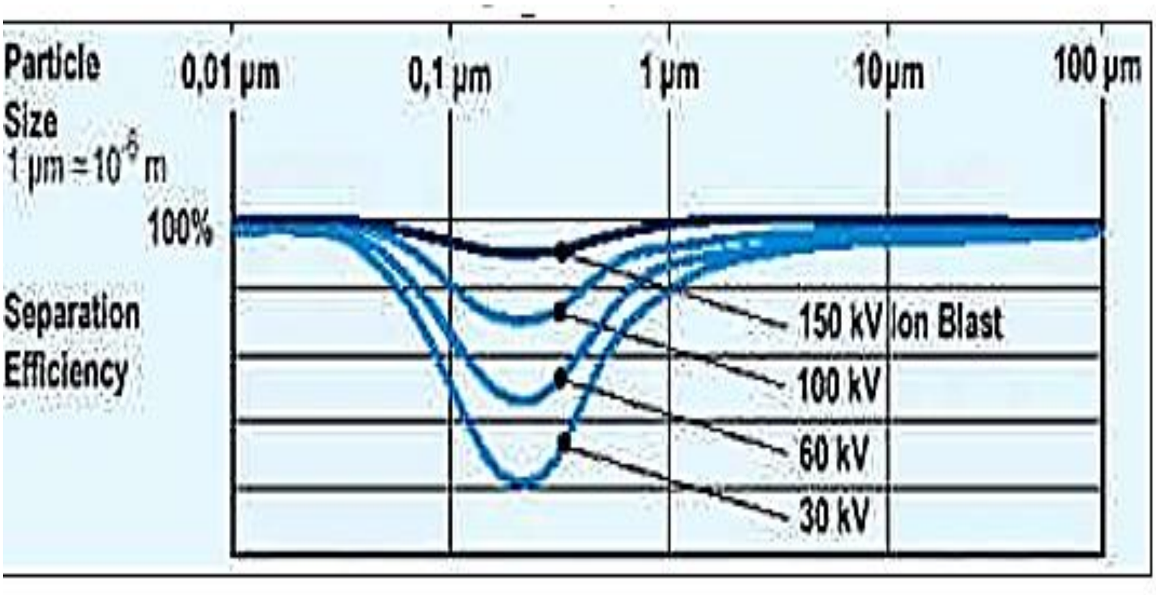


Figure 8 : relation between voltage and separation efficiency

1.4.2 TYPES OF ELECTROSTATIC

1.4.2.1 ELECTROSTATIC PRECIPITATORS ESP

ESP sometimes are also called electrostatic filters. The efficiency of dust removal of electrostatic precipitators is mainly influenced by the resistivity of the dust. If the resistivity of the dust layer increases to values higher than 10 11 to 10 12 Ω-cm the removal efficiencies are reduced. The resistivity of the dust layer is influenced by the composition of the waste. This can quickly change with a changing composition of waste, especially with hazardous waste incineration. Sulphur in the waste (the water content at operating temperatures below 200 ° C often reduces the resistivity of the layer of dust as SO_2(SO_3) in the exhaust gas and therefore facilitates deposition in the electric field. For the deposition of fine dust and aerosols, installations that maintain the effect of the electric field by drop formation in the flue gas (electrostatic precipitators to condensation and wet electrostatic precipitators to condensation, electro filter pumps, chillers ionized Pre-installed spray) may improve the efficiency of removal.

Typical operating temperatures for electrostatic precipitators are 160-260 ° C. An operation at higher temperatures (e.g. Beyond 250 ° C) is generally avoided as this may increase the risk of PCDD / F (and therefore discards).

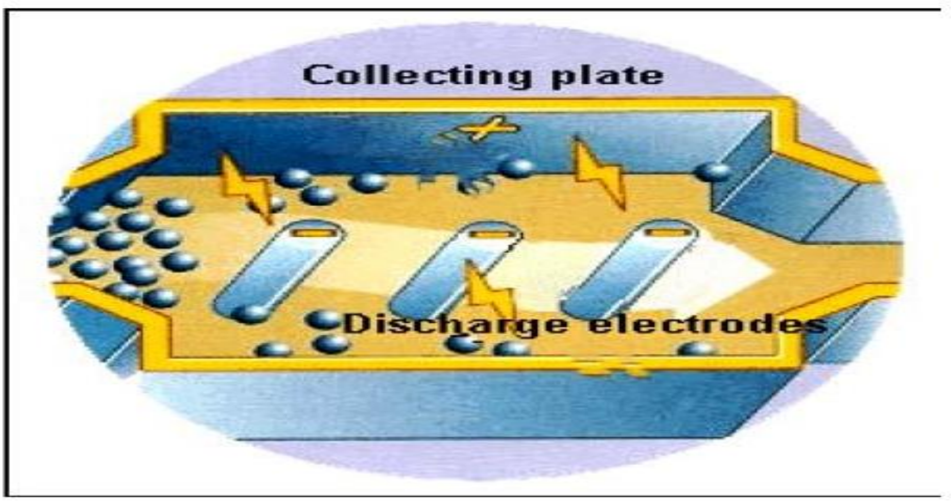
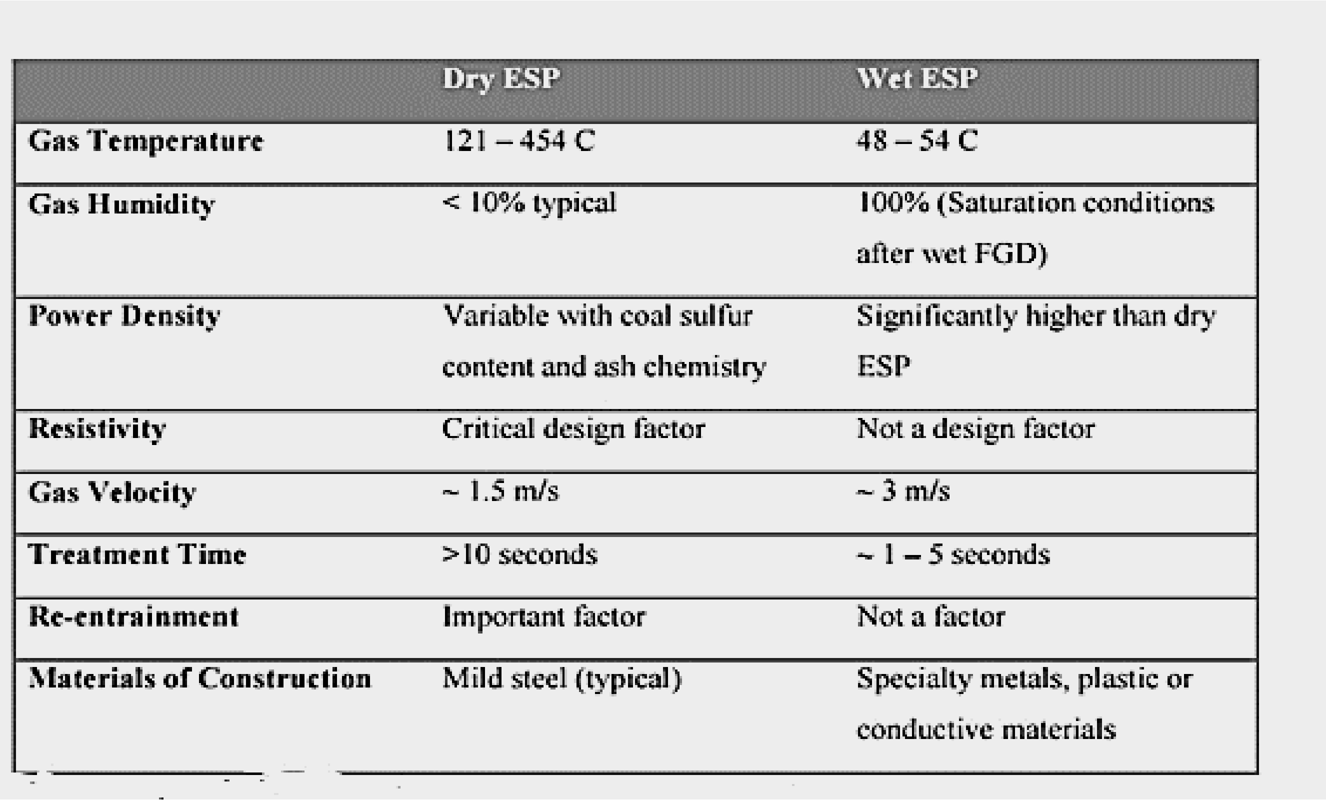


Figure 9: electrostatic filter

1.4.2.2 WET ELECTROSTATIC PRECIPITATORS

There are based on the same technological principle as electrostatic precipitators. With this design, however, the precipitated dust on the collector plates is washed using a liquid, generally water or $CaCo_3$. This can be carried out continuously or periodically. This technique works satisfactorily in the case where wet or cooled flue gas enters the electrostatic precipitator.



	Dry ESP	Wet ESP
Gas Temperature	121 – 454 C	48 – 54 C
Gas Humidity	< 10% typical	100% (Saturation conditions after wet FGD)
Power Density	Variable with coal sulfur content and ash chemistry	Significantly higher than dry ESP
Resistivity	Critical design factor	Not a design factor
Gas Velocity	~ 1.5 m/s	~ 3 m/s
Treatment Time	>10 seconds	~ 1 – 5 seconds
Re-entrainment	Important factor	Not a factor
Materials of Construction	Mild steel (typical)	Specialty metals, plastic or conductive materials

Table 6: Major differences between dry and wet ESP (10)

1.4.2.3 ELECTROSTATIC PRECIPITATOR CONDENSATION

The electrostatic precipitator condensation is used for very fine deposits, solid, liquid or sticky particles, for example, in flue gases from incineration plants of hazardous waste. Unlike conventional wet ESPs, the collecting electrostatic precipitators condensation surfaces comprise vertical plastic pipe arranged in packets, which are water-cooled from the outside.

1.4.2.4 WET SCRUBBERS TO IONIZATION

The purpose of the Wet Scrubber Ionization (EHI) is to remove various pollutants from the flue-gas stream. EHI combines the principles of:

- Electrostatic charging of particles, electrostatic attraction and deposition for aerosols (less than 5 micron)
- Deposition of coarse particles, liquids and solids (greater than 5 mm), and
- Absorption of hazardous, corrosive and malodorous.

The HIE system is a combination of an electrostatic filter and a scrubber packing. It is said that he needs little energy and has a high deposition efficiency for particles in the submicron as well as those of the micron.

A high voltage zone is installed prior to each step a fixed packing. The function of the high-voltage area is to ionize the particles (dust, aerosols, particles less than one micron) contained in the flue gas. The negatively charged particles induce opposing loads on the neutral surface of the moistened packing material and the drops of water falling. Because of this, they are attracted and are then washed in the packing section. This is referred to as attraction Image / Force (IF attraction), i.e. attraction of a shift of electrons. Hazardous, corrosive and malodorous are also absorbed into the same fluid and chemically combined scrubber to be evacuated with the effluent from the scrubber. Another type of wet scrubber includes Venturi ionization. The pressure changes that occur through the Ventures allow fine particles to grow and the electrode the load. They are then collected by the dense layer of deposited droplets through a nozzle, serving as collecting electrode.

1.4.3 SLEEVE FILTERS

Fabric separators also called sleeve filters are very widely used in waste incineration plants. The filtration efficiency is very high for a wide range of particle sizes. For particles less than 0.1 microns, efficiency is reduced, but the fraction of these particles that exist in the flow of exhaust gas of waste incineration plants is relatively low. Low dust emissions are achieved with this technology.

The compatibility of the filter medium with the characteristics of the flue gas and the dust, and the filter of the process temperature are important for effective performance. The filter is a way that should have suitable properties for thermal, physical and chemical -by ex. hydrolysis, acid, alkali, and oxidation). The gas flow rate determines the appropriate filtering surface, that is to say the filtration velocity.

The mechanical and thermal stress on the filter material determines service life, energy and maintenance requirements.

Continuous operation, there is a gradual loss of pressure through the filter because particle deposits. When dry sorption systems are used, the formation of a cake on this medium helps remove the acid. In general, the pressure differential across the filter is used to monitor the need for cleaning. Periodic replacement is required when the residual maturity is reached or in case of irreversible damage (e.g. increasing pressure loss can be caused by irreversible deposit of fine dust in the filter material). Several parameters help to control the lifetime of the sleeves: drift of the pressure drop, visual parameter, microscopic analysis, etc. Potential leaks in the bag filter will also be detected by increased emissions or by process disturbances.

The application of dry deposition is limited to the dust which is hygroscopic at high temperatures (300 to 600 ° C) and become tacky at these temperatures. This type of dust forms deposits in the deposition equipment, which can’t be adequately removed by conventional cleaning techniques during operation, but may need to be removed by vibration ultra sound. They may be dust complex salts, for example from waste containing phosphorus, sulfur or silicon.

Figure 10: Example for a sleeve filters

1.4.4 CYCLONES (THIS FIRST PHASE CAPTURES SOLID HEAVY METALS, DUST BETWEEN 5 AND 30 MICRON)

Multi cyclones use centrifugal forces to separate particulate matter from the gas stream. Multi cyclones differ from simple cyclones in that they comprise a number of small cyclone units. The gas stream enters the separator tangentially and exits through a central port. The solids are forced towards the outlet of the cyclone and collected on the sides to be deleted.

In general, cyclones alone can’t achieve the emission levels now applied to modern waste incinerators. They may, however, have an important role to play where applied as a pre-cleaner prior to the processing steps of the burned gases. Energy requirements are generally low because there is no pressure drop across the cyclone.

Advantages of cyclones are their wide operating temperature range and rugged construction. Erosion of cyclones, especially at the impact point of the burnt gases, can be a problem when the burnt gas is laden with particles. For the purification of air and gases, we generally use the extruded activated carbon (compacted into pellets) or coarse (granular). (8)

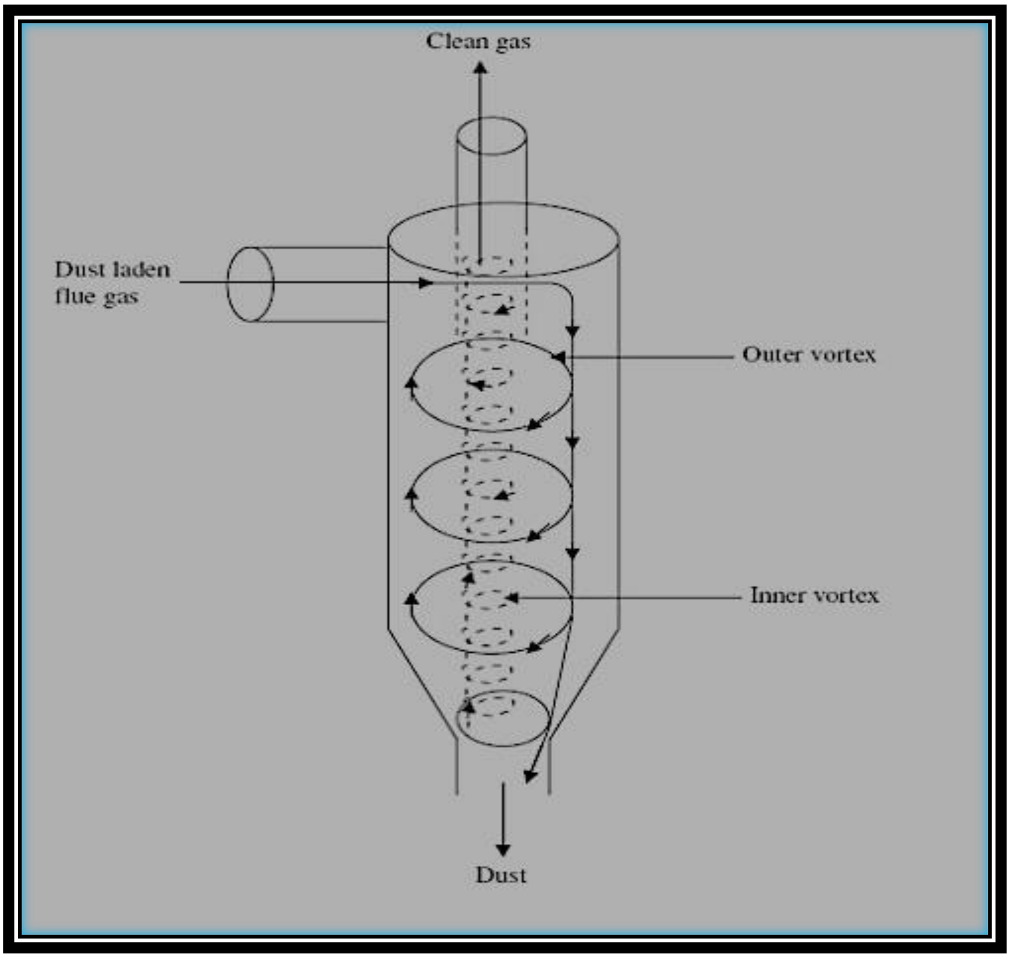


Figure 11: design of cyclone

1.5 SIMPLE CYLINDRICAL ELECTROSTATIC

1.5.1 PRINCIPLE OF OPERATION AND EXPERIMENTAL PROCESS:

The operating principle of the simplest electrostatic filters, wire concentric cylinder, a high electric potential is applied to the wire, called emitter electrode. It is placed in the axis of the vertical cylinder, called the collecting electrode, which is connected there to grounded. The gas carrying the particles to be removed enters through an opening located at the bottom of the cylinder, the particulate laden gas passes through the inter-electrode space. Corona, there is ionization of the gas wire author, and creation of ions and electrons. These pollutants bombarding particles becoming electrically charged and then attracted towards the inner surface of the cylinder under the effect of the electric field. The particles are deposited on the cylinder, where they are, are removed by washing, scraping or rapping, collected in hoppers and finally discharged into the drawer out of the electro filter.

***FEATURE current-voltage**

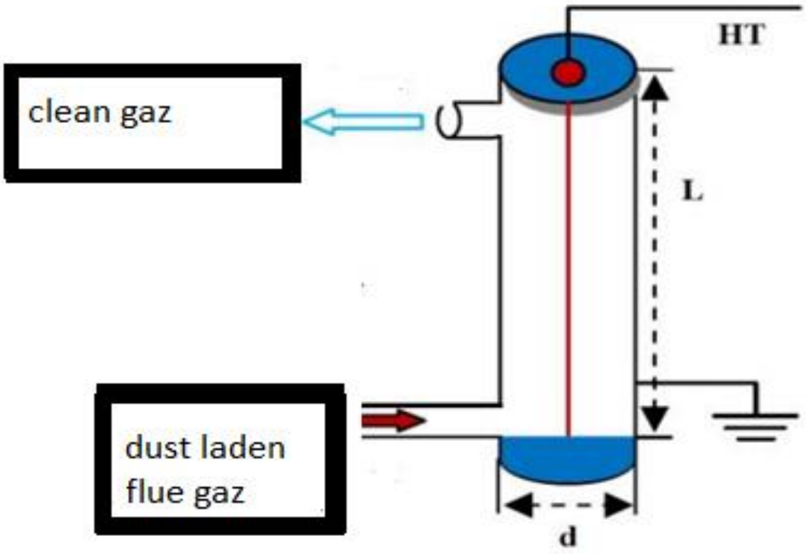


Figure 12: electrostatic cylindrical

1.5.2 INFLUENCE OF THE DIAMETER OF THE WIRE

We apply to the wire, a positive DC electric potential gradually increasing the voltage applied to the yarn and measuring the electric current on the cylinder. We operate in the same way up to a voltage near the breakdown voltage. Used two different diameters of copper wire,

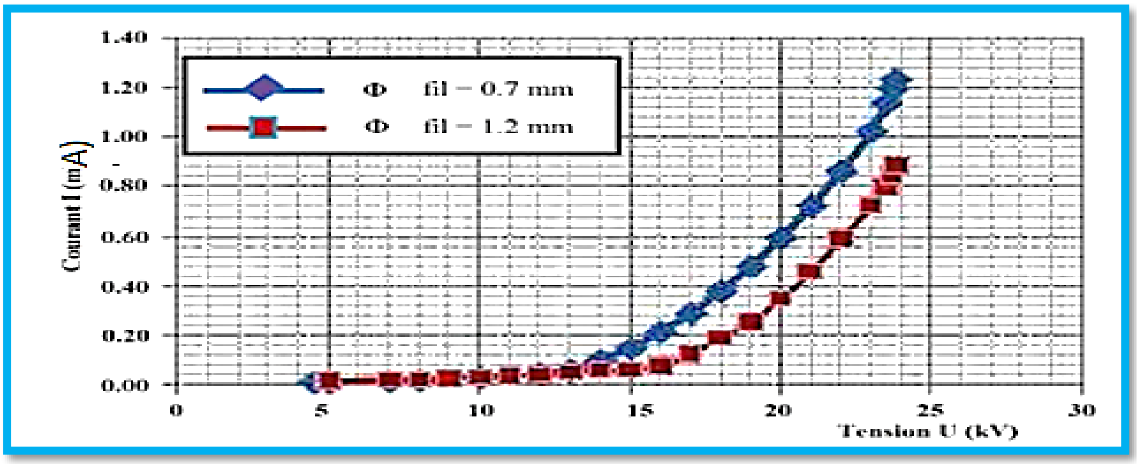


Figure 13: Current-voltage characteristics for two different wire diameters

It can be concluded that the wire diameter is inversely proportional to the electric discharge. This is quite normal because the electric field on the wire is inversely proportional to the radius of the wire R0 (eq below):

$$E = \frac{q}{4 \times \pi \times \varepsilon \times R_0}$$

Therefore, when R0 decreases, E increases and vice versa.

1.5.3 CYLINDER DIAMETER INFLUENCE

We proceed in the same manner as the previous step using two diameters and cylinder with a diameter of 0.7 mm constant corona wire copper. We traced the current - voltage characteristic for a cylinder diameter of 80 mm and 110 respectively

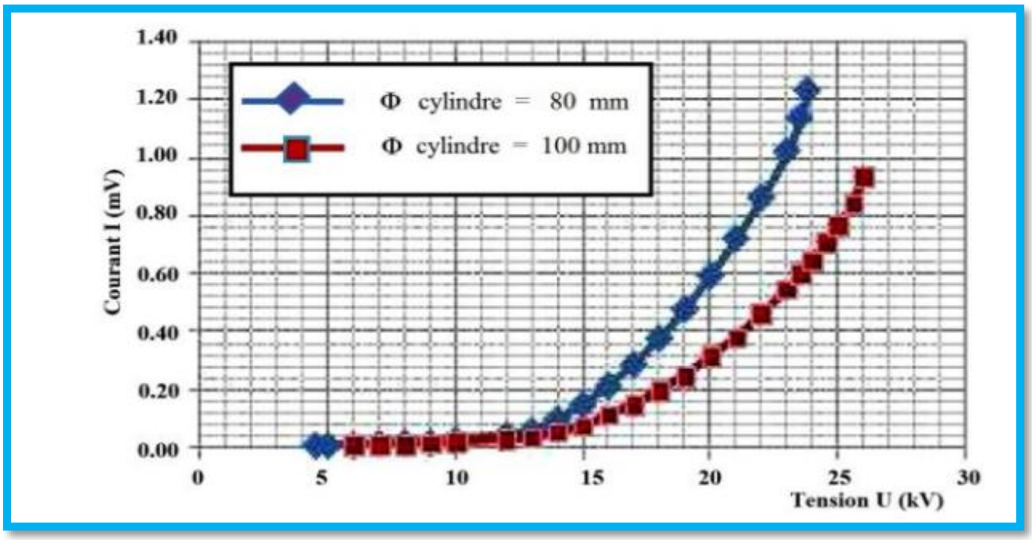


Figure 14: Current-voltage characteristics for two different cylinder diameters

his time also, the increase in the cylinder diameter is induced a decrease of the electric discharge. exegesis can one it by the relationship of the current per unit length of Townsend:

$$I_{\text{linéique}} = \frac{8 \times \pi \times \mu_{ion} \times \varepsilon_0}{R^2 \times \ln \frac{R}{R_0}} \times V \times (V - V_0)$$

$$V_0 = E_0 \times R_0 \times \ln \frac{R}{R_0}$$

With R0, the radius of the wire, and R is the radius of cylinder (11)

1.5.4 EFFICACY OF AN ELECTROSTATIC

Previously, electrical discharge mechanisms of particle charge and forces acting on a charged particle in turn have been studied. From these achievements, the precipitation yield or electrostatic can be evaluated theoretically.

The overall performance of the operation of an electrostatic filter is quantified by a variable named total collection efficiency (or collection efficiency) ηt defined by the following expression:

$$\eta_t = I - \frac{n_s}{n_e}$$

Where ns and ne respectively represent the concentrations at the outlet and at the inlet of precipitator; n may be expressed as number of particles or mass. (12)

1.6 Treatment of toxic gas.

The flue gases are then processed by wet or dry. This phase can capture the acid gas, sulfur oxides and volatile heavy metals.

1.6.1 REMOVAL OF SULFUR DIOXIDE AND HALOGENATED (ACID GAS)

The sulfur dioxide and halogen gases are cleaned flue gas by the injection of chemical or physical agents’ sorption, which are brought into contact with flue gas. According to the technique, the reaction products are dissolved or dry salts.

Dry systems:

In the dried sorption process, the absorbent (generally lime or sodium bicarbonate) is fed in the form of a dry powder reactor. The dosage of reagent may depend upon the temperature and the type of reagent. With lime this ratio is typically **two to three times** the stoichiometric amount of the substance which will be filed with the baking soda ratio is lower. This is necessary to ensure that emission limits are met over a range of input concentrations. Generated reaction products are solid and must be deposited from the flue gas as dust in a subsequent step, usually a bag filter.

Lime over dosage (or other reagent) leads to an increase of the amount of residue, unless the re-circulation of the reagent is performed, when the non-reacted fraction can be recirculated

N.B: Halogens comprise the seventh column of the periodic table of the elements. Fluorine, Astatine, Chlorine, Bromine and Iodine.

If there is no pre-deposition step (e.g. Electrostatic precipitator), particles are removed with the reagent used and the reaction products. Reagent cake that forms on fabric filters allows effective contact between the flue gas and the absorbent.

Plumes are rarely visible with this technique.

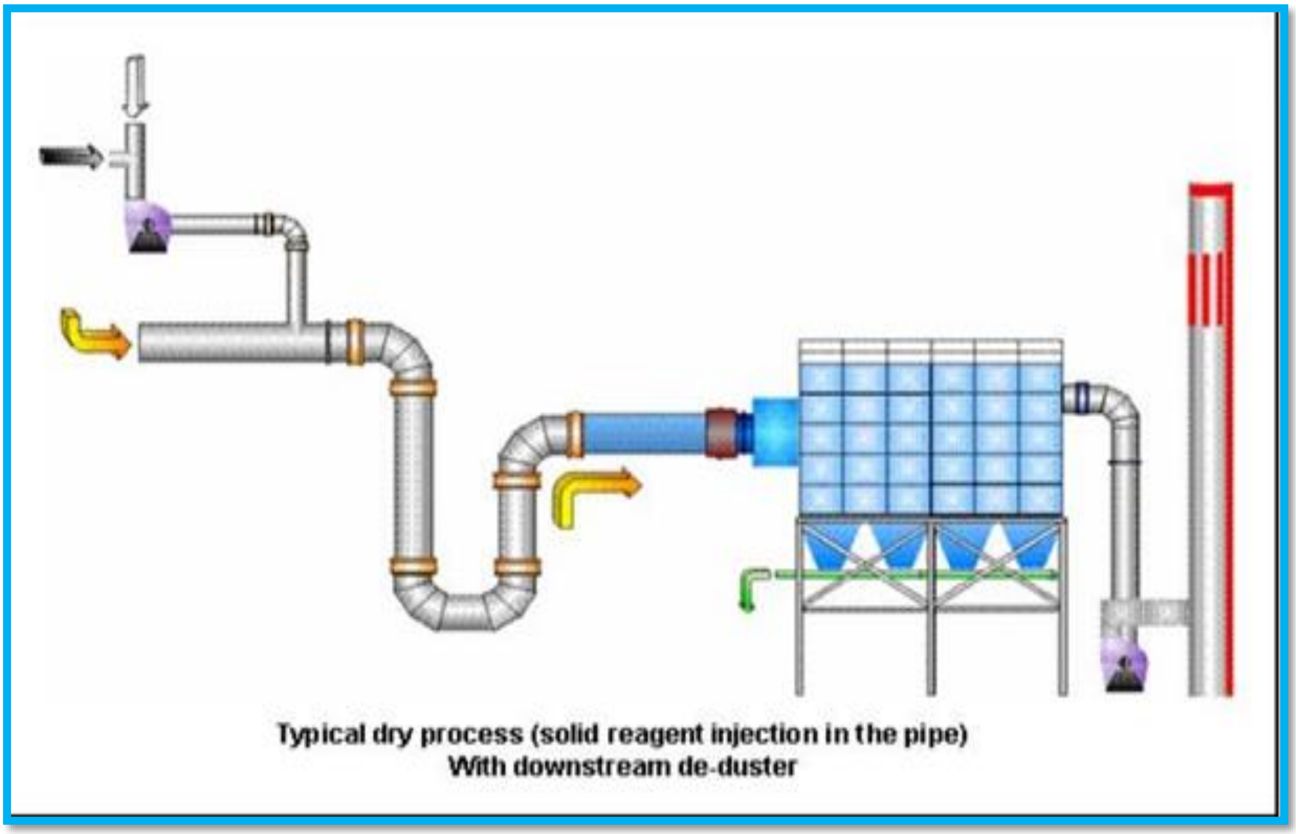


Figure 15: typical dry process (solid reagent injection in the pipe with a downstream precipitator

Semi wet systems:

These are also called semi-dry process. In the spray absorption, the absorbent is injected either as a suspension or solution in the flue-gas flow in a sputtering reactor. This type of process utilizes the heat of the burnt gases for evaporation of solvent (water). Generated reaction products are solid and must be deposited from the flue gas as dust in a subsequent step, for example a sleeve filter. These processes typically require sorbent overdoses of **1.5 to 2.5.**

Here, fabric separator is also an important part of the process. Plumes are rarely visible with this technique.

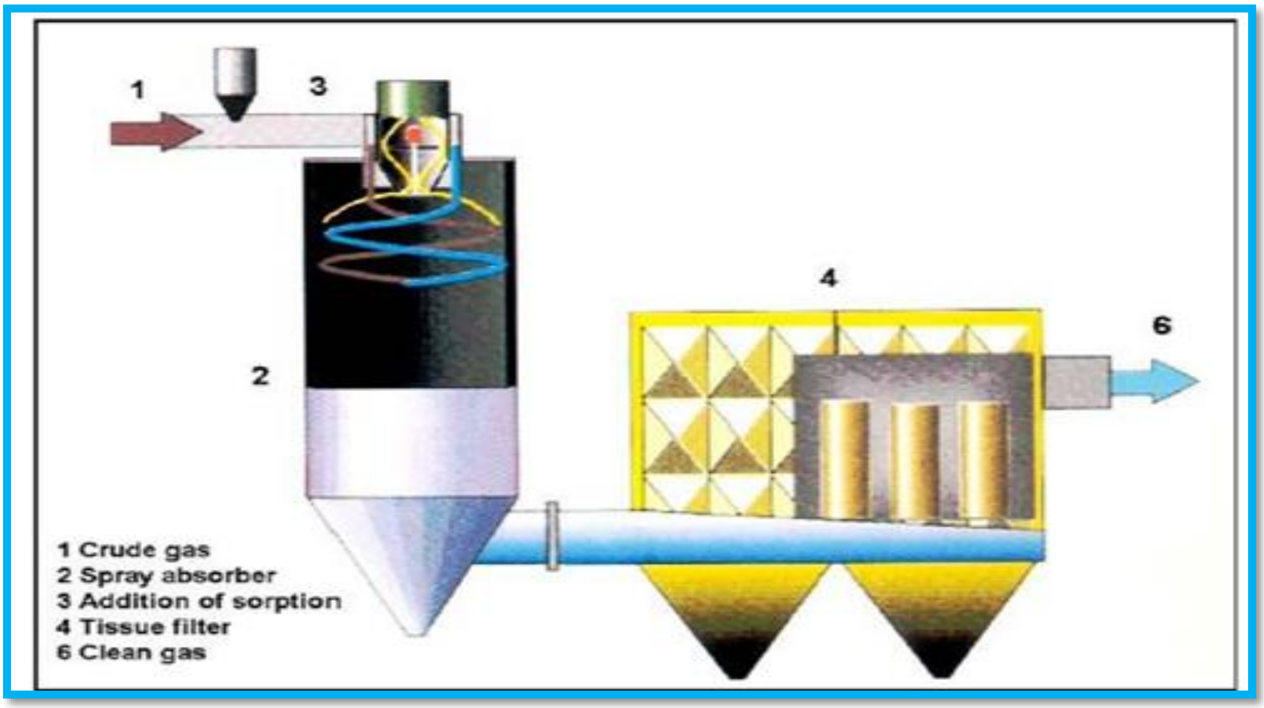


Figure 16: Principle of operation of a spray absorber

Wet systems:

The wet cleaning process the flue gas uses different types of scrubber design. For example:

- jet scrubbers
- rotation scrubbers
- venture scrubbers
- dry tower scrubbers
- spray scrubbers
- static cleaners

The scrubber solution is (only in the case of water injection) strongly acid (pH 0-1) due to the formation of acid in the deposition process. HCl and HF are mainly removed during the first stage of the wet scrubber. The effluent from the first step is recycled several times, with a small amount of clean water and venting of the scrubber to maintain the effectiveness of the acid gas removal. For this acidic medium, deposition of SO_2 is slow, so a second stage scrubber is required to remove it.

Removal of the sulfur dioxide is performed in a controlled washing step at a near neutral pH or alkali (typically at pH 6 to 7) in which is added sodium hydroxide or milk of lime. For technical reasons, this withdrawal takes place in a separate washing step, in which also occurs further removal of HCl and HF.

If the treated waste contains bromine and iodine, these can be deposited from a flue gas flow if waste containing sulfur is burned simultaneously. More sulfur compounds, bromine and iodine in water-soluble salts will form, which can be deposited by the wet cleaning process of SO_2 in the flue gas. In addition, the deposit of bromine and elemental iodine can be improved by the specific use of reductive washing steps. In all cases, it is important to know which waste containing iodine or bromine.

If the milk of lime or limestone is used as a neutralizer agent in the wet stages of cleaning of flue gases, sulfate (gypsum), carbonates or fluorides will accumulate as soluble residues in water. These substances can be removed to reduce the salt load in wastewater and thus reduce the risk of scaling in the sewage system. Residues of the cleaning process (e.g. Gypsum) can be recycled. When using a caustic soda solution there is no risk because the reaction products are soluble in water. If NaOH is used, $CaCO_3$ may form (depending on the hardness of water), which again will lead to deposits in the scrubber. These deposits must be removed periodically by acidification. The diagram below illustrates a typical wet scrubbing system to two steps. The number of purification steps generally ranges between 1 and 4 with multiple steps incorporated in each vessel:

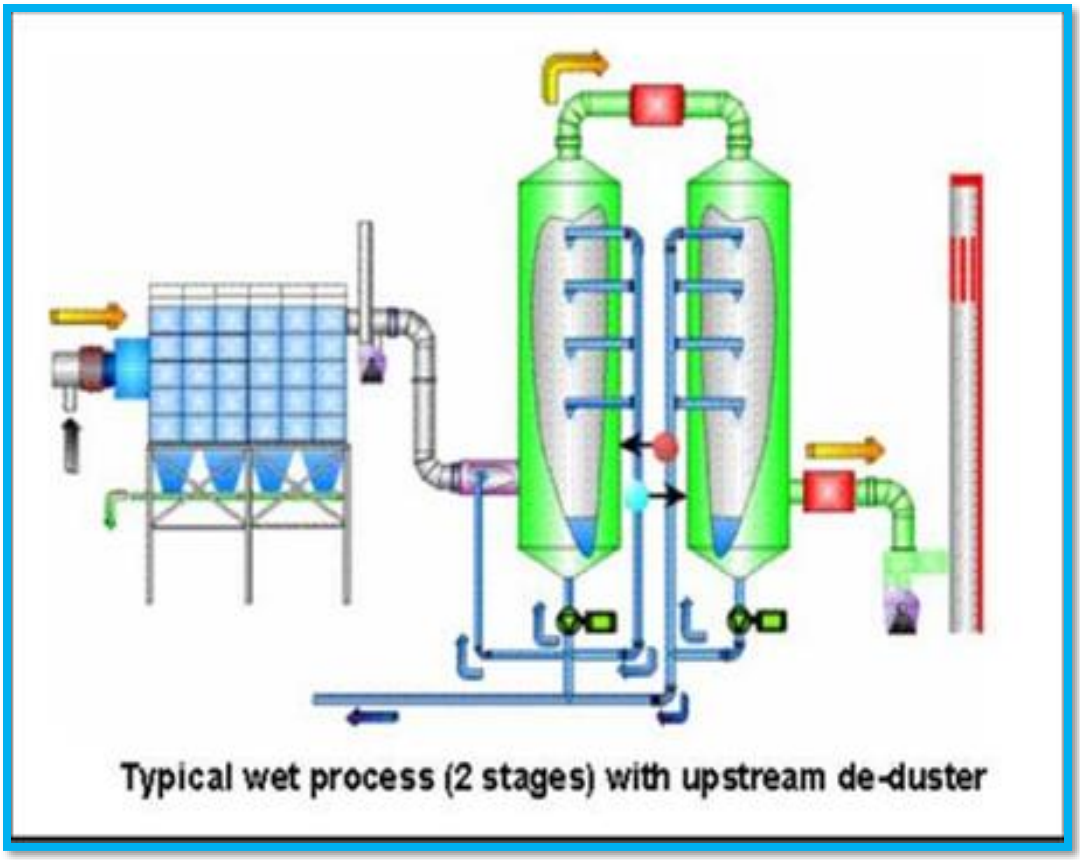


Figure 17: typical wet process (2 stages) with upstream de-duster

N.B WASTE WATER FROM WET SCRUBBERS.

To maintain the purification efficiency and prevent clogging of the wet scrubber system, a portion of the scrubber liquor must be removed from the circuit as waste water. This wastewater must be subjected to special treatment (neutralization, precipitation of heavy metals), before discharge or use internally. It pays particular attention to the mercury removal. The compounds of volatile Hg, such as $HgCl_2$, will be condensed when the exhaust gases are cooled, and dissolved in the effluent from the scrubber. The addition of reagents for the specific removal of Hg is a way to remove the process. In some plants, the waste water produced is evaporated in the incineration plant by spraying it back into the flue gas as a combined tempering with the dust filter.

1.6.1.1 IMPLEMENTATION OF THE TREATMENT WITH SODIUM BICARBONATE

- *GENERAL STEPS*

The reaction between the acid gas (SO_2, HCl) and the sodium bicarbonate (Na_2CO_3) is a surface reaction. The solid is usually ground in order to increase its surface area, ideally to achieve a d50 <20 microns. Upon decomposition into sodium carbonate, the release of gases (CO_2, H_2O) further increases the surface area by increasing the porosity. the BET surface area (Brunauer, Emmet and Teller) of sodium bicarbonate is of about 0.8 m^2/ g after grinding to 20 microns and up to 7 m^2 / g at decomposition as Na_2CO_3, but drops to 2 m^2 / g after aging a few hours.

The powdered sodium bicarbonate is generally injected directly into the flue gases at the outlet of the boiler, where it decomposes. The sorbent is then retained by a filter media which may be fabric or ceramic fibers. This forms a layer of sorbent, having or not having reacted with the acid gas and fly ash from a few millimeters, called "filter cake". Thus, the time of reactive-gas contact cleaned is increased to improve significantly the effectiveness of treatment. (13)

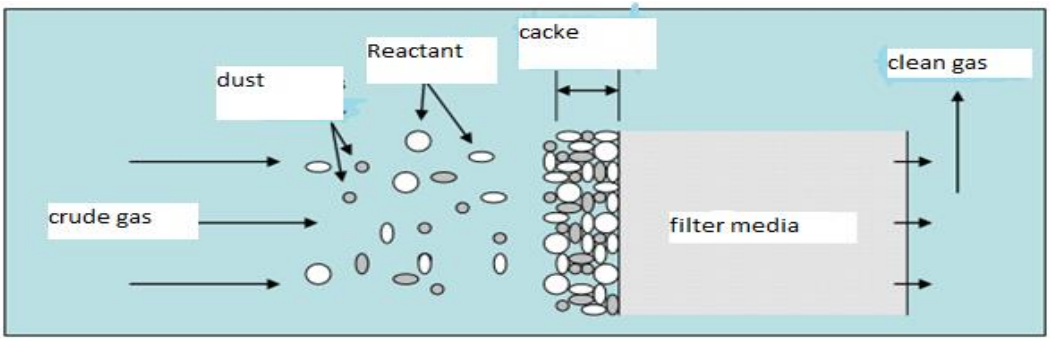


Figure 18: accumulation of particles in filter media

- *FILTER MEDIA*

Filters are formed of several tens of filter media cylinders called candles. This implementation allows increasing the total surface filtration. The accumulation of carbonate and fly ash on the walls of the filter causes a gradual increase in pressure drop across the filter. The measurement of the downstream pressure therefore provides information on the level of filter clogging. When it exceeds a threshold, an entire row of filter cartridges is scoured. For that, a compressed air pulse is sent against the flow within the latter, to create a pressure wave which allows bringing down the cake into a hopper located below the filter.

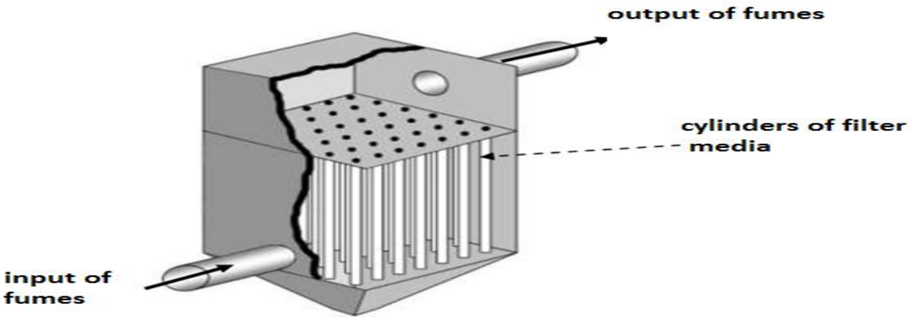


Figure 19: system of filtration

Materials for the manufacture of filter media are: fiber

Choosing as classification criterion their chemical composition, the fibers can classes into 2 categories, organic and inorganic, the same subdivided into sub categories:

Inorganic fiber: glass, carbon, ceramic, asbestos

Organic fibers:

- natural wool, silk, cotton
- Synthetic: polyethylene, polyester

There is a list of fiber available in the market:

Name	manufacturers
NOMEX	DUPONT
KERMEL	kermel
Ricem	Montefibre

Table 7: list of fiber available in the market (14)

- *CHEMICAL REACTIONS:*

- Treatment by $Ca(OH)_2$:

$Ca(OH)_2 + 2HCl \leftrightharpoons CaCl_2 + 2H_2O$

$Ca(OH)_2 + 2HF \leftrightharpoons CaF_2 + 2H_2O$

$Ca(OH)_2 + SO_2 \leftrightharpoons CaSO_3 + H_2O$

$CaSO_3 + 1/2\ O_2 \rightarrow CaSO_4$

- Treatment by $NaHCO_3$:

$NaHCO_3 + HCl \leftrightharpoons NaCl + CO_2 + H_2O$

$NaHCO_3 + HF \leftrightharpoons NaF + CO_2 + H_2O$

$2NaHCO_3 + 1/2\ O_2 \leftrightharpoons Na_2SO_4 + 2CO_2 + H_2O$

In wet case, the reactions are:

- acidic step: $HCl + H2O \rightarrow H3O^+ + Cl^-$

$HF + H2O \rightarrow H3O^+ + F^-$

- basic step: $SO_2 + 2H_2O \rightarrow H_3O + HSO_3^-$

$HSO_3^- + H_2O + 1/2\ O2 \rightarrow H3O^{2+} + SO$

$2NaOH + 2H_3O^+ + SO_4^{2-} \rightarrow Na_2SO_4 + 4H_2O$

$SO_2 + 2NaOH \rightarrow Na_2SO_3 + H_2O$

$HCl + NaOH \rightarrow NaCl + H_2O$

$HF + NaOH \rightarrow NaF + H_2O$

The reaction of sodium carbonate with sulfur dioxide is:

1. $Na_2CO_3(s) + SO_2(g) \rightarrow Na_2SO_3(s) + CO_2(g)$

When the gas cools, sodium sulphite thus formed reacts with oxygen to generate sodium sulfate:

2. $Na_2SO_3(s) + ½O_2(g) \rightarrow Na_2SO_4(s)$

Injection Na_2CO_3 also allows trapping the hydrochloric acid present in the hot gases:

3. $½NaCO_3(s) + HCl(g) \rightarrow NaCl(s) + ½CO_2(g) + ½H_2O(g)$

Similarly, the carbonate may also react with HF to form NaF.

Reaction 1 is a heterogeneous reaction (solid-gas). Treatment efficacy is depending mainly from time reagent-gas contact purify and temperature. However, higher allowances to 95% of SO_2 and HCl can be achieved for stoichiometric ratios of 1.2 to 1.5.

- ***STUDY OF THE REACTIVITY OF NA_2CO_3 LABORATORY***

SO_2 reaction's tests are on the thermally decomposed trona. The proportion of reacted Na_2CO_3 followed by Thermogravimetric Analysis (TGA). They observe two reaction steps due to changes in the size of pores over time. At the start of the reaction all of the sites is accessible; the first step is pretty fast. But gradually as the carbonate reacts, pore size decreases or becomes clogged, the steric bulk of SO_2 is larger than that of CO_2. The second step being limited by the diffusion of gases in the pores, it is then slower.

- ***EFFECT OF TEMPERATURE AND VAPOR***

A study indicates that the operating temperature of the sodium carbonate is at least 130 ° C. It observed during tests with dry gases, increasing efficiency up to 150 ° C and a slight decrease in the test at 220 ° C, especially in the first phase of conversion, which they attribute to sintering.

Few studies have been done on the effect of water vapor on the capture of SO2 by Na2CO3. Stejskalova et al. (1996) conducted adsorption test at 150 ° C for two percentages of H2O in the gas (2% and 5%). They observe a significant increase in the allowance with increasing humidity. They attribute this effect to a catalytic action of water vapor and a rate of oxidation of sulfites to sulfates slower.

- ***ADSORPTION OF NITROGEN OXIDE***

Several authors (Verdone and De Filippis, 2004 Erdös and Mocek, 1994) studied thermodynamically and showed the possibility of reactions between nitrogen oxides and sodium carbonate. Verdone and De Filippis (2004) showed that the reactions of Na_2CO_3 with NO and NO_2 are possible thermodynamically to respectively 160 ° C and 360 ° C.

Lippert et al. (1996) conducted tests NO adsorption and NO_2 in a gas mixture containing N_2, CO2, O2 and H2O. They note that:

- NO_2 only seems to react;

- The reaction only in the presence of H_2O;

- The presence of CO_2 decreases the adsorption of NO_2;

- Reactivity of Na_2CO_3 decreases with temperature between 50 and 150 ° C.

- *ADVANTAGES AND DISADVANTAGES OF THE USE OF SODIUM BICARBONATE*

Of course, with respect to other solid adsorbents, there are many solid compounds other than sodium bicarbonate ($NaHCO_3$) could serve as reagents for treatment of sulfur oxides by means dried. The most widely used industrially are more sodium compounds (Na_2CO_3, $Na_2CO_3.10H_2O$) or calcium compounds (CaO, $CaCO_3$, Ca $(OH)_2$). It is also possible to use magnesia (MgO), but this method seems little used.

Reactant	Advantages	Disadvantages
Sodium bicarbonate (basic reactant to SO_x)	• highly reactive with acid gases • low consumption rates •low residues	• cost / kg of reactant was higher • very corrosive
Quicklime (CaO)	• Average Reactivity Highest Temperature • Cost / kg lower • Low solubility of residues	• Difficult Recovery
Limestone(acid reactant to acid gas)	• Average Reactivity • Cost / kg lower • Low solubility of residues	• Circulation of CO_2

Table 8: difference between reactant selected

(13)

1.6.2 TECHNIQUES FOR THE REDUCTION OF NITROGEN OXIDE EMISSIONS

Nitrogen oxides (NOx) may be formed in three ways:

• Thermal NOx: When burning a portion of the nitrogen in the air is oxidized to nitrogen oxides. This reaction occurs only significantly at temperatures above 1300 ° C. The reaction rate depends exponentially on the temperature and is directly proportional to the oxygen content.

• Fuel NOx: when burning a portion of the nitrogen contained in the fuel is oxidized to nitrogen oxides.

- NOx formation via a radical reaction (prompt NOx): Atmospheric nitrogen can also be oxidized by reaction with CH radicals and intermediate formation of HCN. The formation mechanism is relatively low importance in waste.

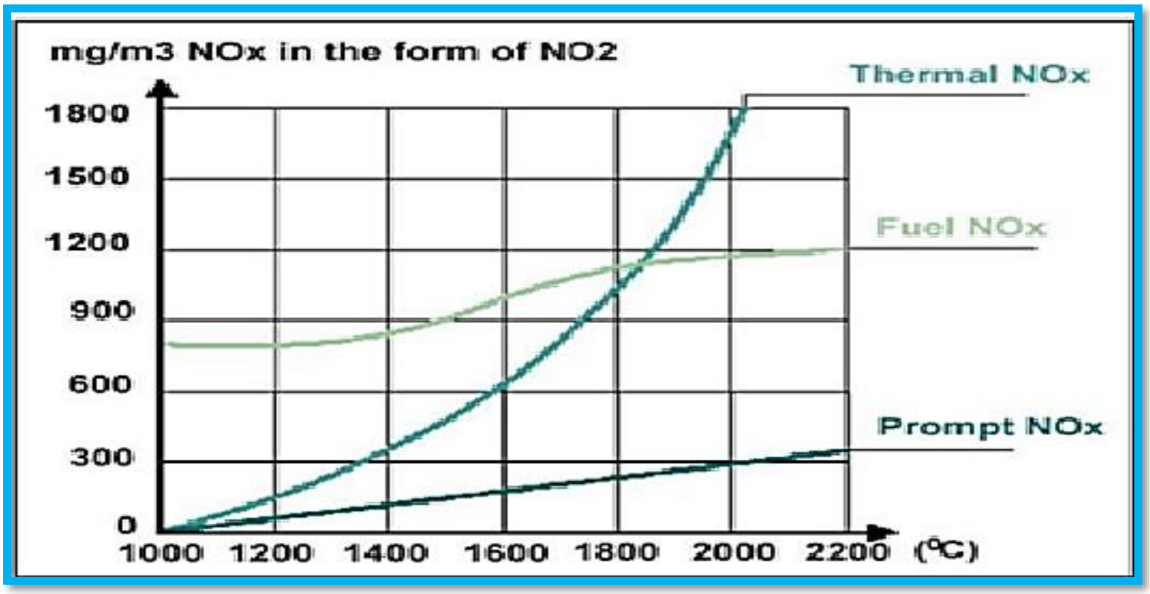


Figure 20: Temperature dependence of various NOX formation mechanisms in waste incineration

**NOx reduction side Techniques

The Directive 2000/76 / EC require a daily average value of clean gas NOx (as NO_2) of 200 mg / Nm^3. To successfully conform to this level, it is common to apply secondary measures. For most processes, applying ammonia or ammonia derivatives (e.g. Urea) as a reducing agent which has proven successful. The nitrogen oxides in the flue gases mainly comprise NO and NO_2 are reduced to nitrogen N_2 and water vapor by the reducing agent.

Equations:

$4 NO + 4 NH_3 + O_2 \rightarrow 4 N_2 + 6 H_2O$

$2 NO_2 + 4 NH_3 + O_2 \rightarrow 3 N_2 + 6 H_2O$

Two processes are important for the removal of nitrogen of flue gases - the Selective Reduction Nonanalytic (SNCR) and Selective Catalytic Reduction (SCR).

NH_3 and urea are applied in aqueous solutions. NH_3 is normally, for safety reasons, delivered in a 25% solution.

1.6.2.1 PROCESS OF REDUCING NON-SELECTIVE CATALYTIC (SNCR)

In the process of Non-Selective Catalytic Reduction (SNCR) of nitrogen oxides ($NO + NO_2$) are removed by selective non-catalytic reduction. With this type of process, the reducing agent (typically ammonia or urea) is injected into the furnace and reacts with nitrogen oxides. The reactions occur at temperatures between 850 and 1000 ° C, with higher reaction rates and lower in this range.

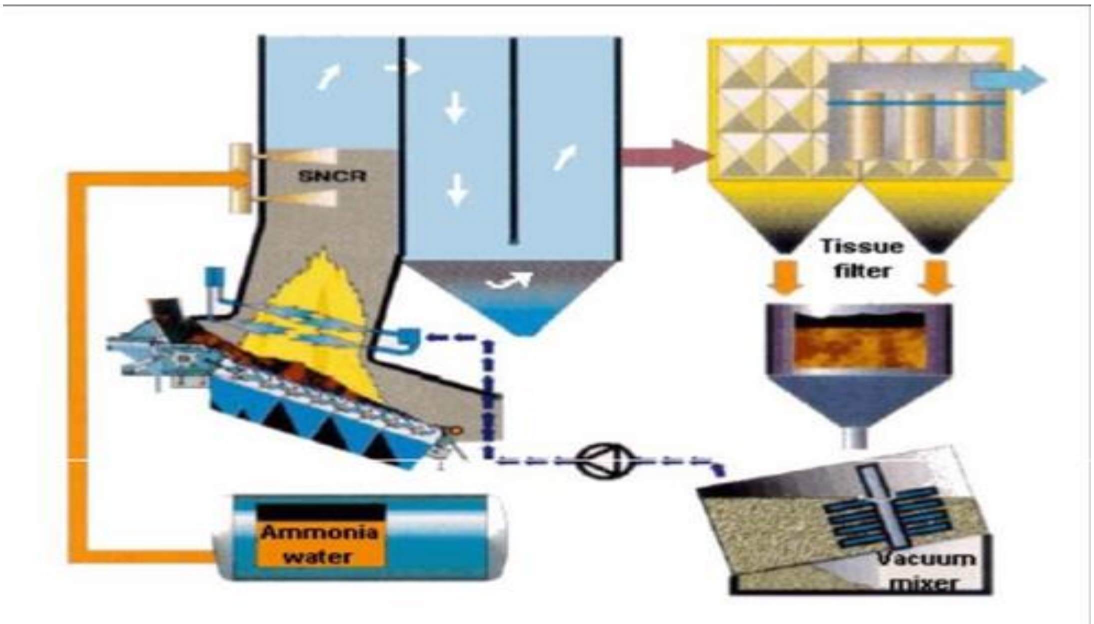


Figure 21: Process of Reducing Non-Selective Catalytic (SNCR)

Reducing NOx by SNCR **more than 60-80%,** requires a higher addition of the reducing agent. This can lead to ammonia emissions, also known as the slip of "ammonia. The relation between NOx reduction, ammonia slip and reaction temperature is given in Figure 15 below:

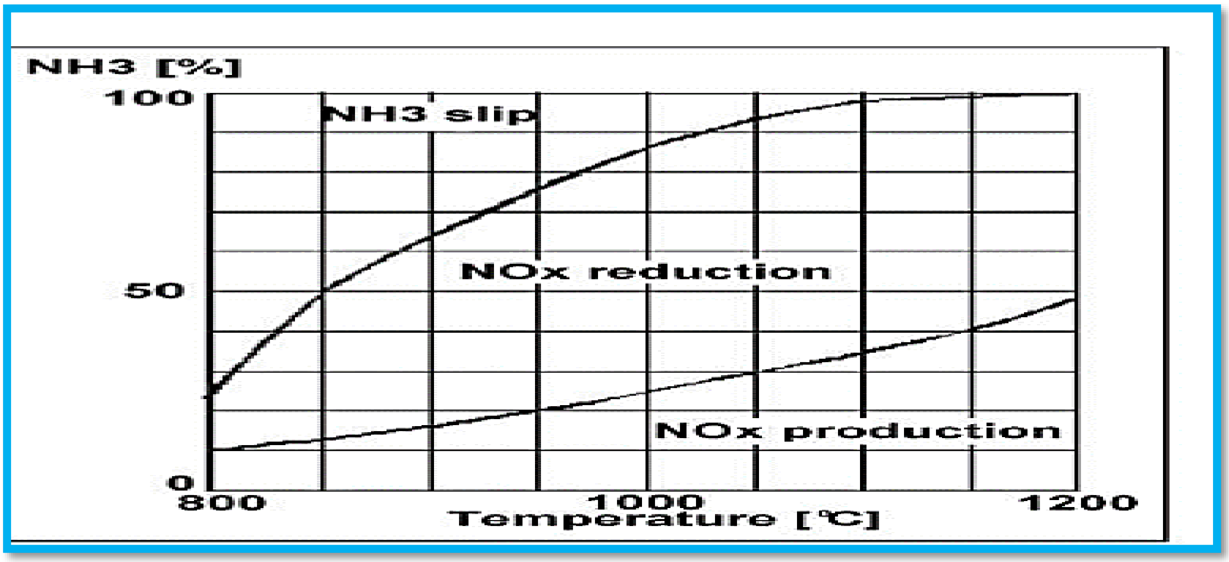


Figure 22: Relation between NOx reduction, production of NOx, and ammonia slip and reaction temperature for the SNCR process.

In figure 20, it shows that at a reaction temperature of, for example, 1000 ° C, NOx reduction would be about 85%, and there would be about 15% ammonia slip. In addition, at this temperature there would be a generation of NOx, from the incineration of the injected NH_3, of about 25%.

Figure 20 shows that at high temperatures (with ammonia), the percentage of reduction of NOx is high, and while the ammonia slips decrease, the NOx producing ammonia increases.

Application of urea instead of ammonia in SNCR leads to relatively higher N_2O emissions compared to the ammonia reduction.

For optimum use of ammonia at different degrees of load, which causes temperature variations in the combustion chamber, NH_3 can be injected into different layers.

1.6.2.2 PROCESS OF SELECTIVE CATALYTIC REDUCTION (SCR)

Selective Catalytic Reduction (SCR) is a catalytic process during which ammonia mixed with air (the reduction agent) is added to the exhaust gas and passes through a catalyst, usually a sieve (e.g. Platinum, rhodium, TiO_2, zeolites). When passing through the catalyst, ammonia reacts with NOx to give nitrogen and water vapor.

To be effective, the catalyst generally requires a temperature between 180 and 450 ° C. The majority of systems uses waste incinerators currently operating at temperatures of the order of 230-300 ° C.

The SCR process gives NO_x reduction rates (typically over 90%) to almost stoichiometric additions of reducing agent. For waste incineration, SCR is mainly applied in the natural gas area, that is to say, after dusting and removal of acid gases. For this reason, the exhaust gases generally require reheating to the efficient SCR reaction temperature. This adds to the energy needs of the flue gas treatment system. However, when the levels of SO_x in flue gases have been reduced to a very low value to the admission of the SCR section, reheating can be substantially reduced or even avoided. Heat exchangers are used to reduce energy demand further.

SCR can also be used for the destruction of PCDD / F. SCR systems multi layers are used to provide a combined control of NOx and PCDD / F.

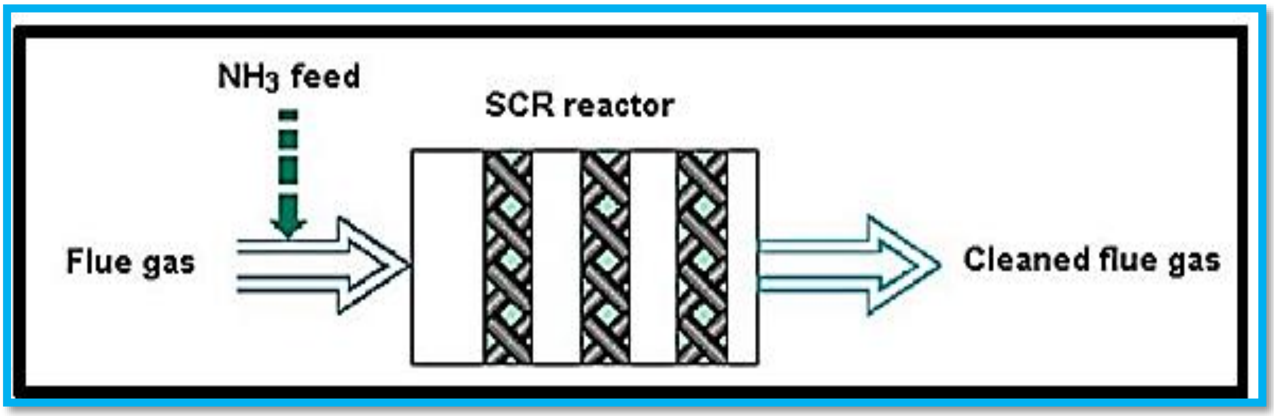


Figure 23: process of SCR (8)

1.6.3 TECHNIQUES FOR REDUCTION OF CO_2, NO_2

Emissions of nitrous oxide from waste incineration can arise from:

- the use of lower combustion temperatures - typically this becomes interesting below 850 ° C
- the use of SNCR for NO_x reduction (particularly where urea is the reagent chosen).

1.6.3.1 USE OF CO_2 IN THE FLUE GAS FOR THE PRODUCTION OF SODA ASH

CO_2 reacts with sodium hydroxide to form sodium carbonate. The liquid is odorless and colorless. Sodium carbonate can be used as crude material, e.g. in chemical plants, the paper industry.

In this process, the amount of exhaust gas required for the generation of carbonate is withdrawn in a controlled flow to the end of the flue-gas cleaning and directly in a CO2 absorption column. The absorption column is made of plastic material reinforced with glass fiber and contains a plastic material coating. The caustic soda solution is added through the top of the column. Caustic soda passes through the coating material and comes into contact with the flue gases produced in the reverse current. This reacted carbon dioxide and sodium hydroxide and form the sodium carbonate and water.

$CO_2 + 2\ NaOH \rightarrow Na_2 2CO_3 + 2\ H_2O$

The burnt gases escape from the column into the atmosphere via a demister. This mist eliminator can be cleaned using fresh water that is provided on demand via a flow controller.

The carbonate solution is pumped from the dewatering trough the column into the consuming systems with a pump via a level control.

1.6.4 TREATMENT OF DIOXIN BY ACTIVATED CARBON

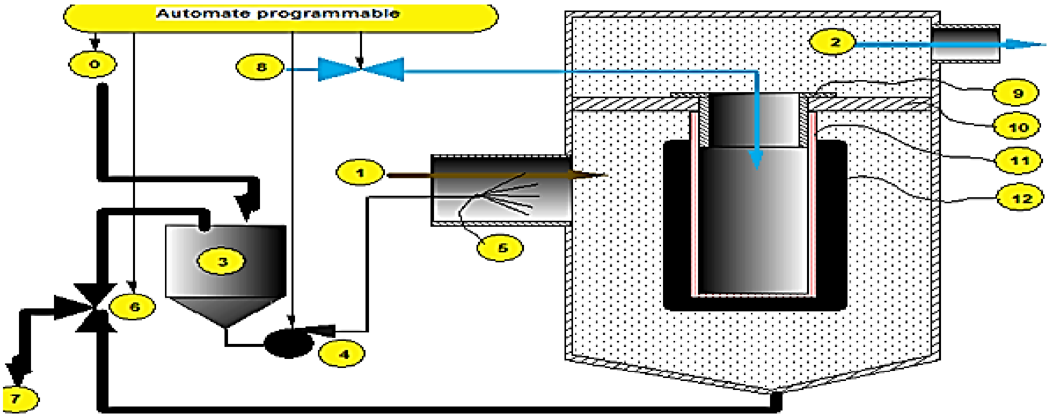


Figure 24: treatment of dioxin

0: new coal Complement.
1: Flow of fumes to be treated.
2: Flow of purified fumes.
3: mixed charcoal Silo
4: Device for coal injection
5: coal injection nozzle.
6: partial recycling valve.

7: Used coal reject.
8: Compressed air filter cleaning.
9: Ruff handle support.
10: horizontal tubular plate.
11: Channel filter textile.
12: Cake normal dioxin filter

Activated carbon is in the form of a fine black talc. Its elementary particles are made porous by a suitable heat treatment so as to create therein pores having dimensions of affinity with the molecules to be filtered. So there are formulations of active carbon adapted to different molecules that one wishes to retain. This product is relatively expensive and operators have an economic incentive to minimize consumption. This activated carbon can be also called "lignite coke." The diagram below shows before a charcoal cake (12), thick enough, which was formed on the sleeve textile (11). Indeed, the smoke flow plate activated carbon on the surface of the sleeve to form a cake therein maintained by the dynamic pressure of the gas. The capture efficiency of dioxins is maximum as the cake is thick enough that the gas molecules "cavil" through the layer thus formed and meet on their way up to elementary particles to be adsorbed therein. The limit of the thickness of the layer depends on the loss of maximum load, so the sleeves do not deteriorate under the effect of pressure and the flow of smoke is not too slow. It is therefore necessary to "unclog" the filter regularly when the pressure drop becomes too high.

Polluants	**Type of treatment**	**basic operation**
SO_2 , HCl , HF (acid gas)	dry way	Injecting a solid absorbent basic, usually calcium or sodium, solid salt formation which can be filtered by intermediary of a media filtant
	semi-wet way	The sorbet is injected in the form of a concentrated solution evaporates. the solid sorbent reacts as obtained by dry way .
	Wet way	acid gases dissolved in a basic solution (NaOH) .the contact can be made either by injecting the solution into the smoke (scrubber) or because the smoke passes through the solution.
NOx	Reburning	Processing gas flame (CH_4, H_2) which forms radicals that react with NO.
	Reduction SNCR selective non – catalytique	Reduction of NOx at high temperature (≥800 ° C) by reaction with NH_3 Reducer example.
	SCR catalytic selective reduction	Reduction of NOx at low temperature (<350 ° C) catalyst, usually oxide vanderuim.
organic compounds	activated charcoal	Activated charcoal possesses a structure a microporous structure which gives it a large area specifiqueet so strong adsorbent power. activated carbon is injected into the conduit and then filtered with the adsorbed pollutants.
Metals		
dust	Multi-cyclones	The fumes are accelerated in a cylinder, the particles will impact on the walls and lose their speed, they are then recuperated in the filter bottom.
	Electrostatic	The dust through a sufficiently large electric field to ionize the gas which in turn will charge the particles of dust .a once charged, they will impact on the cathode.
	Filter sleeves	Big particles will impact on the filter forming a cake for filtering smaller diameter particles.
	Scrubber	Water injected disperses in drops of water in the trap fumes and dusts which are then recovered in solution.

Table 9: general systems for treatment fumes (bicocchi et al, 2009et Le Cloreic 2006) (13)

1.6.5 UNIT OPERATIONS FOR GAS CLEANING:

A large number of unit operations based on primary separation processes can be used for the gas cleaning of the flue gas generated in waste incineration systems. In Table 10 for each type of flue gas pollutant, a combination of unit operations is indicated with the respective typical range of reduction. The well designed sequence of gas cleaning methods allows for a drastic reduction of pollutants (adopted with comments from Table 5.2 of the BREF, 2006).

POLLUTANT	**PROCESS STEPS**	**REDUCTION (%)**
SO_x	Wet scrubber or dry multi-cyclone	50 - 90
HCL	Wet scrubber or semi-dry	75 – 95
NO_x	Selective catalytic reduction	10 - 60
HEAVY METALS	Dry scrubber + electrostatic precipitator	70 - 95
FLY ASH	Electrostatic precipitator + fabric hose filter	95 - 99.9
DIOXINS	Activated carbon + fabric hose filter	50 - 99.9

Table 10:Gas cleaning processes and typical range of specific pollutant reduction by combination of unit operation

CHAPTER 2: CONTRIBUTION

2.1 GLOBAL TREATMENT

The literature review has built a thorough idea about the types and procedures adopted by the Environmentalists for flue gas treatment.

thus distinguishing between two types of treatment:

- physical treatment (mechanical, electrical): cyclone, electrostatic, sleeve
- Chemical treatment: sodium bicarbonate, calcium bicarbonate, activated charcoal.

Different criteria are highlighted (temperature of the smoke, dust size, reactivity) to know what type of filter should be used first in order to be more effective.

A simple representation freecad can simplify the treatment steps of the incineration fumes .

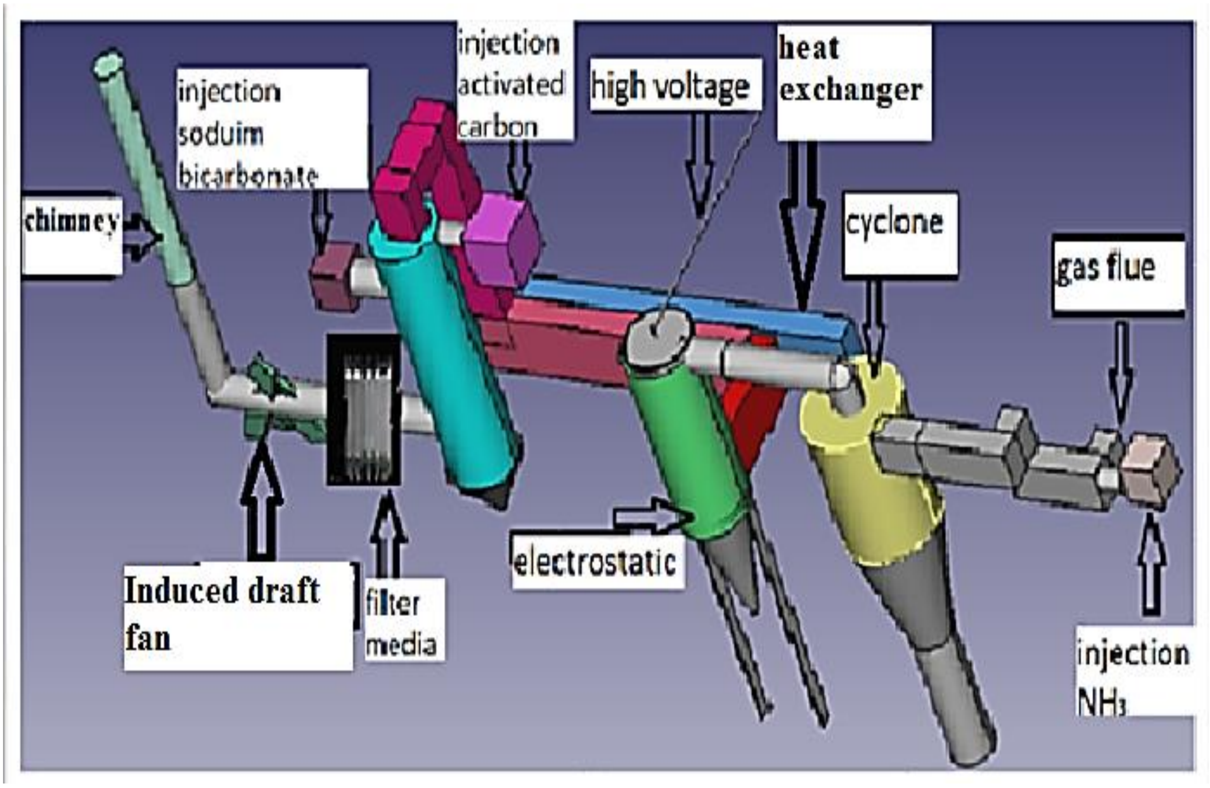


Figure 25: detailed system of treatment

the diagram above can be analyzed as follows:

1-Gas flue at exit (800-1000°C)

2-Injection of NH_3: treatment of nitrogen oxide**.** The reactions realized at temperature between 850 and 1000 ° C, with higher reaction rates and lower in this range. This special reaction takes place:

- 1: directly by injection in boiler (exit of fumes) at a temperature between 850 and 1000°C. It’s correspondent to Selective Non Catalytic Reduction (SNCR)

- 2: with assistance of a catalyst in a temperature range of 170 - 450°C Selective Catalytic Reduction (SCR)

3- Cyclone: The fumes are accelerated in a cylinder, the particles will impact on the walls and lose their speed, they are then recuperated in the filter bottom.it reduce a large percentage of particles.

4- Electrostatic: The dust through a sufficiently large electric field .it's so efficace in order 90 % to eliminate small particles less 5 micron .

5- heat exchanger between gas flue and air that will enter to the boiler and contribue to a combustion .heat exchanger is necessary to minimize the gas temperature to 230°C. at this temperature the charcoal is effective even as bicaronate of soduim.

6-injection of activated charcoal :to reduce the ratio of dioxin and furan in fumes .

7- injection of soduim bicarbonate(powder) : to reduce the ratio of acid gas (**SO_2 , HCl, HF**), at 150- 230°C.

8-filter media: after bicarbonate,charbon was reacted to flue gas ,fumes came to filter media where a cacke was formed in the face ahead flue .it eliminate the toxic gaz and bad smell.

2.2 SIZING INCINERATOR

We will determine the volume of air required for combustion, the volume of actual combustion air, the volume of smoke generated and finally, the flow of wet smoke.

Hypotheses:

Waste composition: it is considered as household waste consist mainly of carbon, oxygen and hydrogen. the contents are neglected by other elements, including sulfur and nitrogen.

70% of the original mass of the waste ends up in gas, mainly CO_2 and H_2O, species that represent the end products of the combustion reactions

Element	Mass Composition (%)
C	57
H	5
O	38

Table 11: mass composition of waste

air factor:

Consider that operates in excess air. So:

$$\lambda = \text{air factor } = \frac{\textit{actual amount of air for combustion}}{\textit{strictly necessary air for combustion}} = \mathbf{1.2}$$

mass flow, humidity and calorific value of the waste:

We work in the most compelling cases:

-Actual capacity furnaces processing is 1t/day (0.042 t/h)

-We Chose the maximum waste throughput: B = 152 t / year

- It is considered that the plant operates all year round, 10h / 24h. The ovens are interrupted seven days per year for maintenance. Thus, each furnace is operated 358 days per year.

Where **B = 0.042 t / h / oven.**

-We Chose the maximum moisture to the waste, either: **E = 60%**

-The Calorific value varies origin of the waste. fixed at **2000 kcal / kg**

Determination of air volumes:

-Volume stoichiometric air required for complete combustion of waste:

Va = 0.089 C + 0.267(H) + 0.033(S-O)

To the extent that we fail the sulfur content, we can write:

Va = 0.089(C) + 0.267 (H) - 0.033(O)

Va = 5.15 Nm^3 / kg of waste

actual combustion air -Volume or specific effective volume of air:

V'a = 6.18 Nm^3 / kg

Determination of smoke volumes:

- specific Volume dry fumes:

V_f = 0,089 C + 0,21 H + 0,008 N + 0,033 S – 0,026 O

To the extent that we fail the sulfur and nitrogen content, we can write:

V_f = 0,089 C + 0,21 H – 0,026 O; with Each carbon atom of the fuel weighing 12g form in the flue gases a mole carbon dioxide occupying 22,4l under normal conditions, each hydrogen atom of fuel weighing 1g formed in the fumes a half mole of water occupying in the normal conditions 22,4l

V_f = 5.14 Nm^3 / kg

specific -Volume of fumes generated:

V_{Fh}=V_f + VH_2O

With V_{H_2O} = 0.112 H + 0.0124 E

V_{H_2O} = 1.3 Nm^3/ kg

Thus: V_{Fh}= 6.44 Nm^3 / kg

specific -Volume of wet smoke:

V’$_{fh}$ =Vfh+ (e / 100) *Va

V'fh = 7.47 Nm^3 / kg

Determination of wet flue gas flow rate:

Q'V_{fh} = B V'fh

Q'Vfh =0.042*7.47= 314 Nm^3/ h

2.3 THE PROCESS OF SORTING WASTE

Waste sorting is a principle basic in the plant because of its importance in reducing the proportion of toxic emissions from the burning of some types of plastics pvc, as well as batteries and hospital waste. In addition to metal materials that are a reason to incomplete combustion.

Waste sorting will be in the following form:

Plastic box(PVC):

They are mostly found in: line pipe, credit card size, PVC films (marketed coils) used (in the form of adhesive film) as lamination or for the advertising print, or (in the form of stretch film) as packaging; Forex used as to the point of sale display (POS).

The elimination of this materials can reduce the emissions of dioxin and acid gas. (15)

-Metal box

- Batteries box

After the sorting, we can conclude that the incineration not include the harmful materials that can be produce by incineration a toxic gas as SO_2, NO_2, dioxin (product of incomplete combustion).

Thus, the main composition of fumes in this case is the dust. treatment was focused on dust by using a cyclone and an electro filter

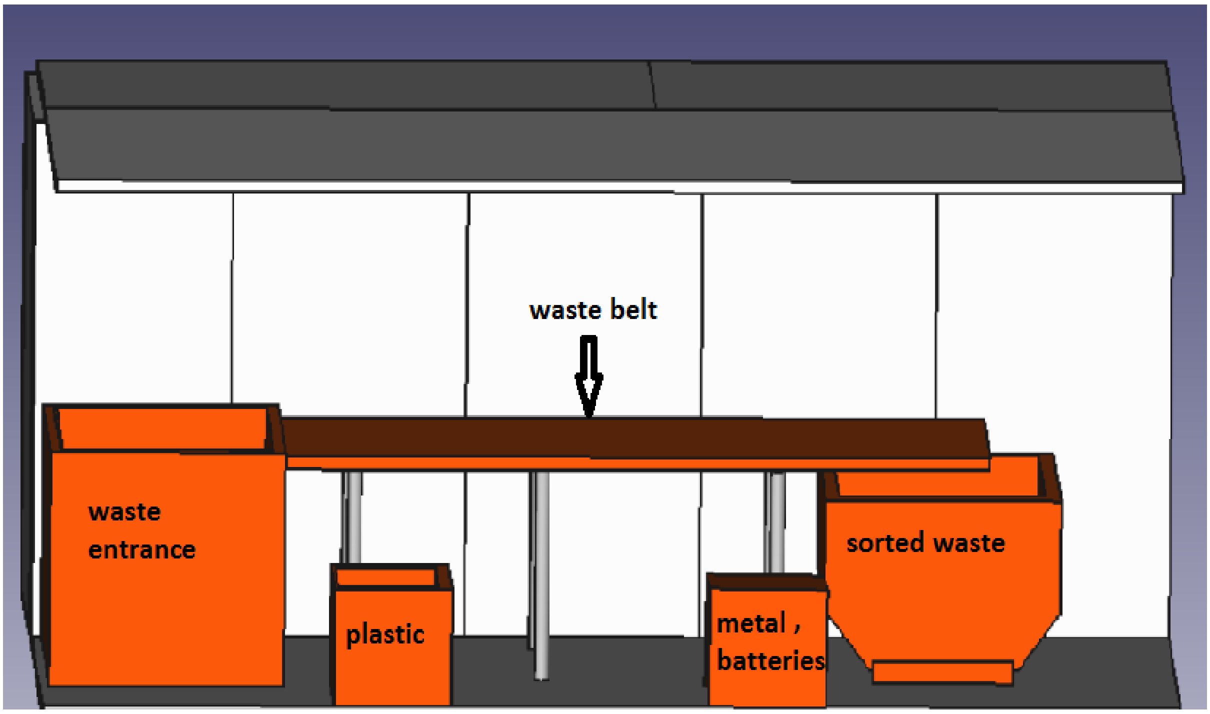


Figure 26: Sorting house by FreeCAD

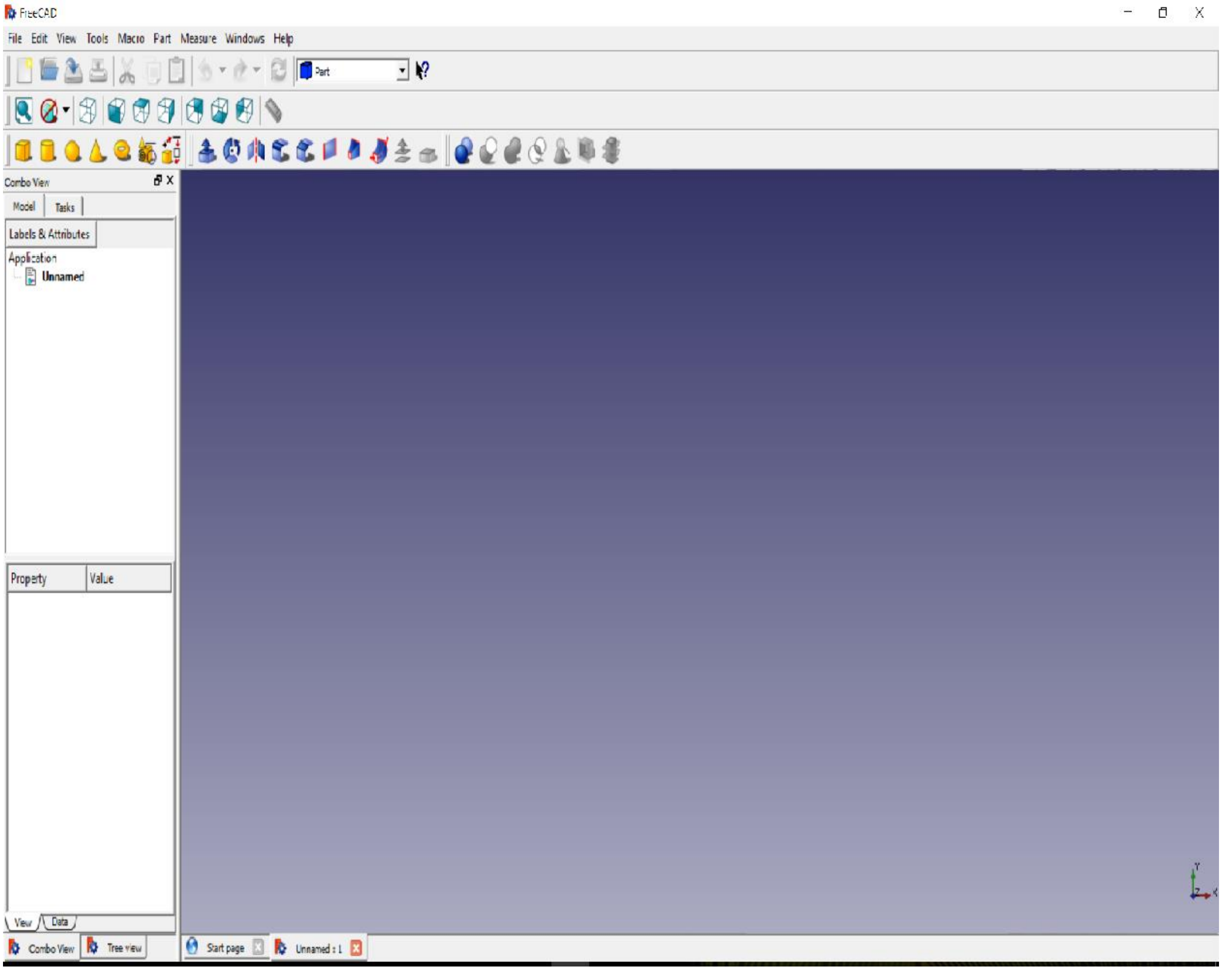


Figure 27: open page of FreeCAD

2.4 DESIGN OF ESP

The electrostatic precipator used to attract particulars less than 5 microns in the gas flue of incineration. ESP will be after cyclone

2.4.1 CYLINDRICAL ELECTROSTATIC

First, this study in TEMO-IPP adopted a cylindrical electrostatic that defined by this dimensions:

- Length :1 m
- Diameter of elec :60 cm
- Diameter of tube : 3,5 mm
- Length of tube : 80 cm
- Nombre of points : 20
- Diameter of point : 0,7 mm
- Length of point : 2 mm
- Space between 2 points : 3,8 cm

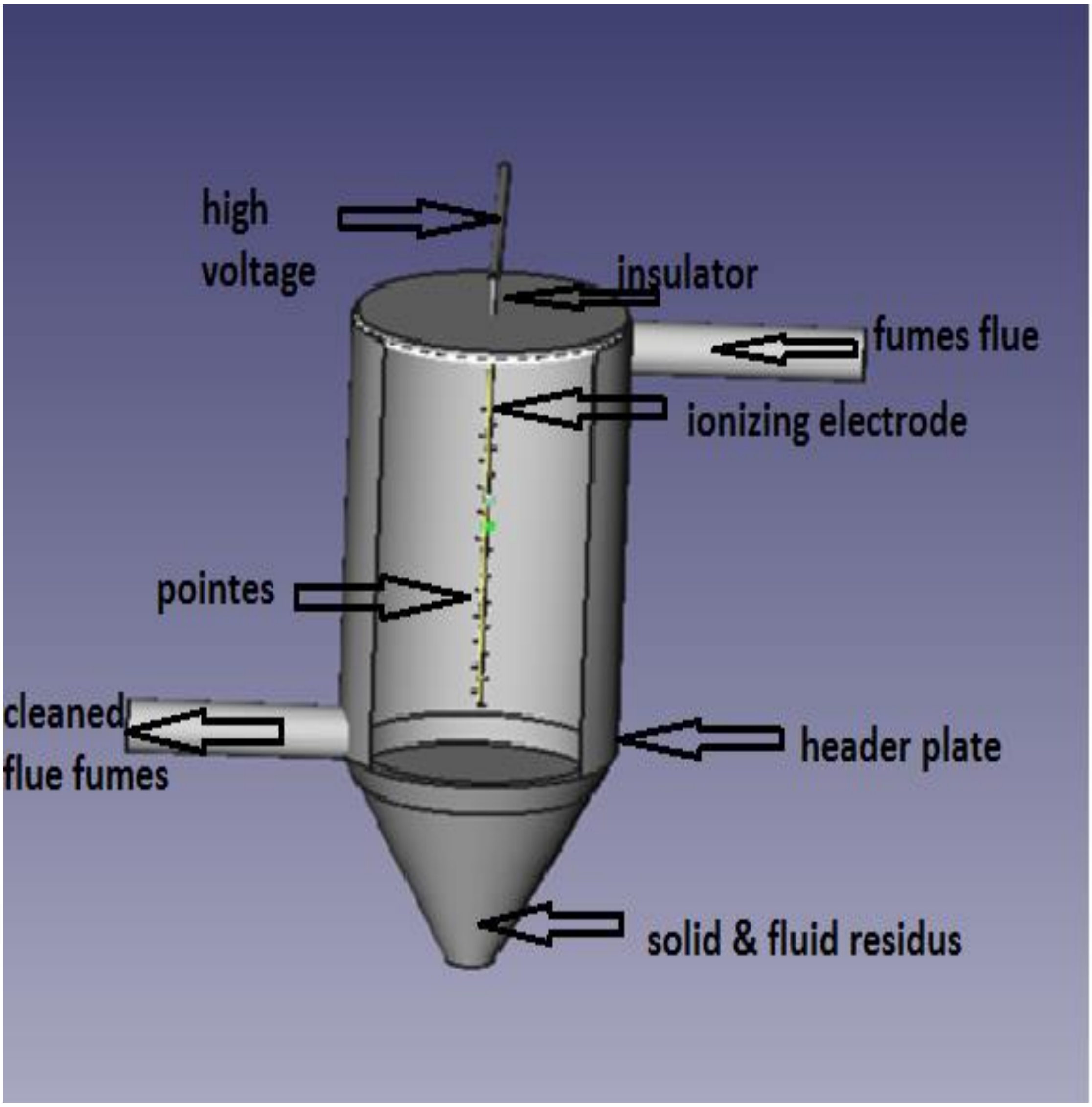


Figure 28: design of cylindrical ESP by FreeCAD

2.4.2 PLANE ELECTROSTATIC PRECIPATOR:

Main dimensions of the plane electrostatic precipator adopted to an incinerator characterize by flue fumes between 200000 & 600000 m^3/h

- The total length 100 cm
- Height h 29 cm
- Distance between the plates 2d 9 cm
- Rods rod diameter d = 3.5 mm
- Pointes
- Dpointe diameter = 0.7 mm
- Lpointe length = 2 mm
- Number of point of each rod =7
- Distance between rods = 4.5 cm
- Distance between pointes = 3.8cm

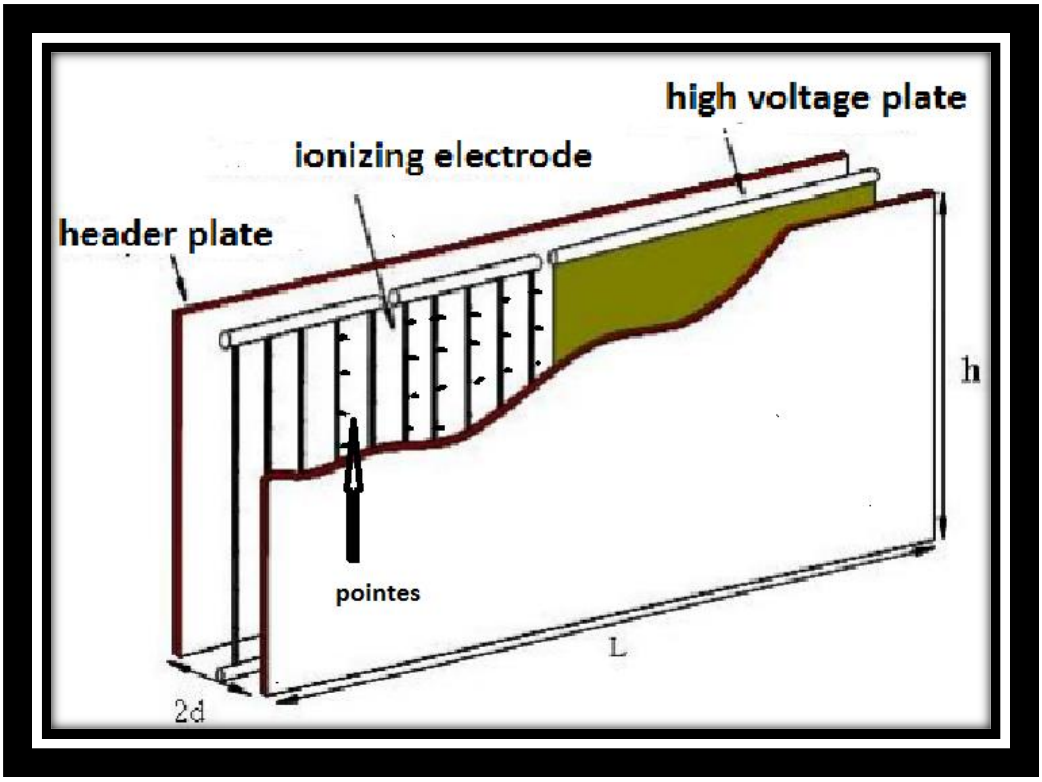


Figure 29: plane ESP (16)

2.4.2.1 STEPS TO OBTAINED AN ESP

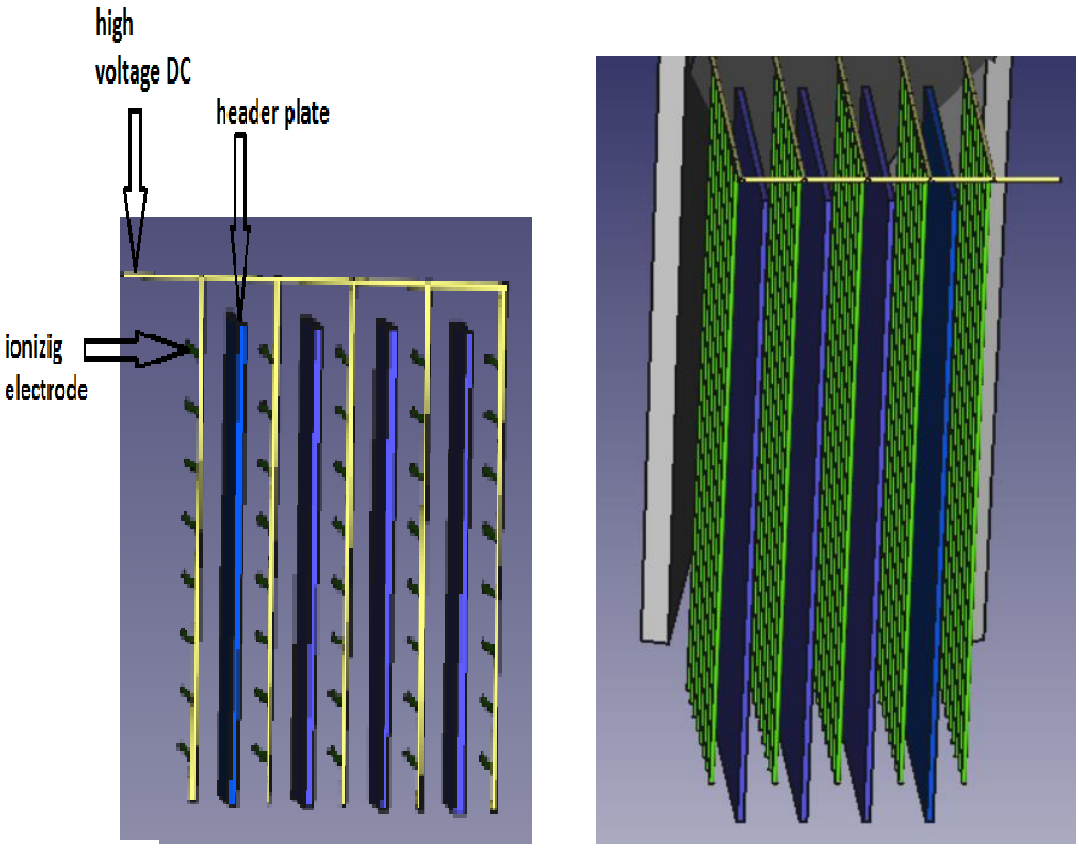


Figure 30: design of plate ESP by FreeCAD

Header plate:

- iron
- sickness: 0.5 mm
- length: 1000 mm
- width: 420 mm

Ionizing electrode:

- copper
- vertical: - diameter :1.75 mm (14)
  - length: 800 mm
- horizontal: - diameter :2mm
  -length: 460 mm

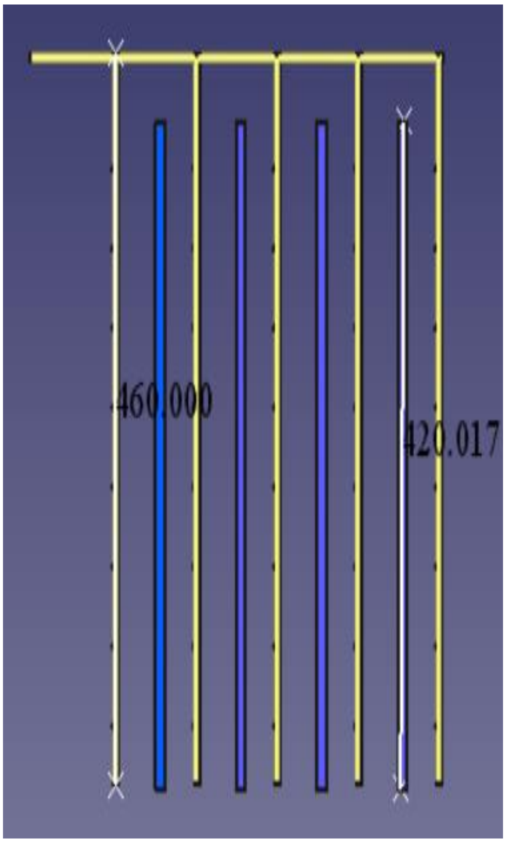


Figure 31: top view

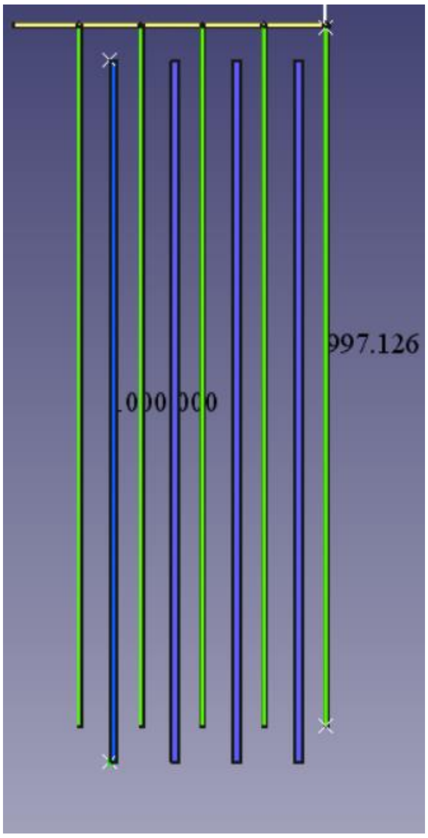


Figure 32: front view

Total area of header plate where the particulars of dust are collected 8*0.4*1=3.2 m^2

A study affirmed that to choose a better ESP, the ratio $\frac{\text{area of filtration}(m^2)}{gas\ flue\ (m^3/h)}$ will be between 0.02 and 0.5 . (17)

In this case: Ratio= $\frac{3.2}{\frac{314*280.46}{1500}}$= 0.05; 0.02 <0.05<0.5 .Thus, this ESP was efficacies.

And, $\frac{\text{width}(\text{l})}{\text{length (h)}}=\frac{460}{1000}$=0.46 ≈0.5, acceptable ($0.5<\frac{l}{h}<2$)

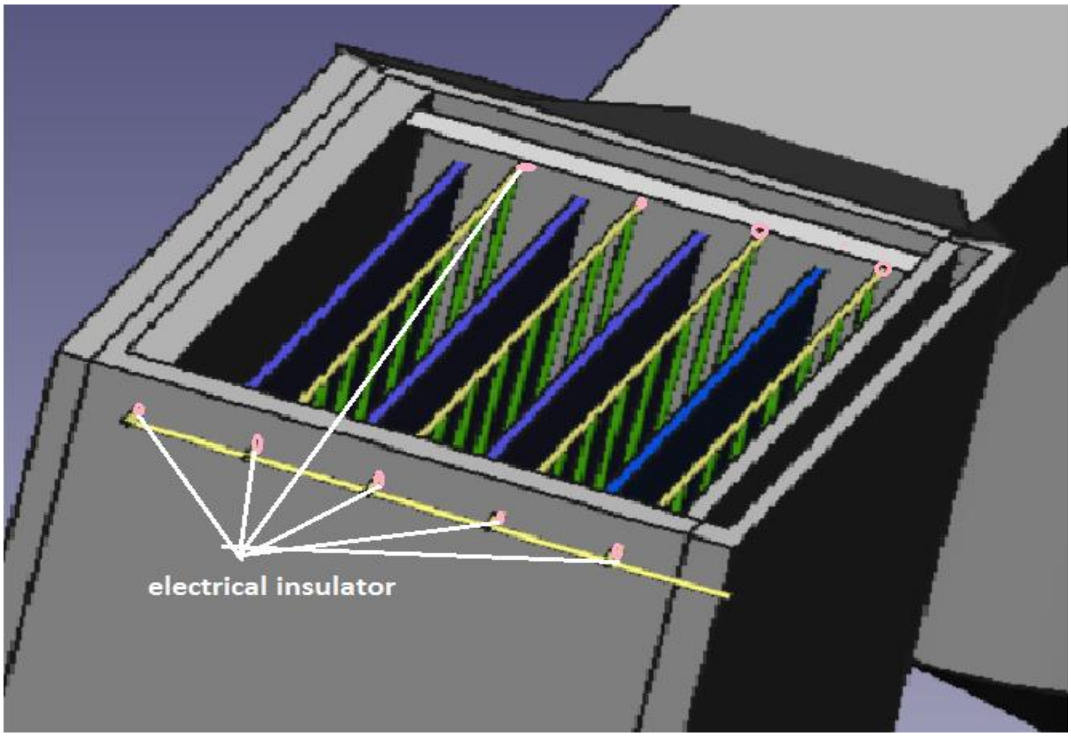


Figure 33: an electrical insulator isolate ionizing electrode from header plate(freecad

Electrical insulator

The charge separation in a parallel plate capacitor generates an internal electric field. The dielectric material (orange) reduces this field and increases the capacitance. A dielectric material (compound word of the prefix dia (δια) - (through) and electric) it contains no electrical charges likely to move macroscopically. The medium thus can’t conduct electric current, and by definition is an electrical insulator. Examples of dielectric media: the empty, glass, dry wood, many plastics, etc.

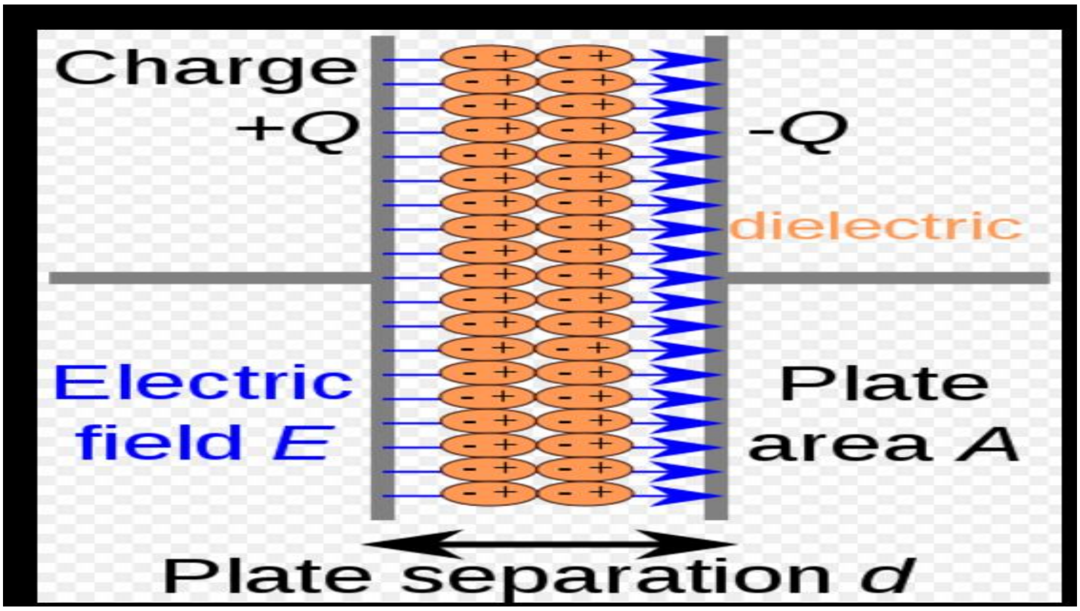


Figure 34: presentation of insulator (1)

Figure 35: insulator used to ESP in the power plant.

Velocity of gas: 1m/s in the station contributed to a medium entrance to the ESP

Between 0.3 & 0.8 m.

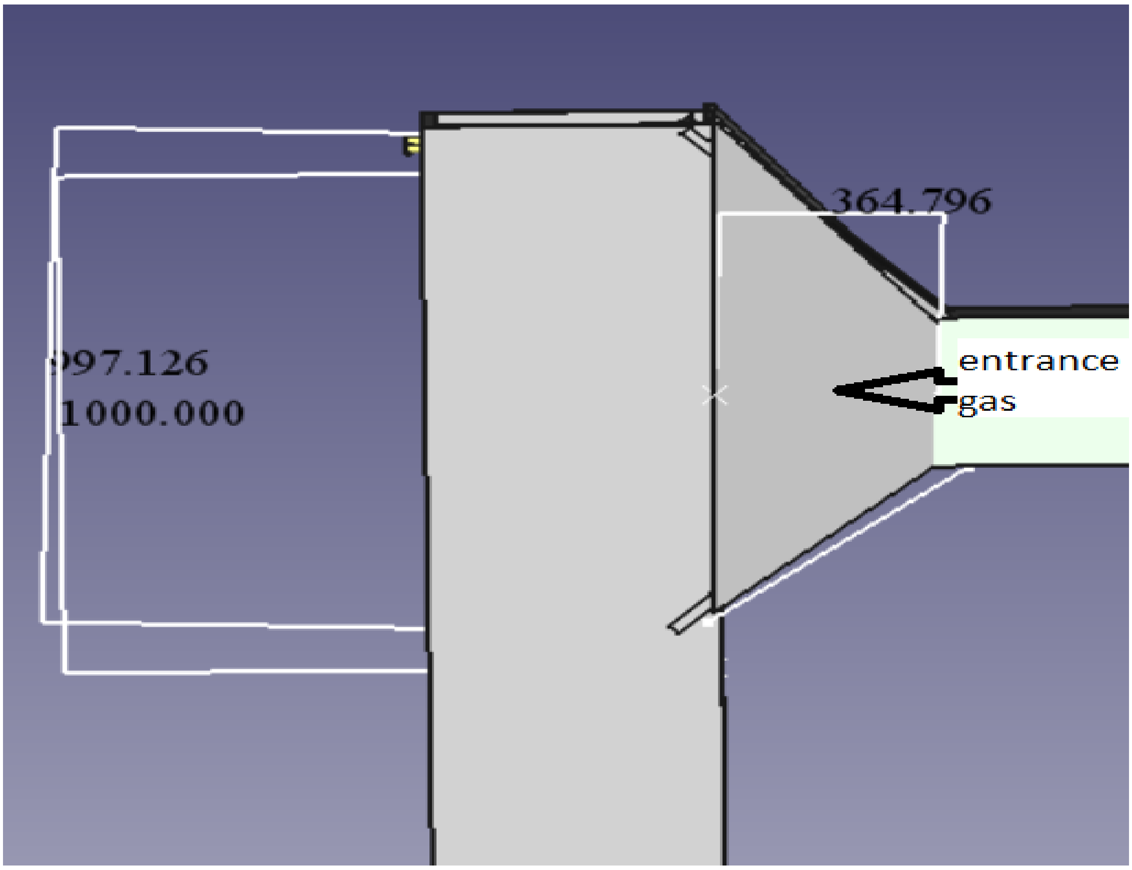


Figure 36: entrance gas to ESP

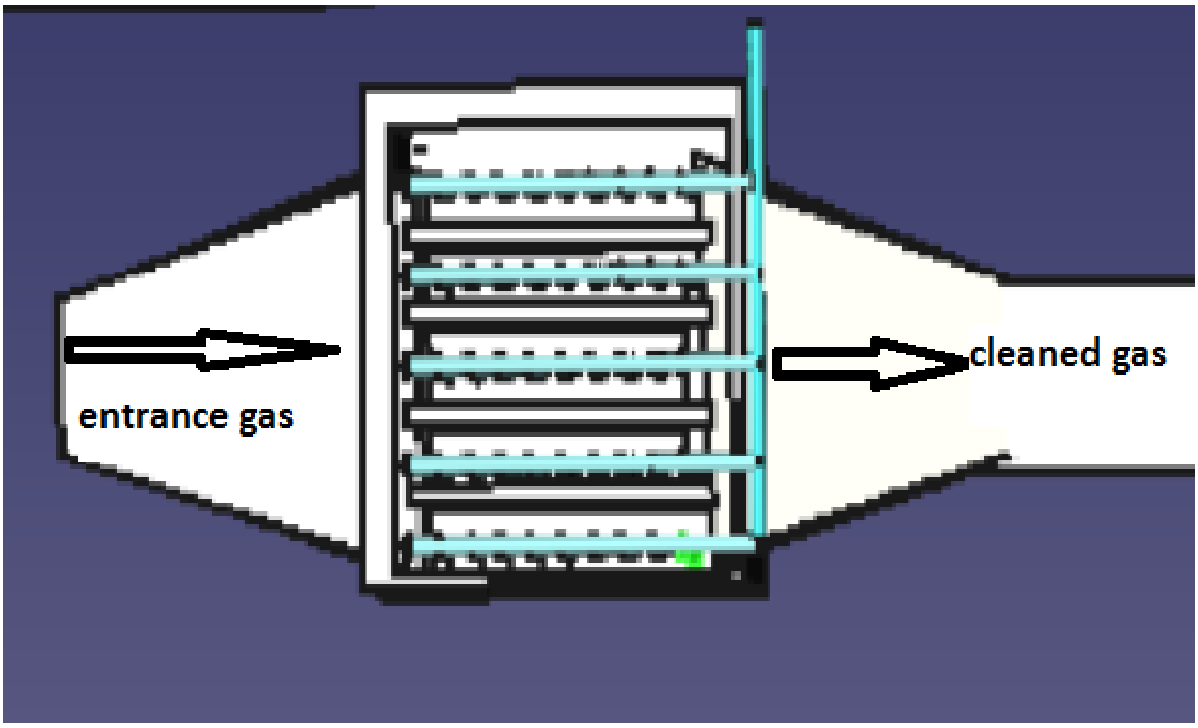


Figure 37: top view of ESP

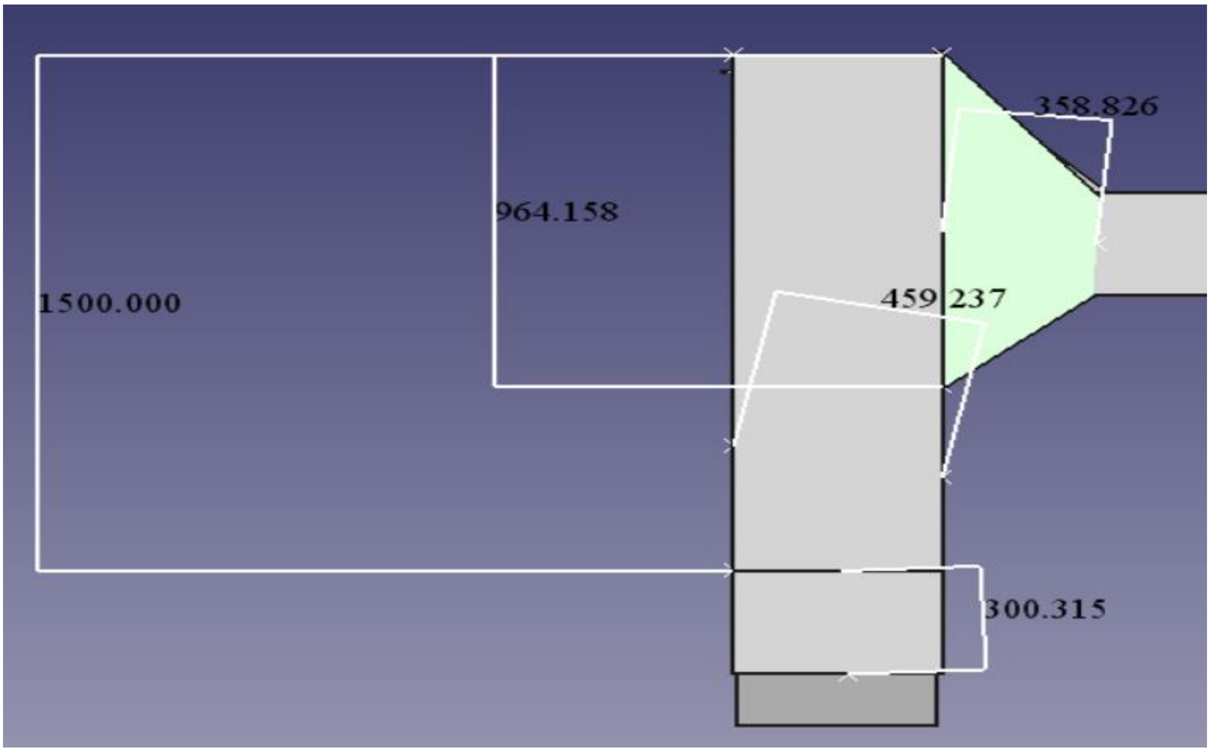


Figure 38: envelop of ESP

After finishing design of ESP, the direct implementation on the station after a request materials needed, such as plate of iron, rods of copper and electrical insulation.

Below is a list of materials that were sent to a commercial company:

quality	عرض(متر) Width	طول (متر) Length	العدد Quantity	السماكة (مم) thickness
حديد مزيبق Iron quicksilver	1	2	6	0.5
فولاذ steel	1	2	1	5
قضيب نحاس Copper rod	قطر 6 مم	0.8	43	–

Table 12:list of materials

Figure 39: insert of plate (iron) & copper wire.

2.4.2.2 HIGH VOLTAGE LOW CURRENT

To activate the ESP, it’s obligated to be connected to high voltage current DC. thus, it’s necessary a transformer that change 220 V to a voltage >10 kV. Then, a rectifier to change the current from AC to DC that ameliorated the ionization of electrode. (18)

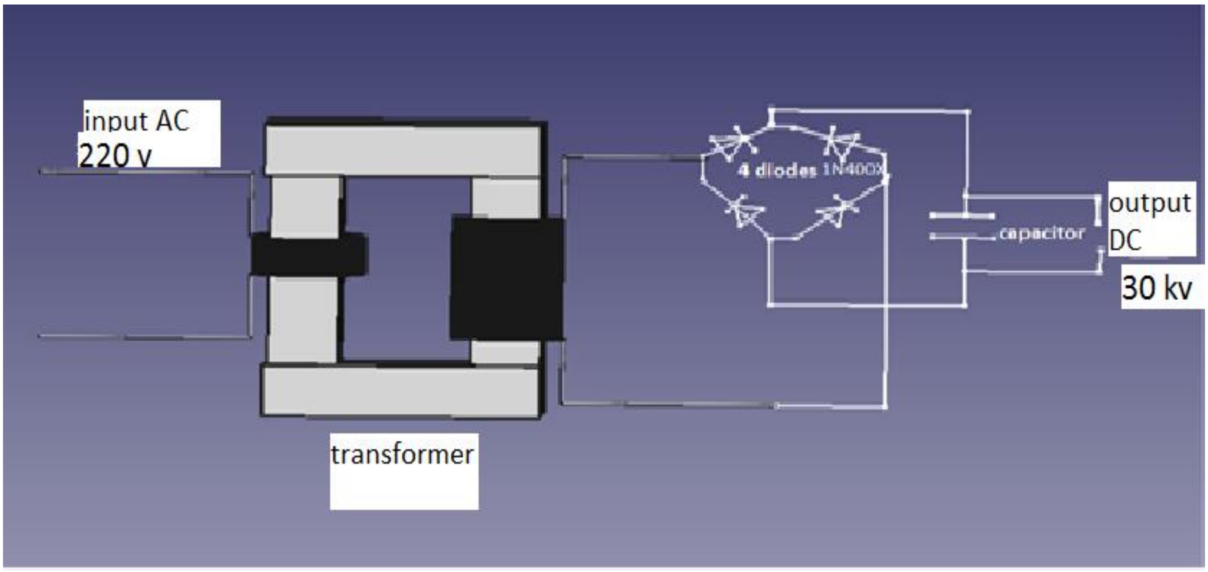


Figure 40: design of electrical system by FreeCAD

The ratio of transformer is m= m= $\frac{\boldsymbol{I\ in}}{\boldsymbol{I\ out}} = \frac{\boldsymbol{n_2}}{\boldsymbol{n_1}} = \frac{\boldsymbol{V\ out}}{\boldsymbol{V\ in}} = \frac{\mathbf{30000}}{\mathbf{230}}$ =136

Secondly, a rectifier is important to use to change the current from AC to DC. A diode bridge with a capacitor and resistance are the main materials used to obtained a DC current.

-type of diode: 2CLG 30KV (5mA High Voltage Diode HV Rectifier Tesla)

-capacitor :1.3 microfarad (19)

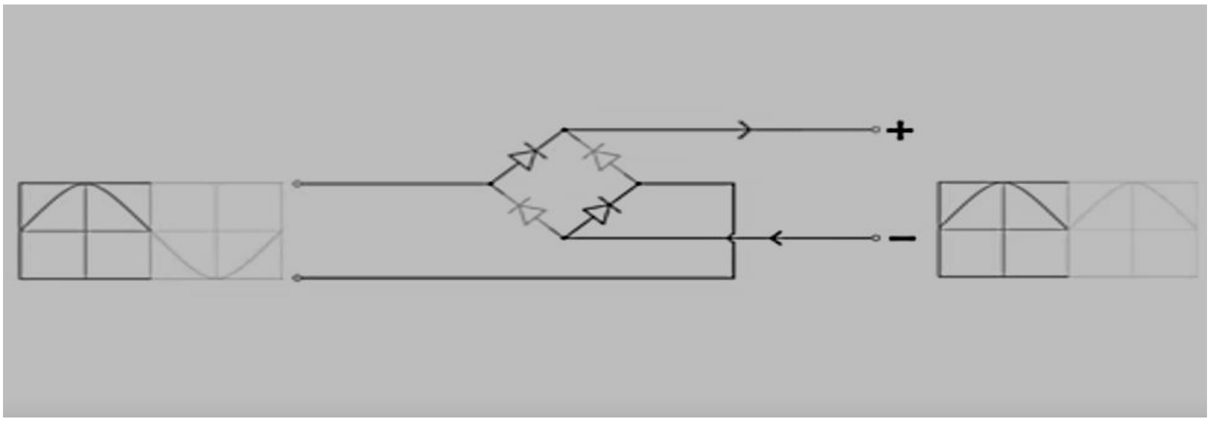


Figure 41: representative circuit

We had connected to long time a lots of company inside and outside Lebanon to buy a transformer with this specification but we don’t find any one.

A decision to create a transformer in the plant.

2.4.2.3 DESIGN OF TRANSFORMER

The Core Area is calculated through the formula given below:

CA = 1.152 ×√ (Output Voltage × Output Current) = 15.45

Calculation of Turns per Volt (TPV)

It is done with the following formula:

TPV = 1 / (4.44 × 10^{-4} × CA × Flux Density (1.45) × AC frequency)

= 1/ (4.44 × 10^{-4} × 15.45 × 1.45 × 50) = 2

Primary Winding Calculations

Basically 2 important parameters need to be figured out while calculating the primary winding of a transformer, they are as follows:

- Number of turns of the primary winding
- Area of the primary winding

Let’s trace out each of the above expressions:

Number of Turns = TPV × Primary Volts =2*220=440 V

Primary Winding Area = Number of Turns / Turns per Sq. cm (from the **table 12**)

Reading **the following Table** is easy: just find out the relevant figures (wire SWG and Turns per sq.cm.) by tallying them with the closest matching value of your selected primary current.

The table below helps you to select the gauge and turns per sq. cm of copper wire by matching them with the selected current rating of the winding appropriately.

SWG	AMP	Turns per Sq.cm.
10	16.6	8.7
11	13.638	10.4
12	10.961	12.8
13	8.579	16.1
14	6.487	21.5
15	5.254	6.8
38	0.0365	3507

Table 13: relation between diameter wire and current .

British Standard Wire Gauge (SWG) diameters

SWG	(in)	(mm)	Step
8	0.160	4.064	0.012"/gauge
9	0.144	3.658	
10	0.128	3h.251	
11	0.116	2.946	
12	0.104	2.642	
13	0.092	2.337	
14	0.080	2.032	0.008"/gauge
15	0.072	1.829	

16	0.064	1.62

Table 14: British Standard Wire Gauge (SWG) diameters

Primary Winding Area = Number of Turns / Turns per Sq. cm=440/12.8=34.375 cm^2

(With consideration that the input current above 10 A)

Secondary Winding Calculations

As explained above, with the help of **Table 12** it should be able to find the SWG of the wire to be used for the secondary winding and the TPV simply by matching them with the selected secondary current.
The Number of turns for the secondary winding is also calculated as explained for the primary winding, however considering high loading conditions of this winding, 4 % extra turns is preferably added to the overall number of turns. Therefore, the formula becomes:

Secondary Number of Turns = 1.04 × (TPV × secondary voltage) =1.04*2*30000=62400

Also secondary winding area = Secondary Turns / Turns per sq. cm. (from **table 12)** **=**62400/3507=17.8cm^2 **(**with consideration that the output current above 10 mA**)**

Calculation of the Core Size of the Steel Laminations or the Stampings

The core size of the steel stampings to be used may be easily found by suitably matching the relevant information with Total Winding Area of the transformer. The Total Winding Area thus needs to be calculated first, it's as follows:
Total Winding Area = (Primary Winding Area + Total Secondary Winding Area) × Space for External Insulation.

The third parameter i.e. the space for the insulation/former etc. may be taken approximately 25 to 35 % of the sum of the first two parameters.

Therefore, the above formula becomes:

Total Winding Area = (Primary Winding Area + Total Secondary Winding Area) × 1.3= (34.375 +17.8) *1.3=67.8 cm^2

Type-------------------Tongue----------Winding

No. --------------------- Width-------------Area

8(E/I) -------------------- 5.080 ----------49.803

This is the type of laminations correspond to an array >49.803cm^2

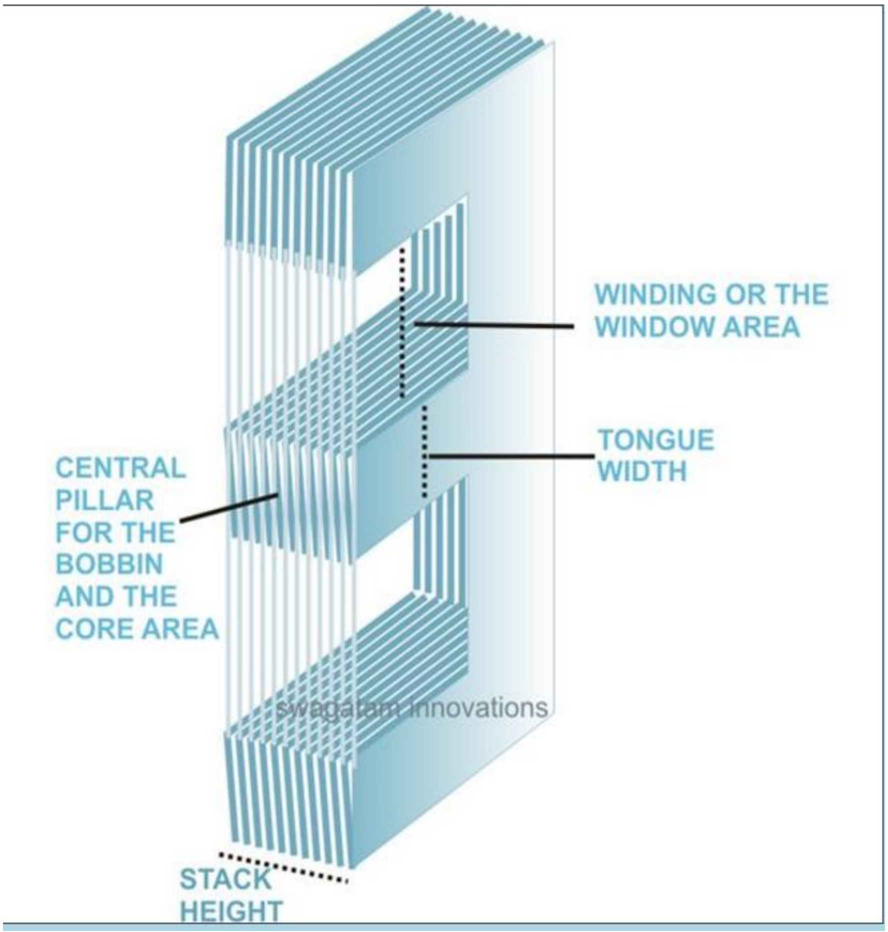


Figure 42: style of laminations

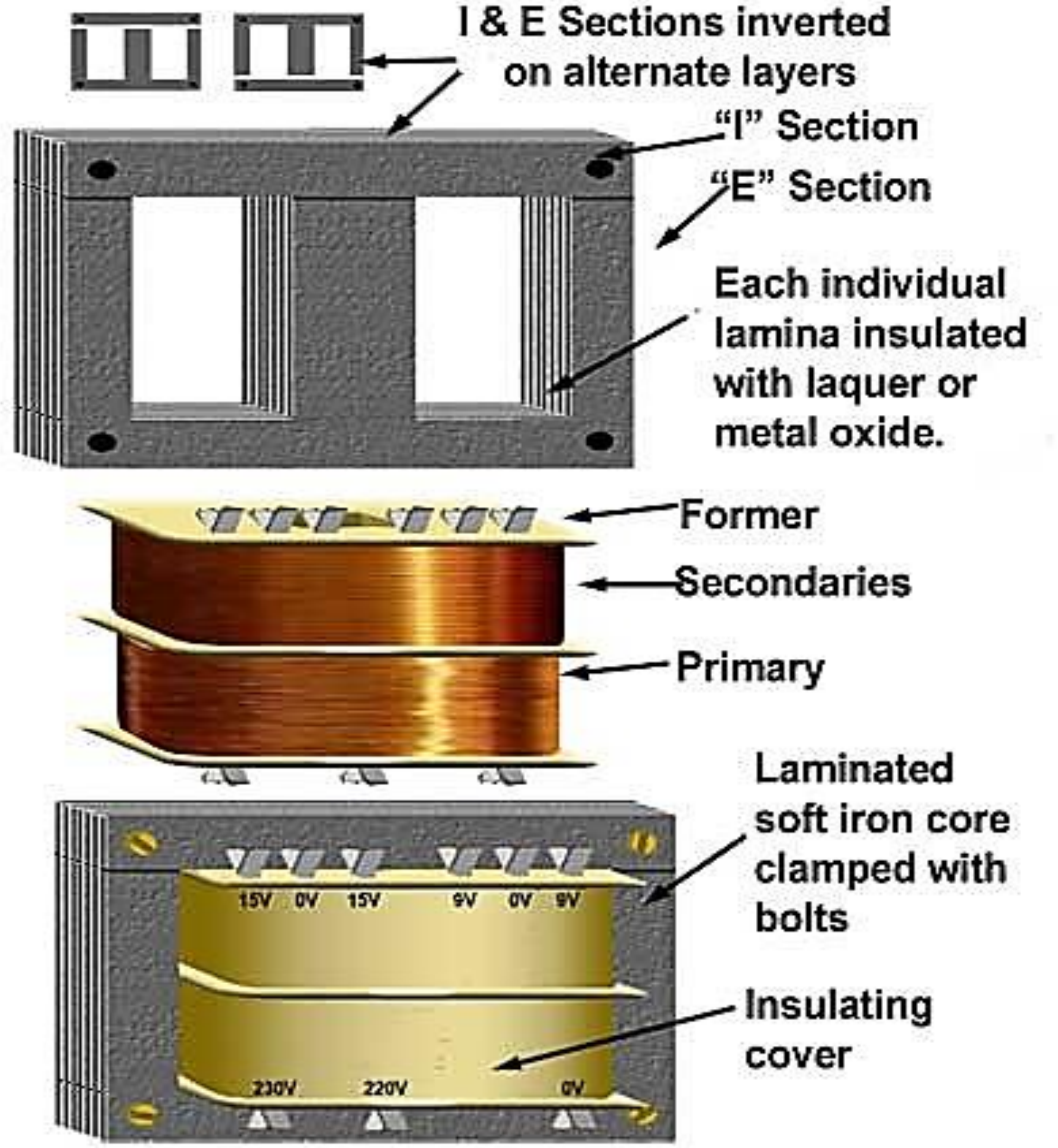


Figure 43: fabrication of transformer

Mass of copper necessary to primary and secondary winding:

Copper is identified by: 8.96 g/cm^3

To first winding:

- The diameter of the copper wire is 2.6 mm
- Number of turns: 440
- Primary Winding Area: 34.375 cm²
- Mass of wire: 7 kg

To second winding:

- the diameter of the copper wire is 0.15 mm
- Number of turns :62400
- secondary winding area: 17.8cm²
- mass of wire:1.75 kg

Total mass of wire above 9 kg.

Or the total mass of transformer includes in addition to wire:

- mass of core (laminations)
- mass of insulator

Thus, here the problem is the weight of transformer, as the voltage which is to be stepped up increases the insulation level of the transformer increases and hence it becomes bulky. Apart from this the rectification process is carried out using rectifier grade diodes which are slow and filtering is done using high value capacitors which are heavy in weight.

So to mitigate all the above mentioned problems the voltage multiplier circuits can be used where load current is less and voltage is high. Negative voltage can be achieved by inversing the diode direction.

2.4.2.4 DESIGN OF COCKCROFT WALTON VOLTAGE MULTIPLIER:

- PRINCIPLE OF VOLTAGE MULTIPLIER CIRCUIT

One of the cheapest and popular ways of generating high voltages at relatively low currents is the classic multistage diode/capacitor voltage multiplier, known as Cockcroft Walton multiplier, named after the two men who used this circuit design to be the first to succeed in performing the first nuclear disintegration in 1932. A voltage multiplier is an electrical circuit that converts AC electrical power from a lower voltage to a higher DC voltage and less current, using a network of capacitors and diodes. In industrial as well in research area high voltage DC Power Supplies are widely used for testing purpose. (20)

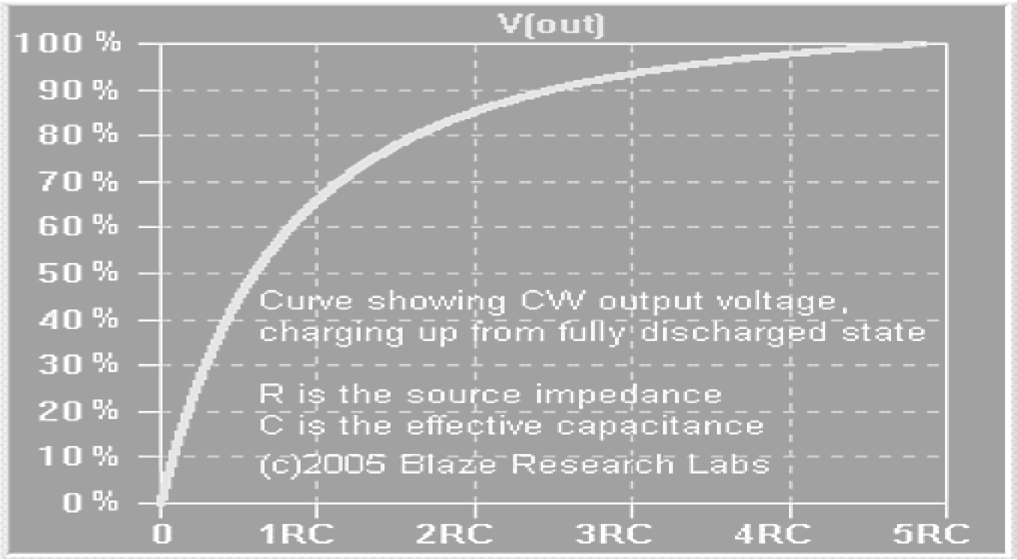


Figure 44: relation between number of RC circuit and output voltage

1. Voltage Doubler

In voltage doubler circuit fig.43 shown below gives a brief idea about the principle of negative voltage doubler where the diodes are rectifier grade diodes and the capacitor diode assembly acts like half wave rectifier. In the circuit during positive half cycle of input voltage first diode is forward biased and second one is reverse biased. Therefore, the flow of current charges the capacitor to negative peak value and capacitor C1 is charged through diode D1 to –Vin

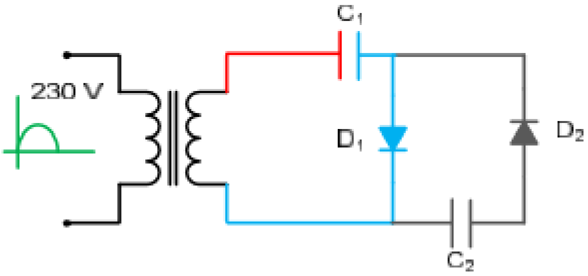


Figure 45: voltage doubler in positive alternation

Similarly, in the fig.41 shown below circuit during negative half cycle of input voltage hence first diode is reverse biased and second one is in forward biased. Therefore, the potential of capacitor C1 adds with that of the source, thus charging C2 to –2Vin through D2.

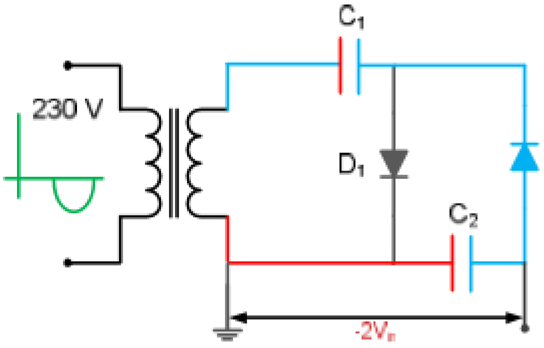


Figure 46: Voltage Doubler in negative alternation

2. Voltage Quadruple

The principle of voltage quadruple is same as voltage doubler; the only difference is number of stages is 2 in quadruple circuit. For positive and negative input voltage the direction of current flow is shown in figures below where in positive alternation potential of capacitor C1 drops to 0 V and allow C3 to be charged through D3 to –2Vin. And in negative alternation potential of C1 rises to –2Vin, also charging C4 to 2Vin. The output voltage (the sum of voltages under C2 and C4) raises till -4Vin as in figure 42

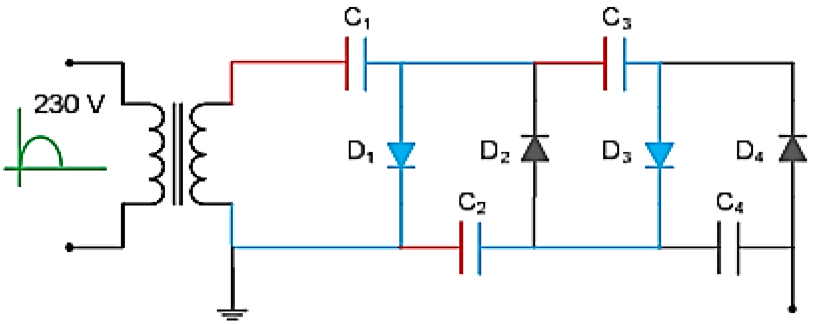


Figure 47: Voltage quadruple in positive alternation

3. DESIGN SPECIFICATION

Output voltage requirement, needed to test the system at -70 kV, 50 mA deciding the rating of transformer is the primary task.

a- Transformer Specification

The first stage of the power supply is transformer which is basically is an isolation transformer used when it is desired to produce such high voltages. The role of isolation transformer in this circuit is step up the voltage and to isolate the low voltage side from high voltage side. So, primary task to design a voltage double is to decide the voltage rating of secondary winding transformer. The output voltage of a quadruple is given by:

$2 \times N \times V_{max} = 70kV$ eq (1)

Where,

N = no. of stages

Vmax = peak output voltage

Vmax = 17.5 kV

Vrms = Vmax ÷1.414 = 12 kV

KVA rating of Supply = 70KV × 50mA = 3.5 KVA

Assuming efficiency of voltage multiplier as 75 percent.

KVA rating of transformer = KVA rating of power supply / 0.75 KVA

$$\text{Rating of transformer} = \frac{3.5\text{KVA}}{0.75}$$

$$= 4.6\text{KVA} \approx 5\text{KVA}$$

So the step up transformer is rated for 230V/12 KV, 5KVA.

b- Capacitor Specification

The value of capacitors used is inversely proportional to the frequency of input signal. So, the capacitors are rated for 2Vmax.

For voltage quadruple circuits: 2× Vmax = 35kV.

$\text{Noptimum} = \frac{\sqrt{(\text{Vmax} \times \text{f} \times \text{c})}}{I}$ eq (2)

$\text{C} = \frac{\text{Noptimum} \times \text{I}}{\text{Vmax} \times \text{f}}$ eq (3)

By putting Vmax = 17.5 KV and I = 50mA

$\text{C} = \frac{\mathbf{(4 \times 50 \times 10)}}{\mathbf{(17.5 \times 10 \times 50)\ C}}$ = 0.22 micro farad.

Therefore, 35kV, 0.32 microfarad capacitor is used.

c- Diode Specification

The maximum reverse voltage across a diode is called peak inverse voltage and the reverse voltage seen by each diode is 2×Vm, so it's a general practice to select a device with PIV rating of 2 × Vmax. When this value of voltage is less than specified value, a small current called leakage current flows through the device. When this voltage exceeds the limit, the device may fail.

From the 230V /12KV transformer Peak output will come up to 12 × 1.414kV = 16.96kV, so twice of it will give nearly 35 kV. So we have taken diode of 40 kV for safety purpose and also for extending the range, as such rating diodes was unavailable so it has been connected two power diodes of 20 kV to make it equivalent to 40kV. Each is having a reverse blocking resistance in the range of mega ohms.

So, the leakage current flowing through each diodes is of the order of =100uA. Thus, resistor while designing of Static Equalizing Circuit for voltage quadruples,

Therefore $\text{R} = \frac{\text{v}}{\text{I}}$ eq (4)

$= 200\text{M}\Omega$

Power rating = $\text{I}^2 \times \text{R}$ eq (5)

$= (100 \times 10^{-6})^2 \times (200 \times 10^{-6})$

= 2 W

d- Calculation of Output Voltage

For design of multiplier circuit, it is very essential to calculate the voltage regulation and percentage ripple. After considering above values the output voltage of Voltage Quadruple Circuit can describe as

$\text{Vout} = (2 \times \text{N} \times \text{Vmax}) - \Delta\text{V} - \delta\text{V}$ eq (6)

Where,

Vout = output voltage of N stage voltage multiplier

N = no. of stages (it is no. of capacitor divided by 2)

Vmax = maximum or peak input voltage ΔV = resultant drop across the capacitors δV = ripples voltage (peak to peak)

$$\Delta V = \left(\frac{I}{f \times c} \times \left\{ \left((2 \times n^3) \div 3 \right) + (n^2 \div 2) - (n \div 6) \right\} \right)$$

eq (7)

So, at 50mAmp Voltage drop in the multiplier circuit is given

as: $\Delta V = (50 \times 10^{-3}) \div (50 \times 0.25 \times 10^{-6})$

$= 28000$ V

Ripple voltage (peak to peak) given by

$$\delta V = \left(\frac{I \times n \times (n+1)}{4 \times f \times c} \right)$$

eq (8)

So, at 50 mAmp $\delta V = 6000$V

Now, Regulation of Voltage $= \frac{\Delta V}{2\ \mathrm{Vmax}}$ eq (9)

$$= \frac{28000}{2 \times 17500}$$

$= 0.8$

Percent Percentage Ripple $= \frac{\delta V}{2\ \mathrm{Vmax}}$ eq (10)

$= 0.171$ percent

When load is not connected, in that case δV and ΔV both are zero thus the above equation get reduce to, $V_{out} = 2 \times N \times V_{max}$ eq (11)

$V_{out} = 2 \times 2 \times 1.414 \times 12 = 67.87$KV

Thus, by choosing appropriate values, power supply is made which is also work negative supply can provide by reversing diode direction. As diode direction is reversed output supply is -67.87Kv..

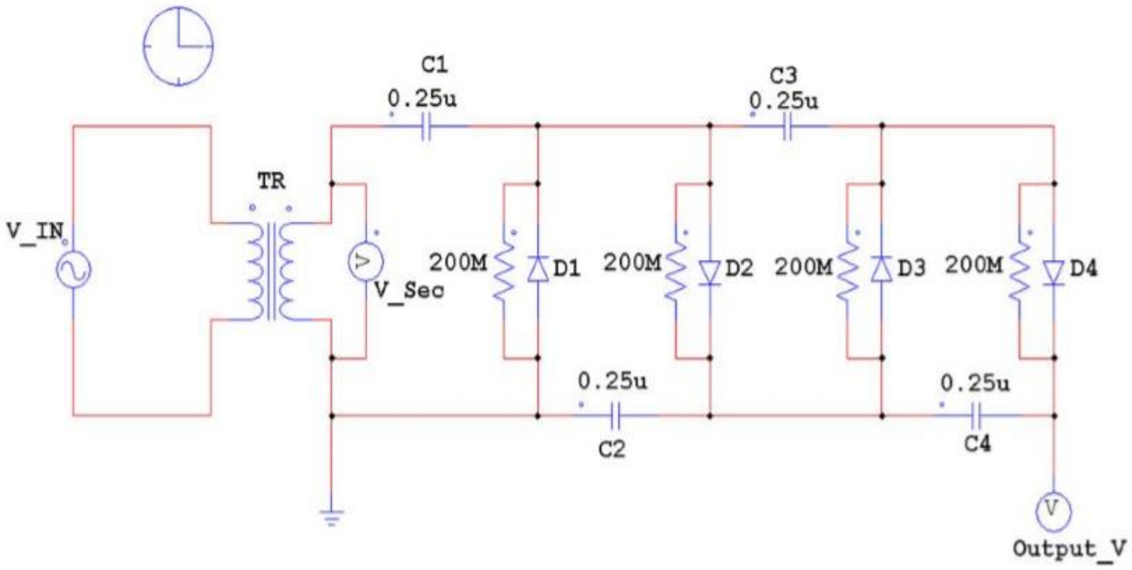


Figure 48: Voltage Quadruple circuit without load

Finally, to manufactured this circuit it’s necessary to immerge it in oil transformer to protect us from any short-circuit or other danger.

Materials	Quantity
Diodes (200 MΩ , 2w)	4
Capacitor (0.25 μF)	4

Table 15: list of materials formed the circuit

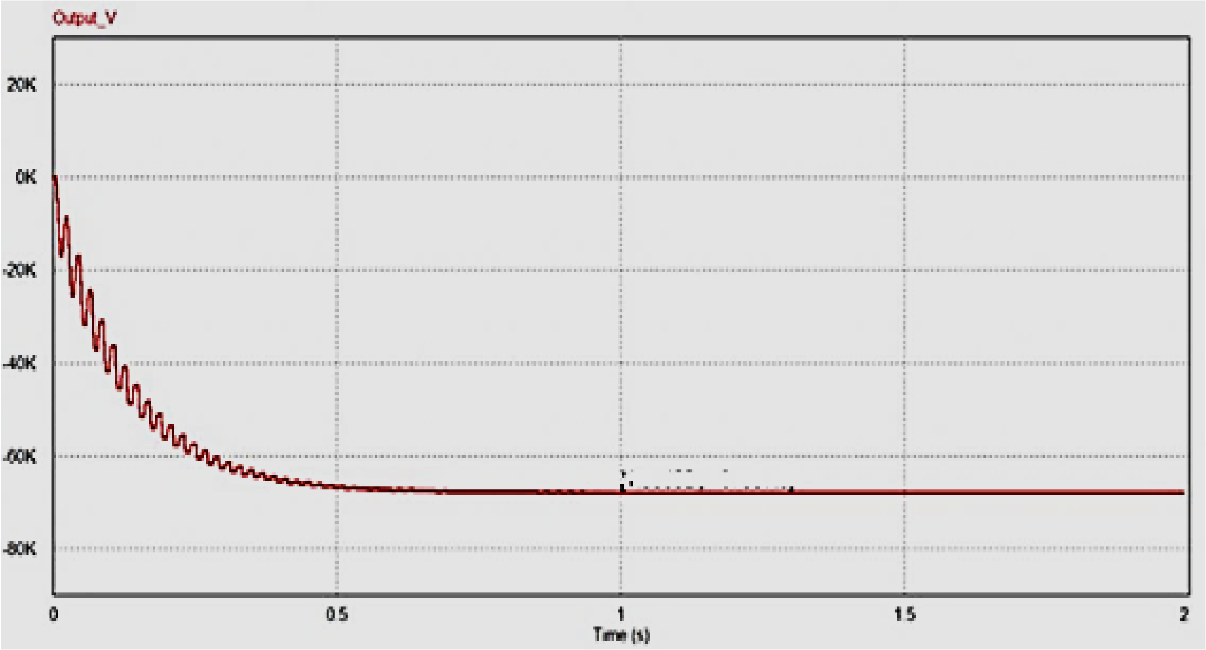


Figure 49: Output Voltage of Quadruple without load

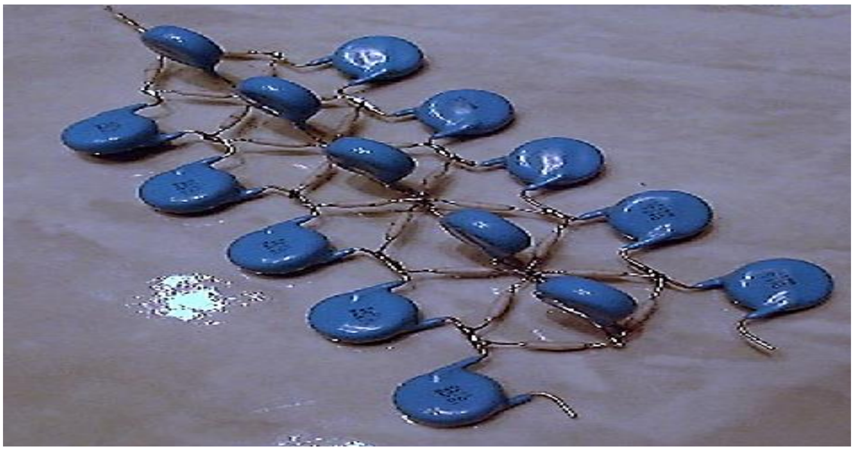


Figure 50: circuit 5 stages

2.5 DESIGN OF CYCLONE

Cyclone filter used to attract particulars more than 5 microns in the gas flue of incineration.

It will be available in this power plant to minimize the quantity of dust in gas flue.

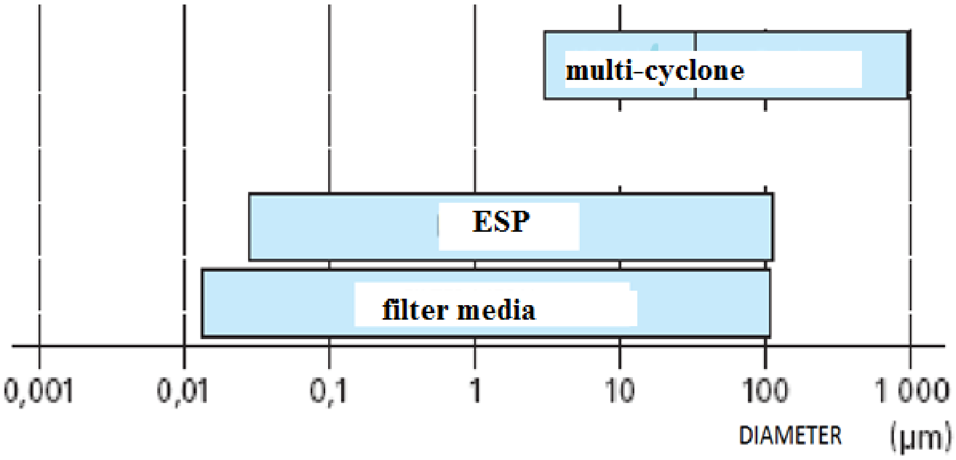
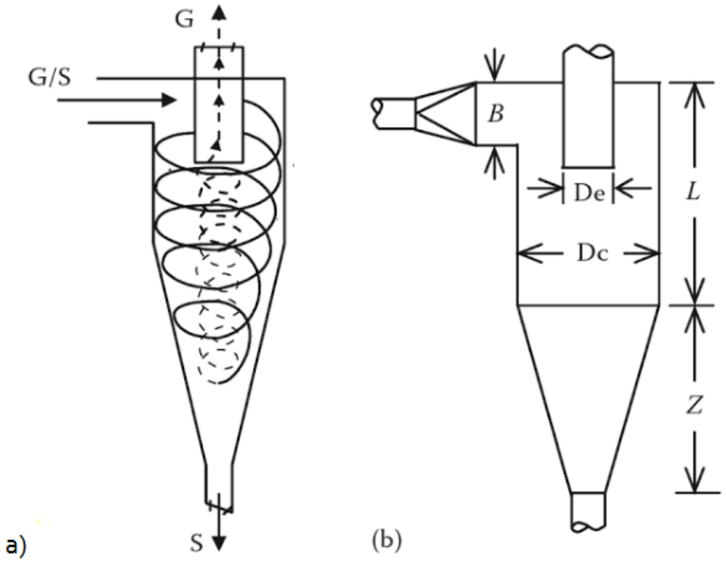


Figure 51:range of particles eliminated

(21)

- **Dimensions of cyclone:**



a) Flow pattern in cyclone separator. (b) Standard cyclone dimensions. S, solids; G, air; Dc, cyclone diameter; 2Dc; B = De = Dc/2.

Figure 52: dimensions of cyclone

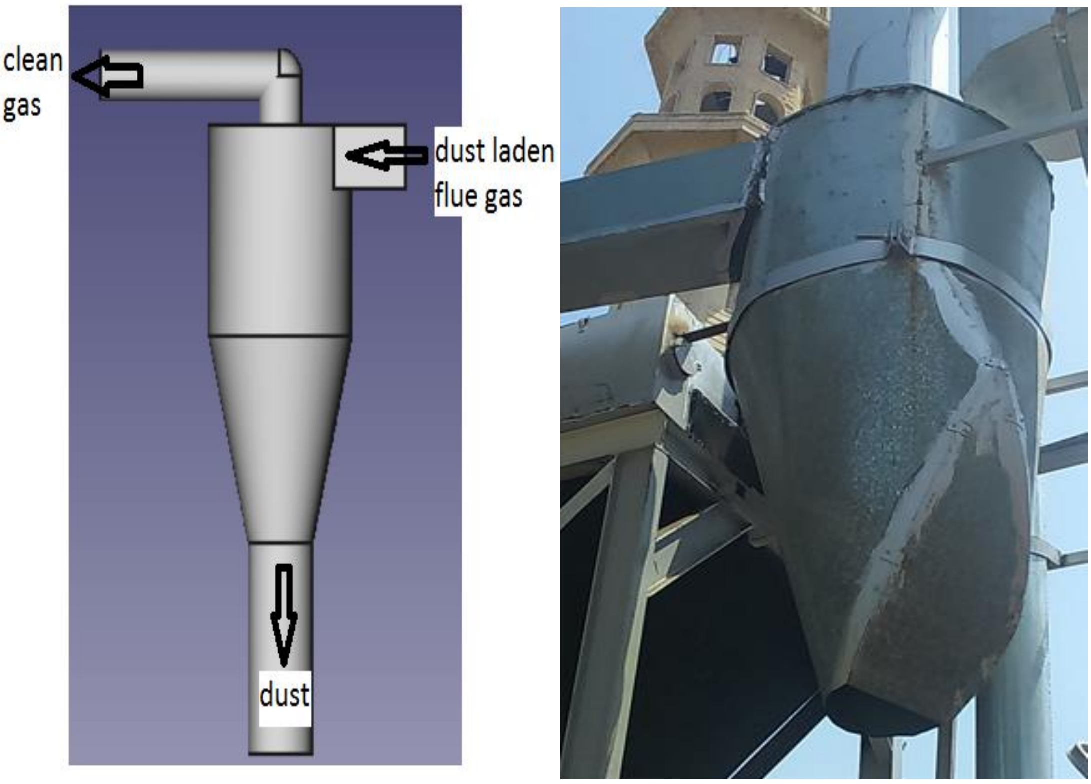


Figure 53: design of cyclone by freecad

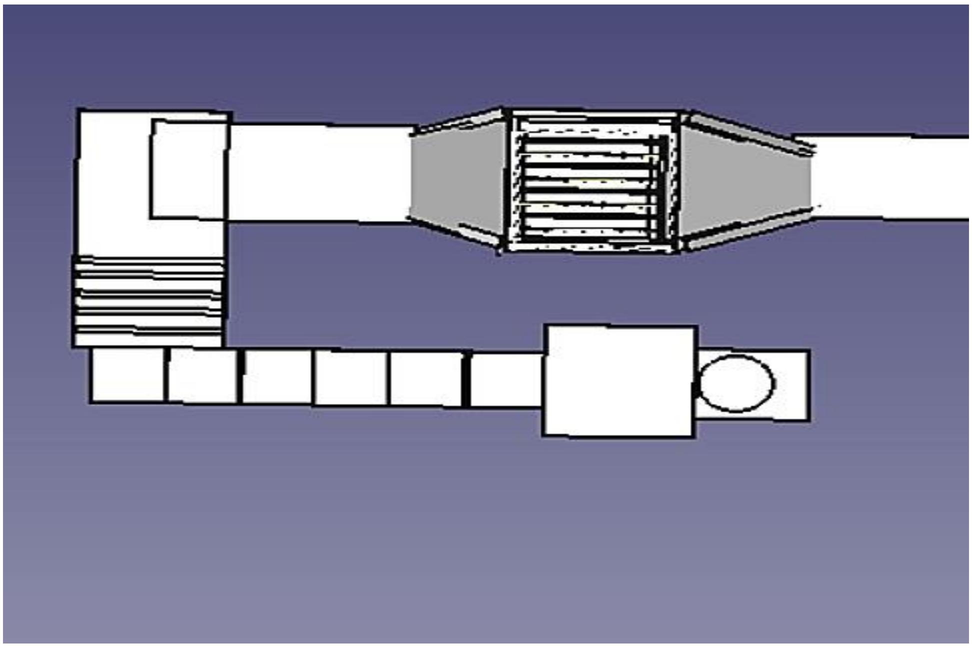


Figure 54: top view of final system of treatment realized in the station (freecad)

2.6 DRY CHEMICAL TREATMENT

Injection of: activated carbon and sodium bicarbonate (in powder form) is by a mechanical action using a compressor (playing the role of a blower).

When the compressor is on, the powder passes in the flow of smoke and reacts with the gas up to reach the filter media, instead of the more efficient reaction (surface reaction) and formed a cake of filtration.

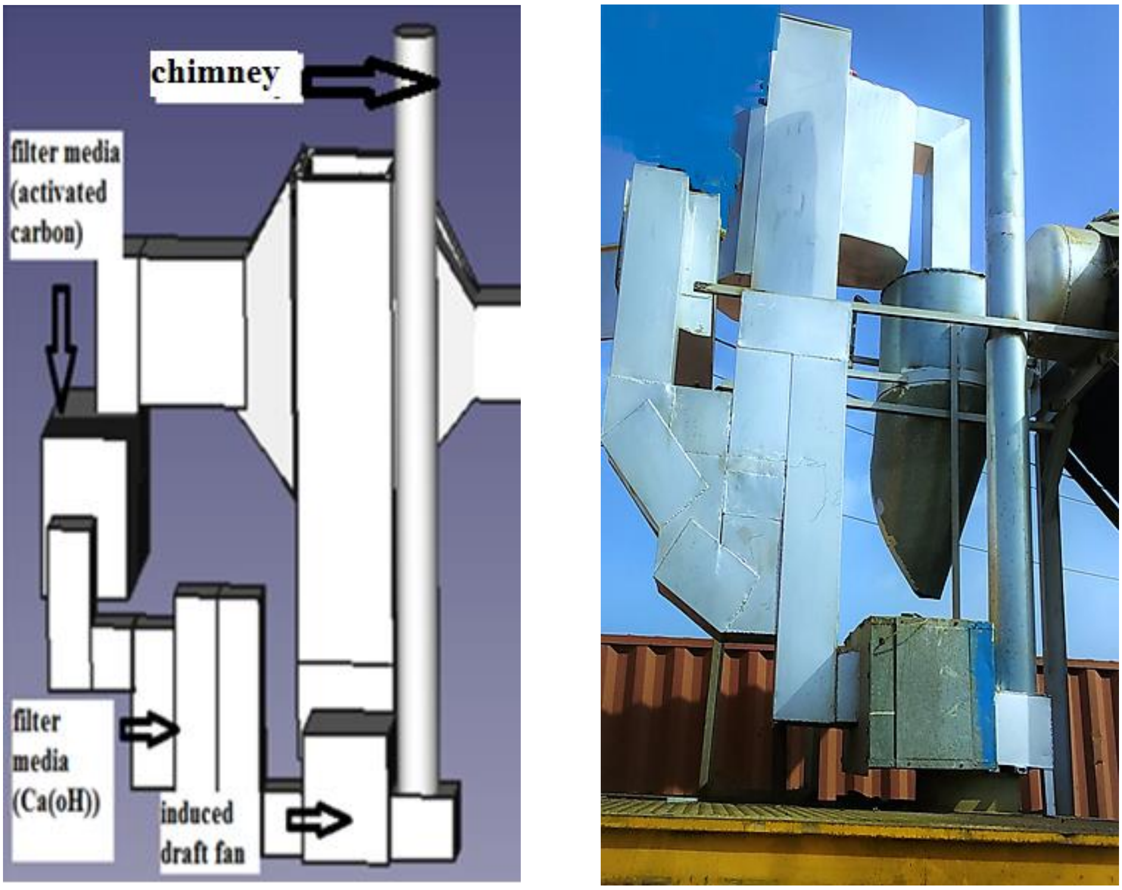


Figure 55: chemical treatment

Parameter	**units**	**Value**	**Comments**
reagent consumption	**Kg/ton of waste incinerated**	**10 - 15**	**the values corresponding to a soda consumption in a municipal waste incinerator**
stoichiometric ratio of reactants	***Ratio***	***1.25*** ***$(NaHCO_3)$***	***In case of baking soda***
		1.5-2.5 **CaOH**	**In case of limestone**
Residues/type			**Residues of treatment are collected sets if a pre-dusting step**
Residues	**Kg/ton of waste incinerated**	**7-25**	**value provided from a ton of waste incinerated**

Table 16: parameter related to the type of treatment

2.7 INSERTION OF FILTER MEDIA

Figure 56:filter media used in the power plant

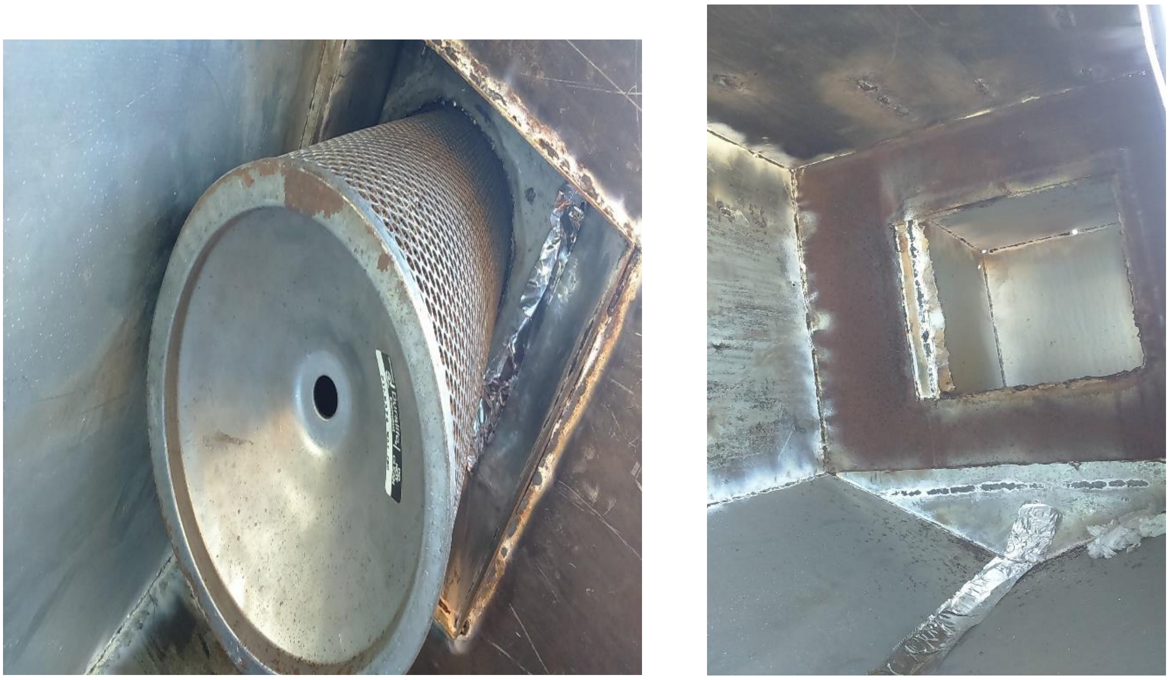


Figure 57:insert of cylindrical media filter after electro filter

Figure 58:insertion of filter (filter media, large size)

We use environmentally friendly filters, 100% recyclable manufacture by Nordic Air Filtration-member of Hengst Group - is a high technology.

2.8 COMPLETING OF INTEGRATION OF TEMO-IPP INCINERATION POWER PLANT

quality (width 80cm)	TOT (height m)	quantity	total m	quality	height m	iron sheet	
TOT	4	3	12	iron (width 2m)	2	4	sorting house
TOT	2.2	3	6.6	Empty iron bar (40 mm, 40	6	4	
TOT	2.23	18	40.14	Door hinges		8	incinerator house
TOT	1.9	11	20.9				turbine house
TOT	0.9	3	2.7				
TOT	1.9	2	3.8				
Total meter of TOT sheet			86.14				

Table 17: List of materials necessary to covering the power plant

- **Sorting house**

Figure 59: basic of sorting house

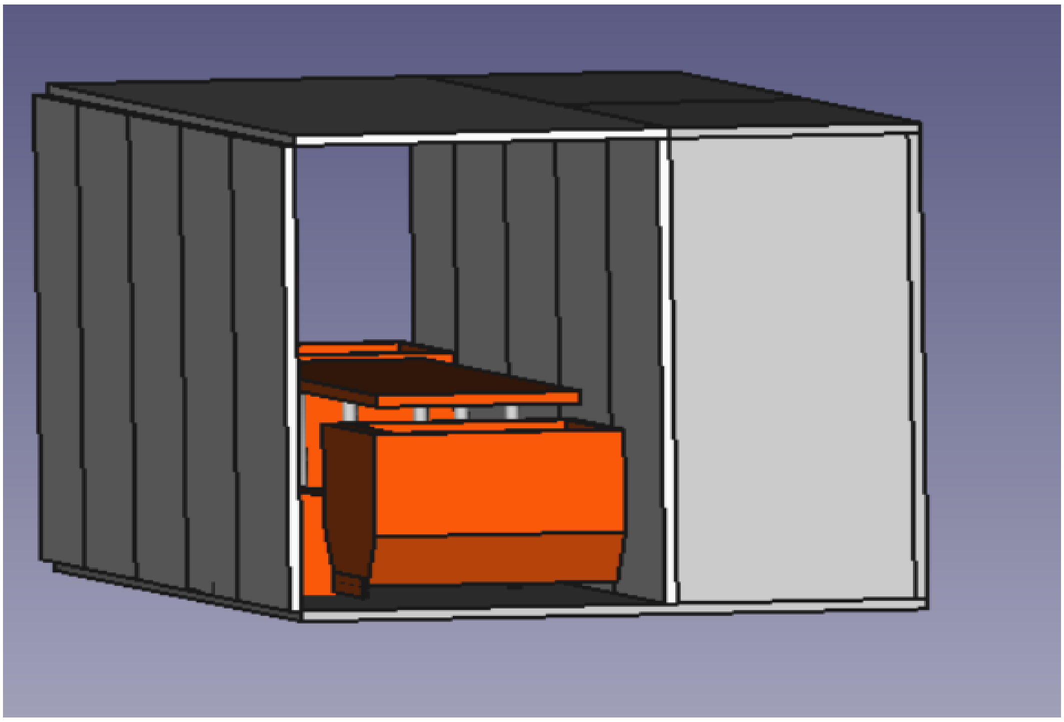


Figure 60: sorting house by FreeCAD

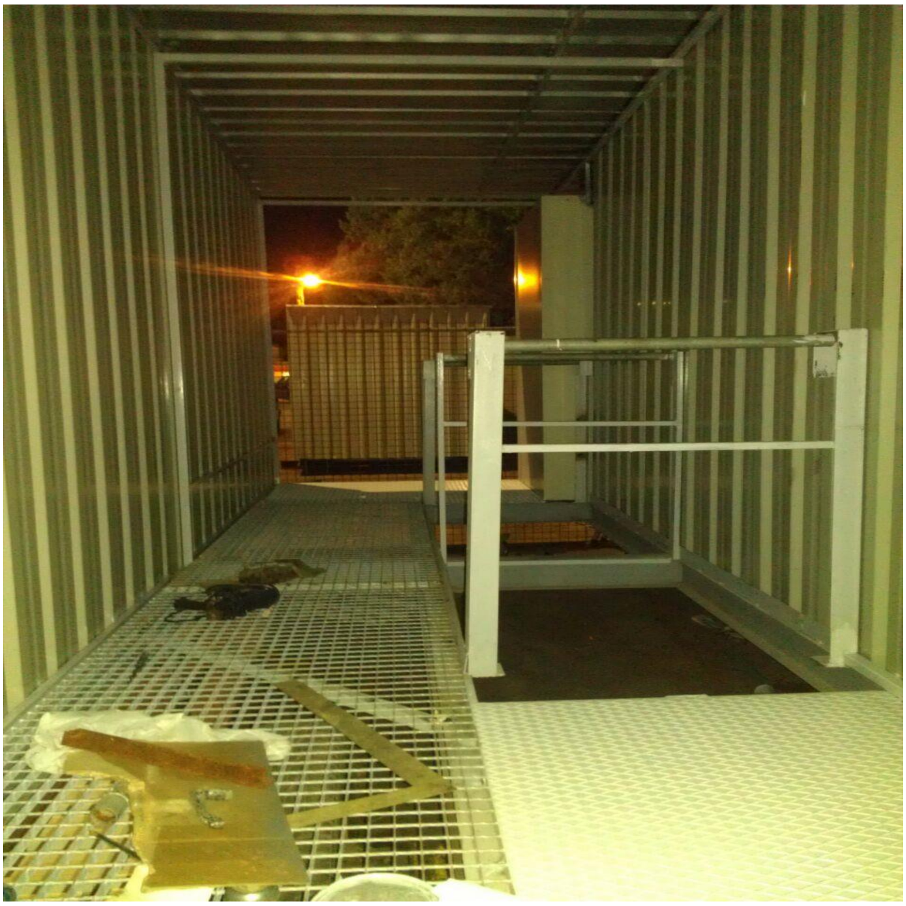


Figure 61: sorting house

- **Turbine house**

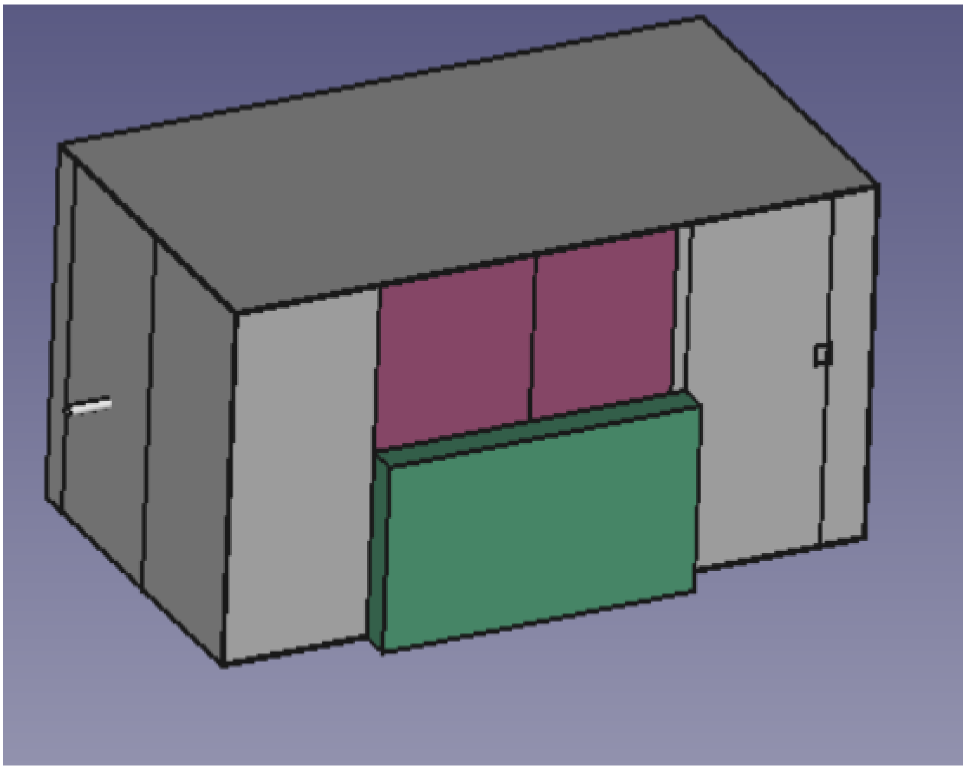


Figure 62: front view of turbine house (FreeCAD)

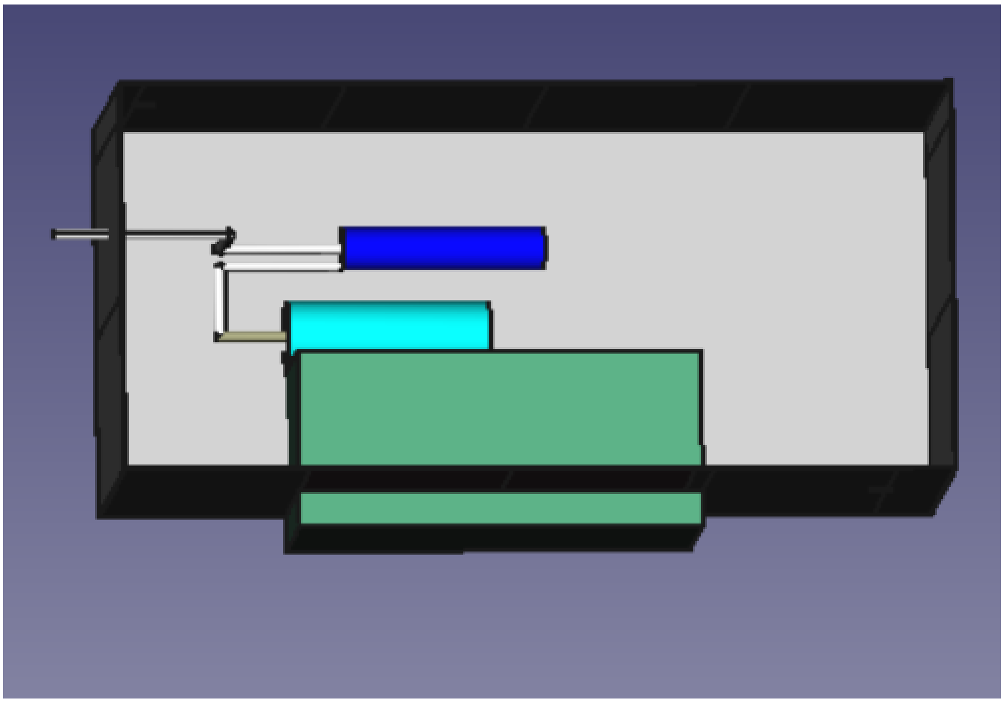
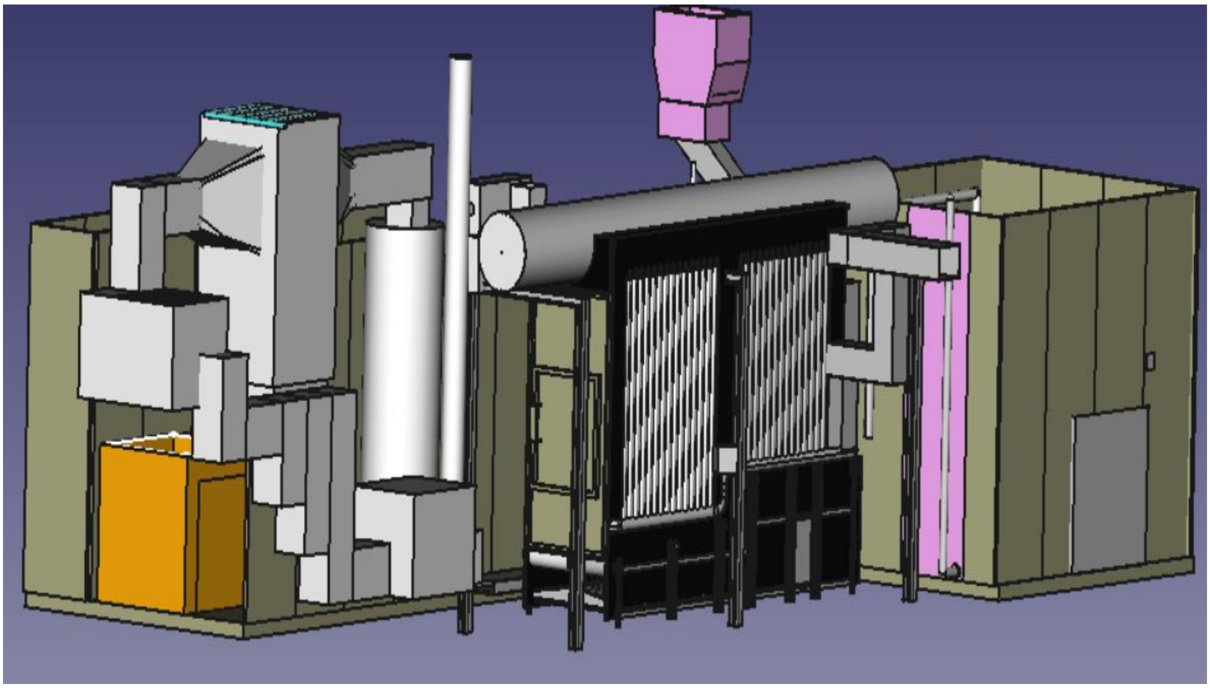
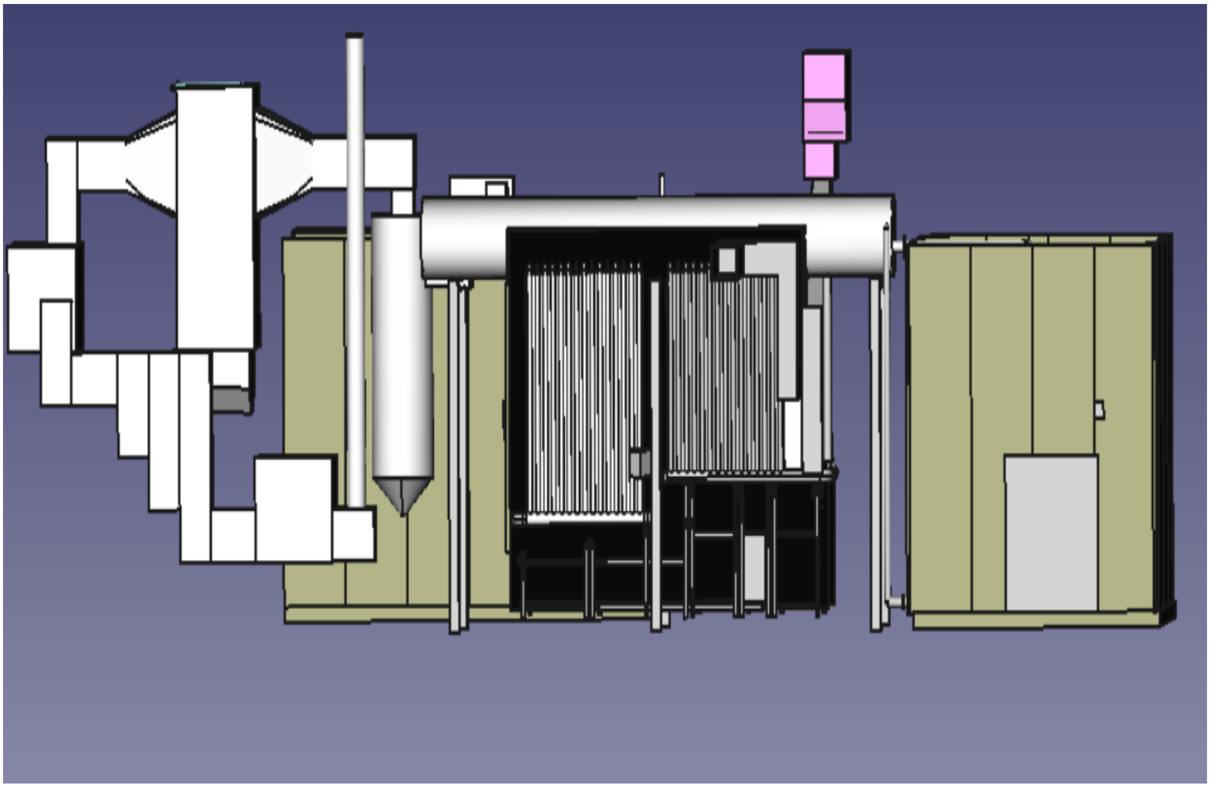


Figure 63: top view of turbine house (FreeCAD)





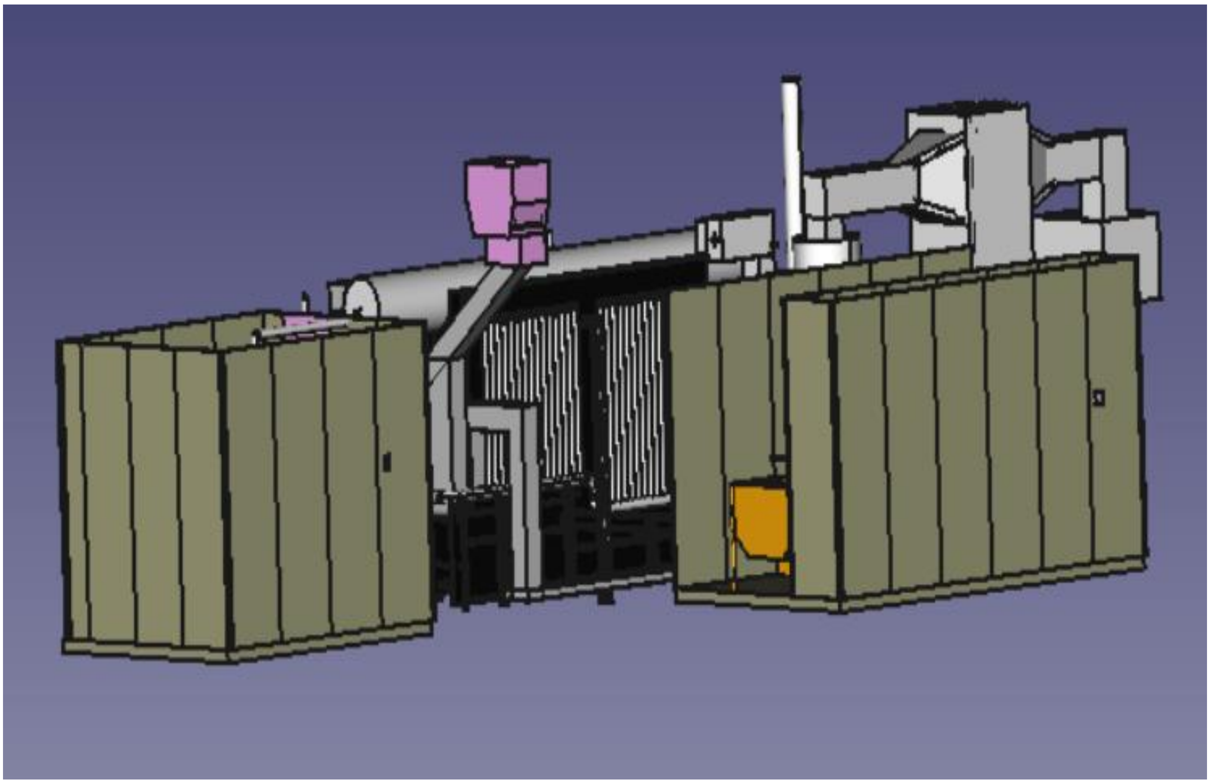


Figure 64: integration of incinerator system (FreeCAD)

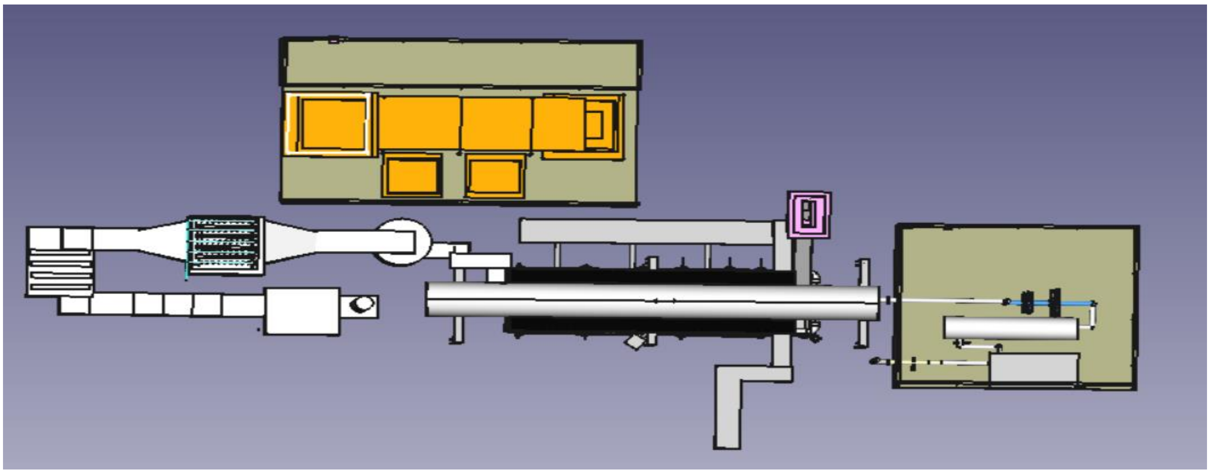


Figure 65: top view of incinerator (FreeCAD)

After that, a simple coloration relized to the station .

Finally, all parts of the station are transferred to a mobile platform with a grue.thus , the station can be operated in any place we want to get rid of non-hazardous waste by incineration and produce at the same time electricity .

Figure 66: incinerator on platform mobile

CHAPTER 3:RESULTATS AND DISCUSSION

3.1 in-situ gas analysis

Analysis controlling gas (O_2,CO_2,CO,NO,SO_2) is through a portable multi-gas analyzer, Horiba PG 250. gases are first filtered by the sampling probe M & C PSP4000H then dried by the packaging system SSPS M & C-5.

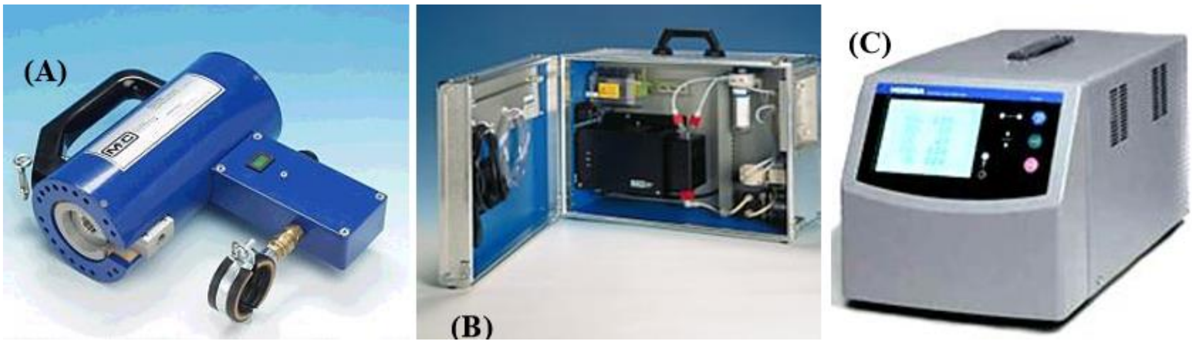


Figure 67: system to analyze in-situ controlling gas

(A) : filter M&C PSP4000H ; (B) : conditioner M&C PSS-5 ; (C) : Analyzer PG-250

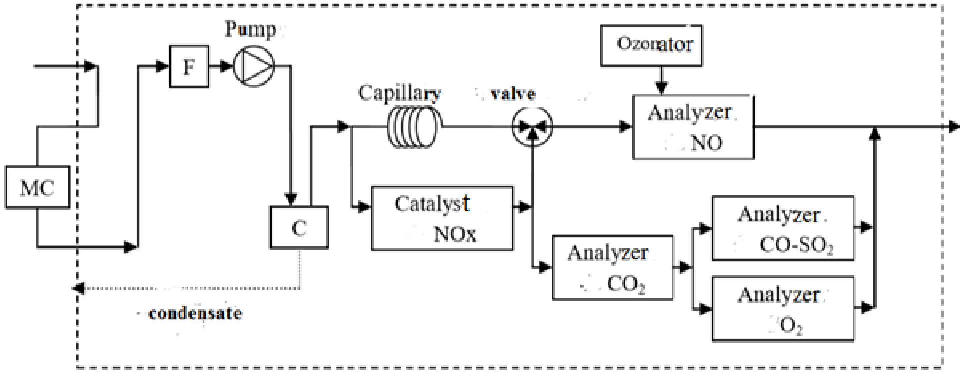


Figure 68:picture of Horiba multi-gas analyzer

MC : Mist Catcher, F : Filter, C : Condenser

Fixed appliances continuous measurements using different properties of the gas such as :

Infrared measurement: is especially suitable carbon-containing gas (CO_2, CO, CH.) because they have the property to absorb very well. It measures the difference absorption of infrared radiation between a reference gas and smoke sample continuously removed.

Chemiluminescence gas: is utilized for NOx analyzers. When reacting NO with ozone O_3, the reaction produces light whose intensity is proportional to the NO concentration.

Paramagnetivity of oxygen: is used in particular by the oxygen analyzer magneto-pneumatic. In a magnetic field not uniform it is attracted to the part stronger field increasing pressure in that part. This increase in pressure is proportional to the oxygen concentration.

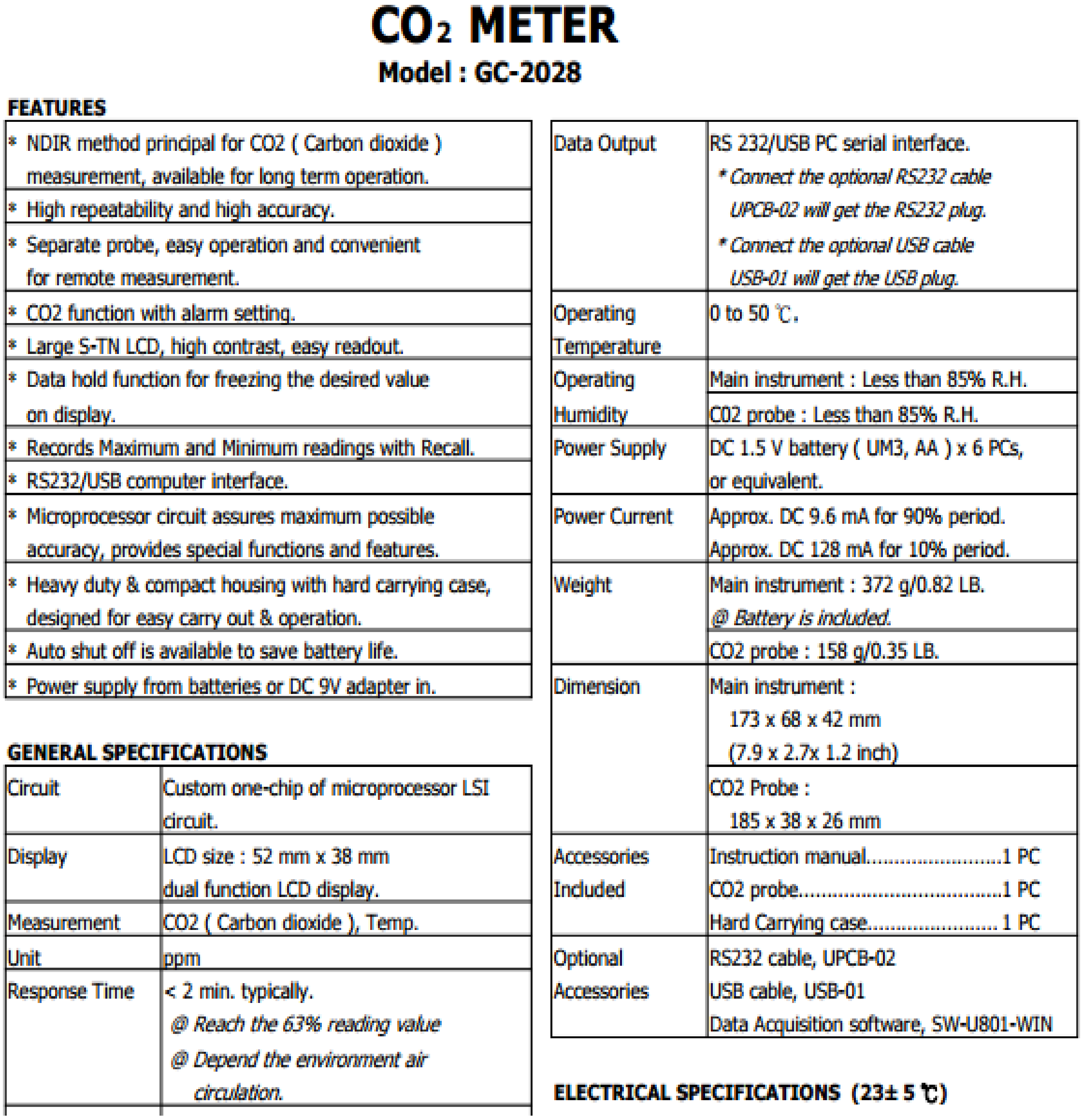
The measure by solid electrolyte: The best known is the λ probe for oxygen functions as a fuel cell. A solid electrolyte made of sintered zirconium is in contact on one side with the smoke to be measured and the other with the ambient air. The partial pressure difference and by other causes ddp of 1V. The response of the sensor is very abrupt at the passage of the stoichiometry (absence of O_2: 1V; presence 0V).

This meter is very expensive, it is more than $ 2,500, and when the budget is low, so it is difficult to buy this analyzer (annex E), it's available in Tripoli

System to analyzer the concentration of gas in air of Tripoli

Figure 69: System to analyzer the concentration of gas in air of Tripoli

in Lebanon: it's not available a multi-gas analyzer, only in Electronics Katrangi trading we find a CO_2 analyzer (40 CO_2 METER LUTRON GC2028, 392 $), and a gas sensor (town gas)



CO₂ METER

Model : GC-2028

FEATURES

- NDIR method principal for CO2 (Carbon dioxide) measurement, available for long term operation.
- High repeatability and high accuracy.
- Separate probe, easy operation and convenient for remote measurement.
- CO2 function with alarm setting.
- Large S-TN LCD, high contrast, easy readout.
- Data hold function for freezing the desired value on display.
- Records Maximum and Minimum readings with Recall.
- RS232/USB computer interface.
- Microprocessor circuit assures maximum possible accuracy, provides special functions and features.
- Heavy duty & compact housing with hard carrying case, designed for easy carry out & operation.
- Auto shut off is available to save battery life.
- Power supply from batteries or DC 9V adapter in.

GENERAL SPECIFICATIONS

Circuit	Custom one-chip of microprocessor LSI circuit.
Display	LCD size : 52 mm x 38 mm dual function LCD display.
Measurement	CO2 (Carbon dioxide), Temp.
Unit	ppm
Response Time	< 2 min. typically. *@ Reach the 63% reading value* *@ Depend the environment air circulation.*
Data Output	RS 232/USB PC serial interface. ** Connect the optional RS232 cable UPCB-02 will get the RS232 plug.* ** Connect the optional USB cable USB-01 will get the USB plug.*
Operating Temperature	0 to 50 ℃.
Operating Humidity	Main instrument : Less than 85% R.H. C02 probe : Less than 85% R.H.
Power Supply	DC 1.5 V battery (UM3, AA) x 6 PCs, or equivalent.
Power Current	Approx. DC 9.6 mA for 90% period. Approx. DC 128 mA for 10% period.
Weight	Main instrument : 372 g/0.82 LB. *@ Battery is included.* CO2 probe : 158 g/0.35 LB.
Dimension	Main instrument : 173 x 68 x 42 mm (7.9 x 2.7x 1.2 inch) CO2 Probe : 185 x 38 x 26 mm
Accessories Included	Instruction manual.......................1 PC CO2 probe..................................1 PC Hard Carrying case...................... 1 PC
Optional Accessories	RS232 cable, UPCB-02 USB cable, USB-01 Data Acquisition software, SW-U801-WIN

ELECTRICAL SPECIFICATIONS (23± 5 ℃)

Figure 70: CO₂ meter and gas sensor with some electrical specification

CO meter: A carbon monoxide detector for a car can detect the presence of potentially dangerous fumes. Carbon monoxide detectors are generally not marketed for vehicles specifically but can be used in them because they are small and battery-powered.in the same time, we can use this detector to measure the level of CO in incinerator exhaust fumes.

3.2 MEASUREMENT OF PARTICLE EMISSIONS WITHOUT PLASTIC

the particulate emissions measurement by standard method NF X43-017 Available in two versions:

BETA 5M: particle measurement methods in "dry"

BETA 5M / H: Measuring dust processes "wet"

Beta gauge determines the concentration of particles by measuring the amount of energy absorbed by the sample exposed to a radioactive source.

During a sampling cycle set, the particles are deposited on a filter strip. At the end of sampling, the filter containing the dust deposit is exposed to radiation beta gauge low energy. The result is an independent mass measurement of the physicochemical nature of the particles, their shape or color.

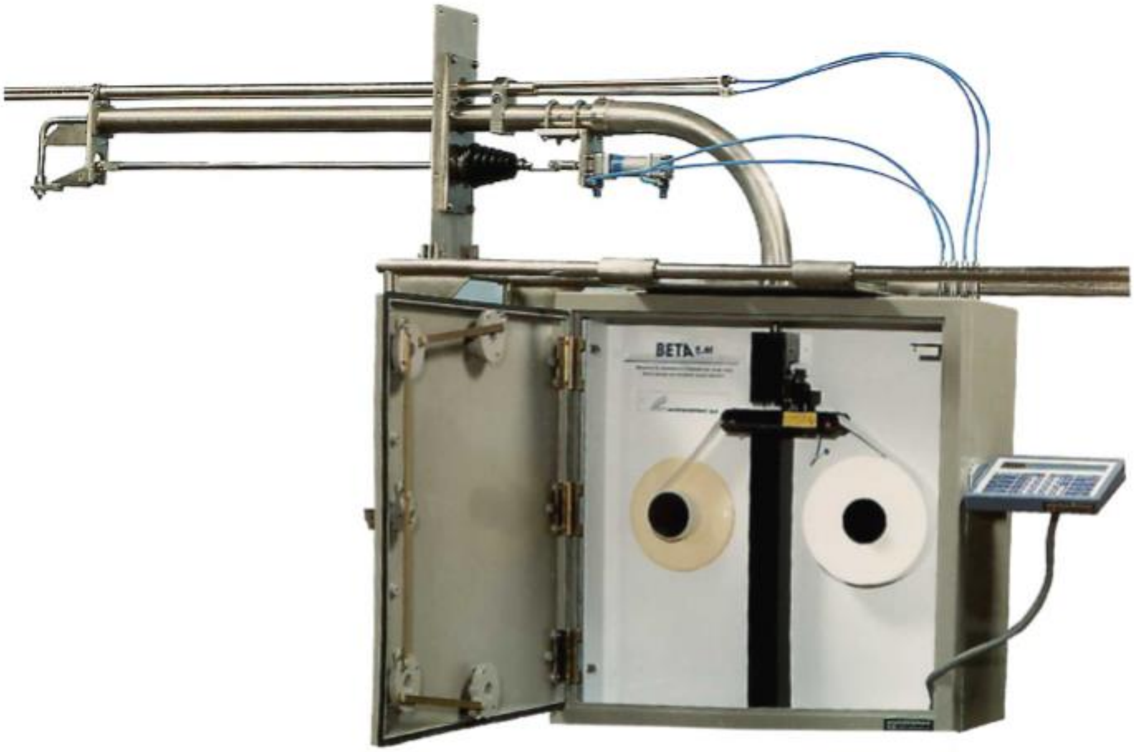


Figure 71: particulate analyzer BETA 5M

This study executed in dry conditions.

The second method to measure the concentration of particulate emissions is tm measure the mass of filter inserted in chimney before and after treatment during a period to know the quantity of m^3/h of fumes .this is the method adopted in this study.

Figure 72:insertion of filter media in chimney

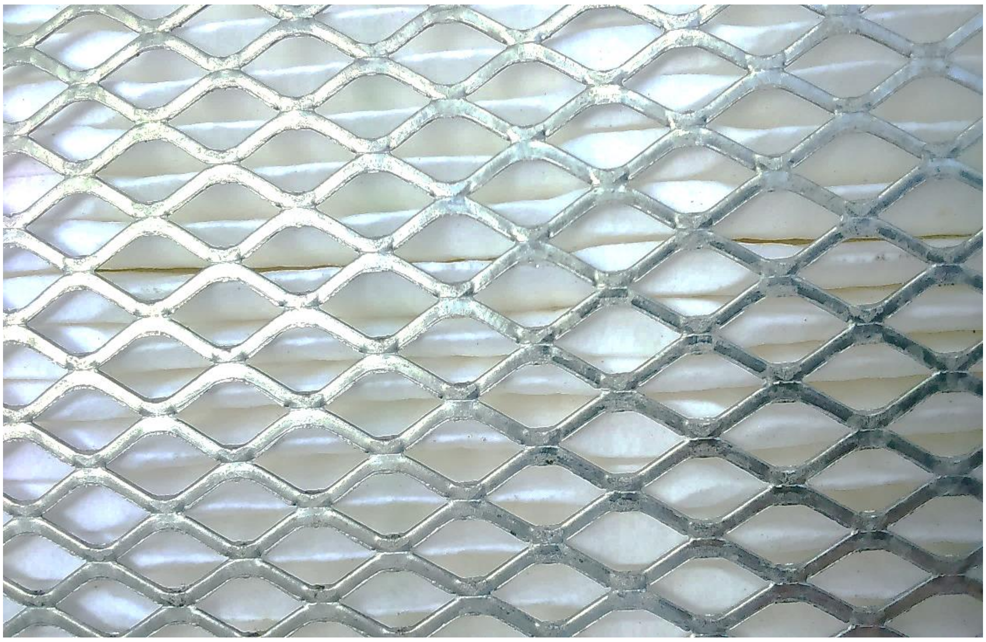


Figure 73:color of media before treatment

the flow of smoke produced by burning 42 kg for one hour is already calculated (paragraph 2.2) in normal circumstances (0°C, 1 atm),

- 42 kg: mass of waste after sorting by eliminating metal, batteries and heavy plastic.
- incineration takes place through the fuel oil 400 ml.
- system installed with pressure sensor that integrated with the current of fumes.

Figure 74:waste after sorting

Figure 75:belt for incineration

Figure 76: Closing the pores that leak fumes

Figure 77:beginning of combustion

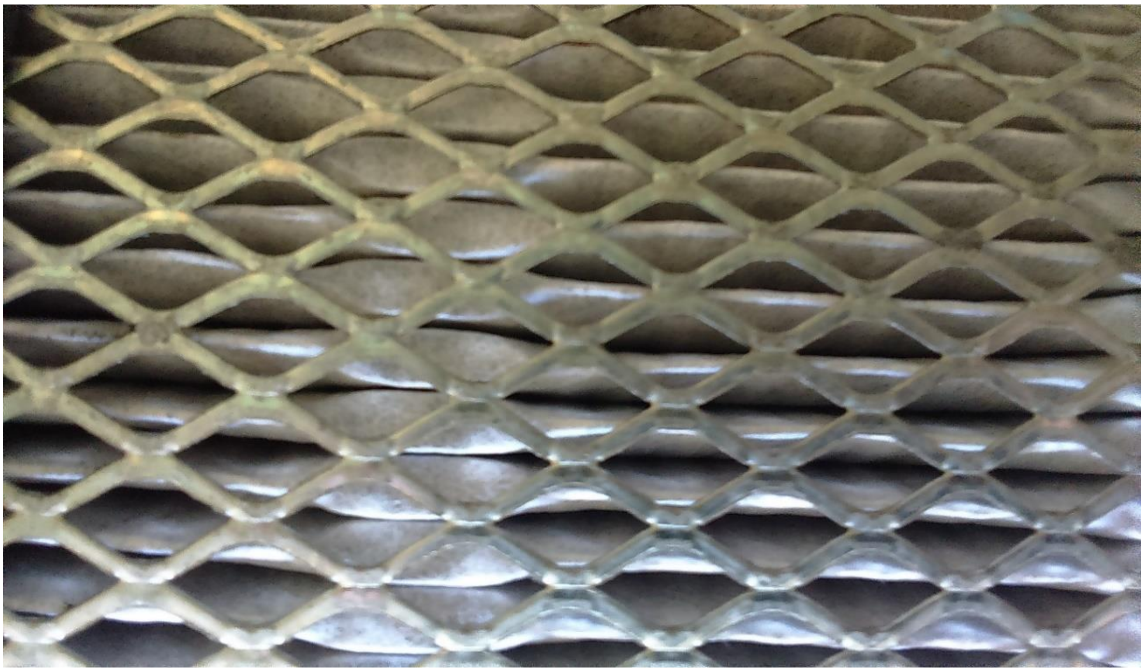


Figure 78: filter media after treatment

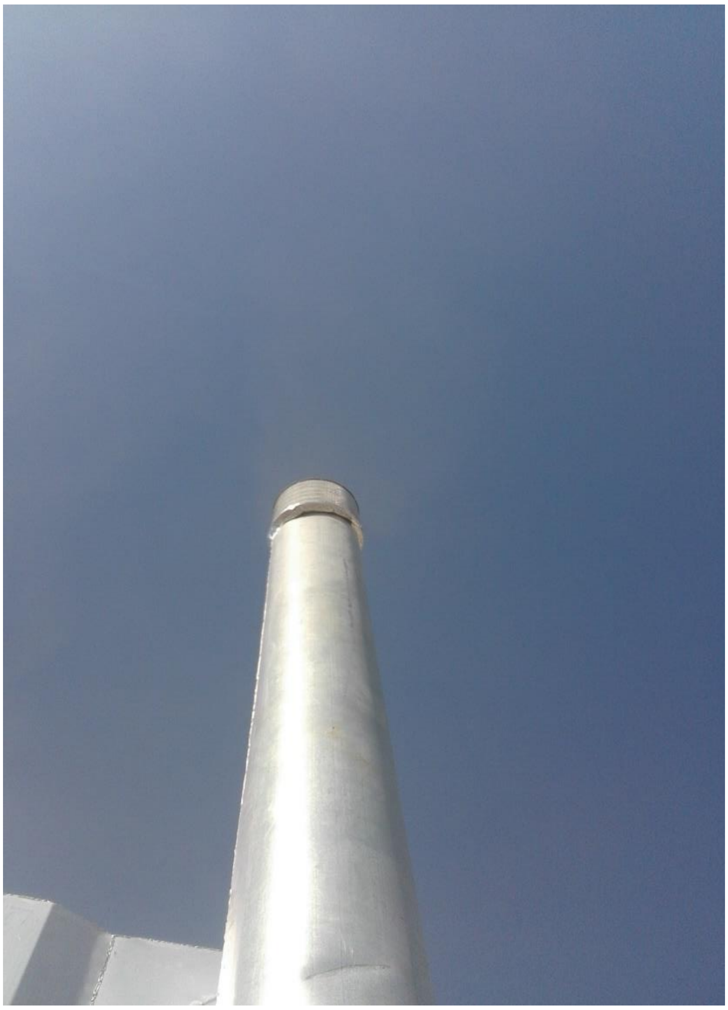


Figure 79:chimney during incineration

Calculation of emissions

$V_2 = V_1 * (P_1/P_2) * (T_2/T_1) * (Z_2/Z_1)$

Converting to uniform units

$V_1 = 314.000$ Nm³/h
$P_1 = 1.000$ atm

$T_1 = 273.150$ °K
$T_2 = 323.150$ °K

$P_2=1.000$ atm

P_1, T_1 normal conditions

P_2, T_2 specification for exhaust

$Z_1=1$ (ideal), $Z_2=1.01$(at 1 atm): Compressibility Factor

Calculation for V_2

$V_2 = 314.000*(1.000/1.000) *(323.150/273.150) *(1.100/1.100)$

$V_2 = 375\ m^3/h$

Or mass of filter before treatment =1300 g

mass after treatment =1364

the total mass of particulate =1364-1300=64 g

375 m^3/h correspond to 64 g

Thus 170 mg / m^3 <200 mg/ m^3 confirm to Lebanese standard (annex D) positive results

3.3 MEASUREMENT OF PARTICLE EMISSIONS WITH PLASTIC

- 10 kg: mass of waste with plastic
- 300 ml (fuel)

Combustion took an hour and half hour,

We noticed that there are a lot of leaks that should be closed

Discussions:

The amount of dust, which dealt with the filter and descended to the silo equal to more than twice the amount obtained without plastic.

Figure 80:dust in silo with H_2O condensed

CHAPTER 4: CONCLUSION AND PERSPECTIVES

After this long study, we have the radical solution that allow to make classify incineration as a renewable source of energy and as a result the "greening" will be a feature of the incineration.

Especially the solution is classified into various types of treatment: electrical, mechanical and chemical.

we saw that the cyclone and the electrostatic ensures the elimination of solid particles of smoke. We have made sure of that after the tests we have had on emissions after installing filters as cyclone.

secondly, the sodium bicarbonate and calcium carbonate are the most important chemicals that play a main role in the treatment of the fumes by eliminating the majority of gas especially toxic gases CO, NO, SO ...

the materials produced in the smoke processing are sent to storage centers for processed, stabilized and finally used in public works (road, cement)

In the next steps we will realize the chemical treatment of smoke in dry condition (to minimize the rate of residue after treatment) to study the effectiveness Activated charcoal to reduce the amount of released toxic gases in case of incineration heavy plastics.

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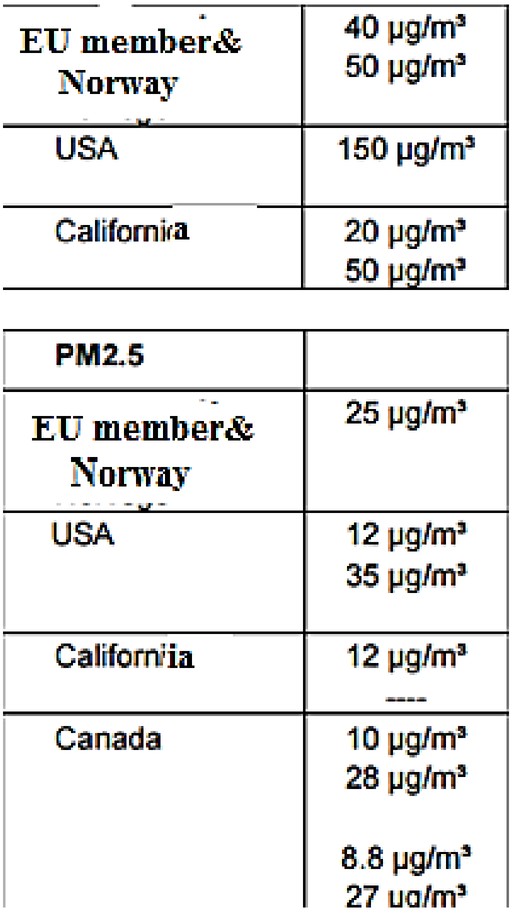
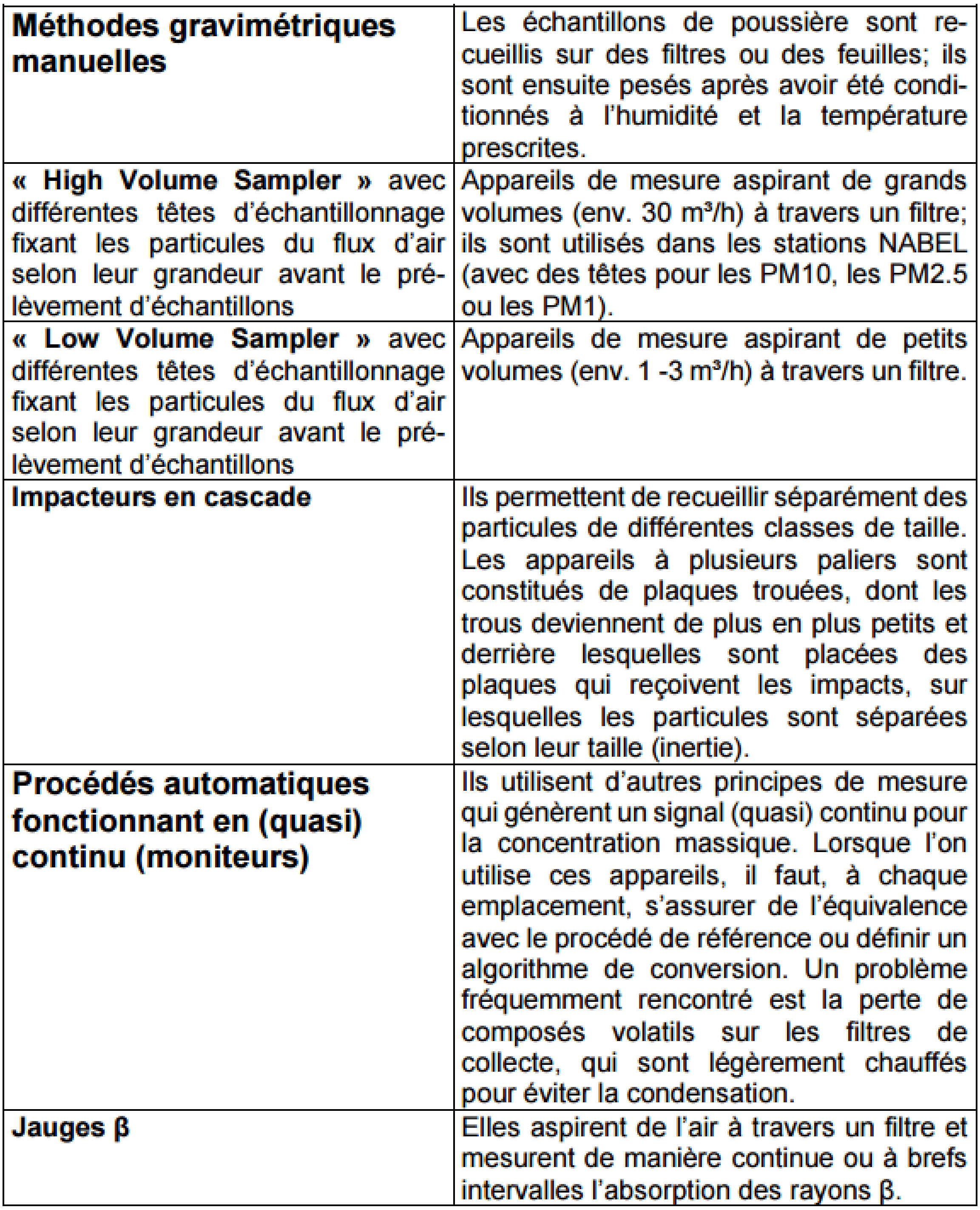
Appendix:



EU member& Norway	40 µg/m³ 50 µg/m³
USA	150 µg/m³
California	20 µg/m³ 50 µg/m³

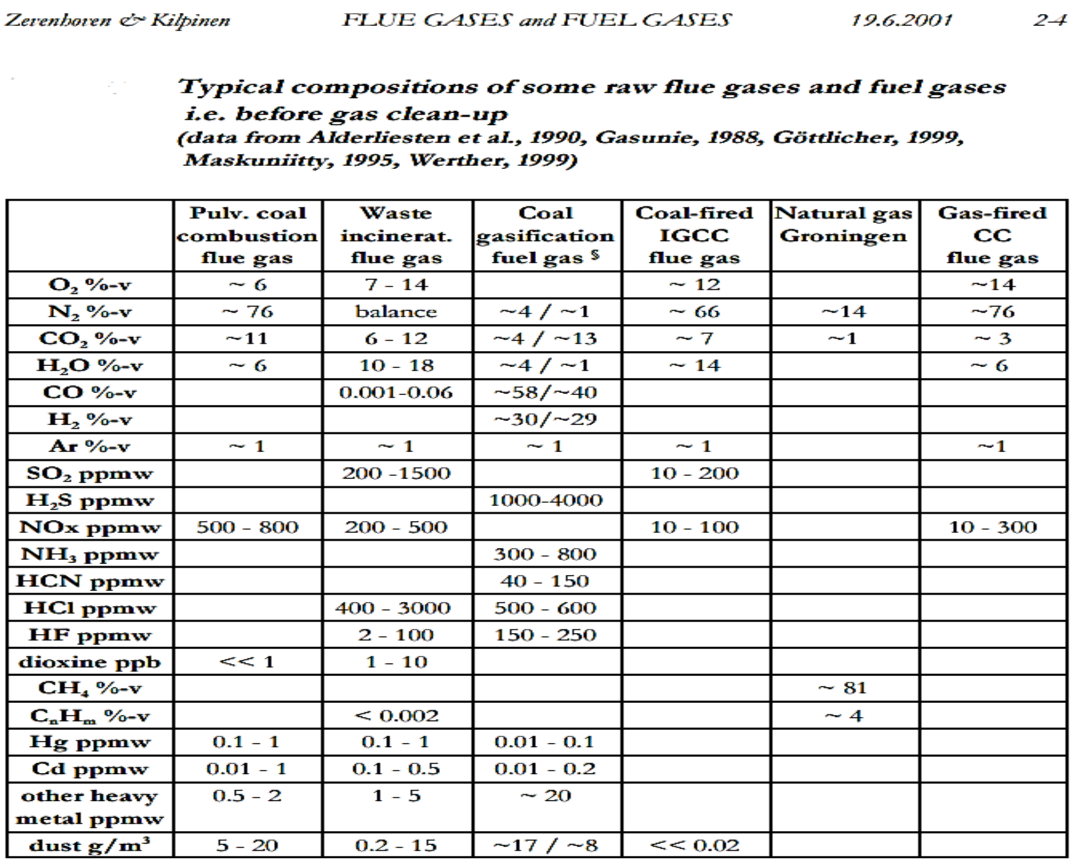
PM2.5	
EU member& Norway	25 µg/m³
USA	12 µg/m³ 35 µg/m³
California	12 µg/m³ ----
Canada	10 µg/m³ 28 µg/m³ 8.8 µg/m³ 27 µg/m³

A: limits of emissions of dust (PM10 & PM2.5) in USA, California, Canada



Méthodes gravimétriques manuelles	Les échantillons de poussière sont recueillis sur des filtres ou des feuilles; ils sont ensuite pesés après avoir été conditionnés à l'humidité et la température prescrites.
« **High Volume Sampler** » avec différentes têtes d'échantillonnage fixant les particules du flux d'air selon leur grandeur avant le prélèvement d'échantillons	Appareils de mesure aspirant de grands volumes (env. 30 m³/h) à travers un filtre; ils sont utilisés dans les stations NABEL (avec des têtes pour les PM10, les PM2.5 ou les PM1).
« **Low Volume Sampler** » avec différentes têtes d'échantillonnage fixant les particules du flux d'air selon leur grandeur avant le prélèvement d'échantillons	Appareils de mesure aspirant de petits volumes (env. 1 -3 m³/h) à travers un filtre.
Impacteurs en cascade	Ils permettent de recueillir séparément des particules de différentes classes de taille. Les appareils à plusieurs paliers sont constitués de plaques trouées, dont les trous deviennent de plus en plus petits et derrière lesquelles sont placées des plaques qui reçoivent les impacts, sur lesquelles les particules sont séparées selon leur taille (inertie).
Procédés automatiques fonctionnant en (quasi) continu (moniteurs)	Ils utilisent d'autres principes de mesure qui génèrent un signal (quasi) continu pour la concentration massique. Lorsque l'on utilise ces appareils, il faut, à chaque emplacement, s'assurer de l'équivalence avec le procédé de référence ou définir un algorithme de conversion. Un problème fréquemment rencontré est la perte de composés volatils sur les filtres de collecte, qui sont légèrement chauffés pour éviter la condensation.
Jauges β	Elles aspirent de l'air à travers un filtre et mesurent de manière continue ou à brefs intervalles l'absorption des rayons β.

B: several methods to weigh the amount of each type of dust



Zevenhoven & Kilpinen *FLUE GASES and FUEL GASES* *19.6.2001* *2-4*

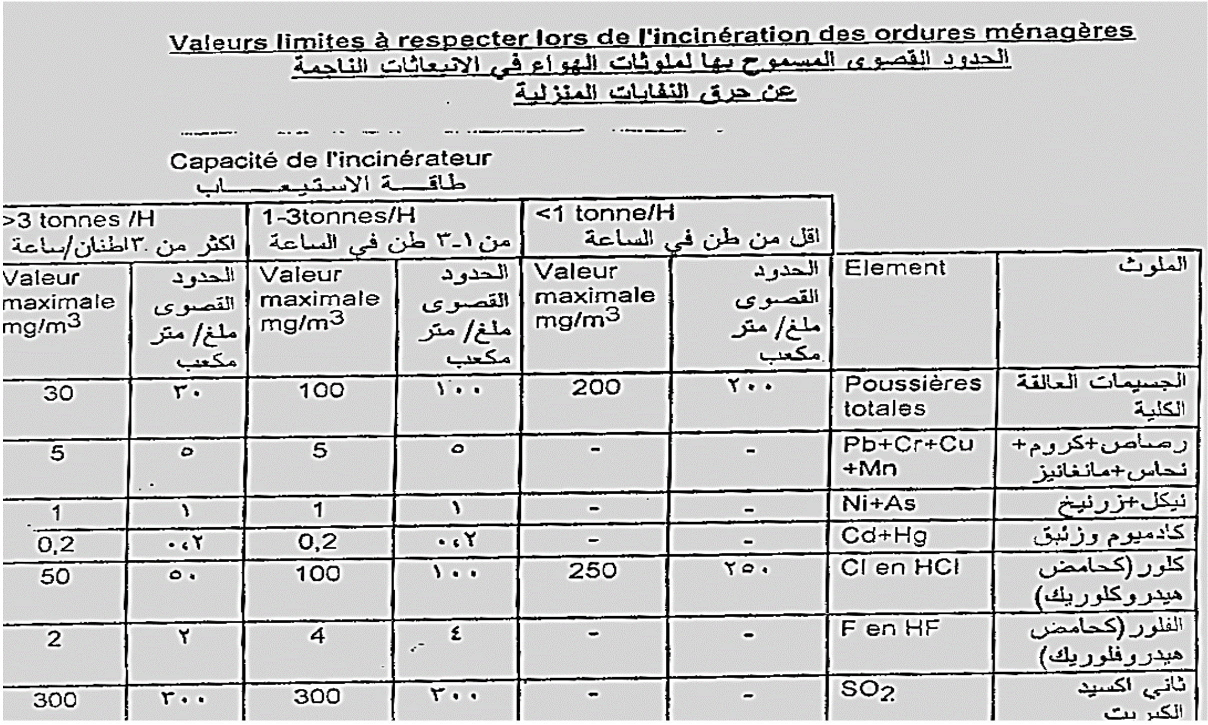
Typical compositions of some raw flue gases and fuel gases i.e. before gas clean-up

(data from Alderliesten et al., 1990, Gasunie, 1988, Göttlicher, 1999, Maskuniitty, 1995, Werther, 1999)

	Pulv. coal combustion flue gas	Waste incinerat. flue gas	Coal gasification fuel gas $^{\$}$	Coal-fired IGCC flue gas	Natural gas Groningen	Gas-fired CC flue gas
O_2 %-v	~ 6	7 - 14		~ 12		~14
N_2 %-v	~ 76	balance	~4 / ~1	~ 66	~14	~76
CO_2 %-v	~11	6 - 12	~4 / ~13	~ 7	~1	~ 3
H_2O %-v	~ 6	10 - 18	~4 / ~1	~ 14		~ 6
CO %-v		0.001-0.06	~58/~40			
H_2 %-v			~30/~29			
Ar %-v	~ 1	~ 1	~ 1	~ 1		~1
SO_2 ppmw		200 -1500		10 - 200		
H_2S ppmw			1000-4000			
NOx ppmw	500 - 800	200 - 500		10 - 100		10 - 300
NH_3 ppmw			300 - 800			
HCN ppmw			40 - 150			
HCl ppmw		400 - 3000	500 - 600			
HF ppmw		2 - 100	150 - 250			
dioxine ppb	<< 1	1 - 10				
CH_4 %-v					~ 81	
C_nH_m %-v		< 0.002			~ 4	
Hg ppmw	0.1 - 1	0.1 - 1	0.01 - 0.1			
Cd ppmw	0.01 - 1	0.1 - 0.5	0.01 - 0.2			
other heavy metal ppmw	0.5 - 2	1 - 5	~ 20			
dust g/m^3	5 - 20	0.2 - 15	~17 / ~8	<< 0.02		

(22)

C: typical compositions of some raw flue gases and fuel gases before treatment



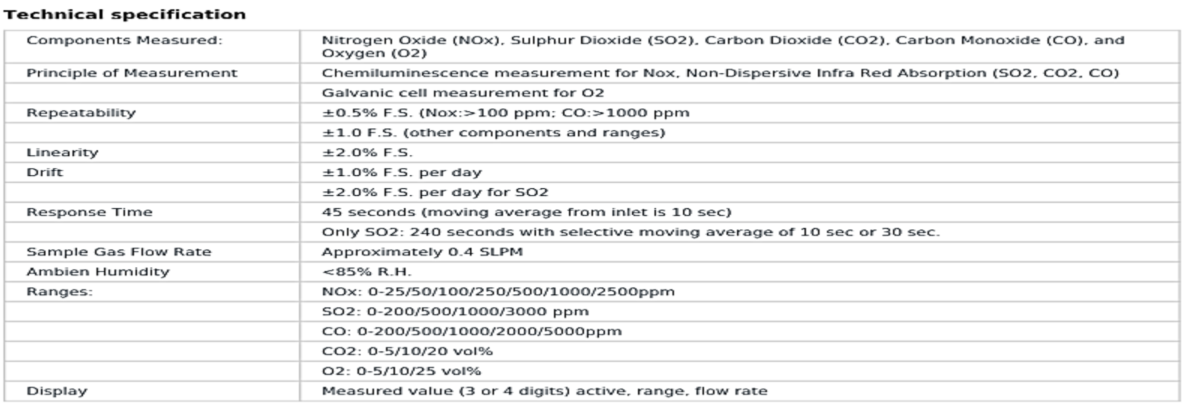
Valeurs limites à respecter lors de l'incinération des ordures ménagères

الحدود القصوى المسموح بها لملوثات الهواء في الانبعاثات الناجمة عن حرق النفايات المنزلية

Capacité de l'incinérateur
طاقة الاستيعاب

الملوث	Element	<1 tonne/H اقل من طن في الساعة		1-3tonnes/H من ١ـ٣ طن في الساعة		>3 tonnes /H اكثر من ٣.اطنان/ساعة	
		الحدود القصوى ملغ/ متر مكعب	Valeur maximale mg/m^3	الحدود القصوى ملغ/ متر مكعب	Valeur maximale mg/m^3	الحدود القصوى ملغ/ متر مكعب	Valeur maximale mg/m^3
الجسيمات العالقة الكلية	Poussières totales	٢٠٠	200	١٠٠	100	٣٠	30
رصاص+كروم+ نحاس+مانغانيز	Pb+Cr+Cu +Mn	-	-	٥	5	٥	5
نيكل+زرنيخ	Ni+As	-	-	١	1	١	1
كادميوم وزئبق	Cd+Hg	-	-	٠،٢	0,2	٠،٢	0,2
كلور (كحامض هيدروكلوريك)	Cl en HCl	٢٥٠	250	١٠٠	100	٥٠	50
الفلور (كحامض هيدروفلوريك)	F en HF	-	-	٤	4	٢	2
ثاني اكسيد الكبريت	SO_2	-	-	٣٠٠	300	٣٠٠	300

D: limits of emissions in Lebanon

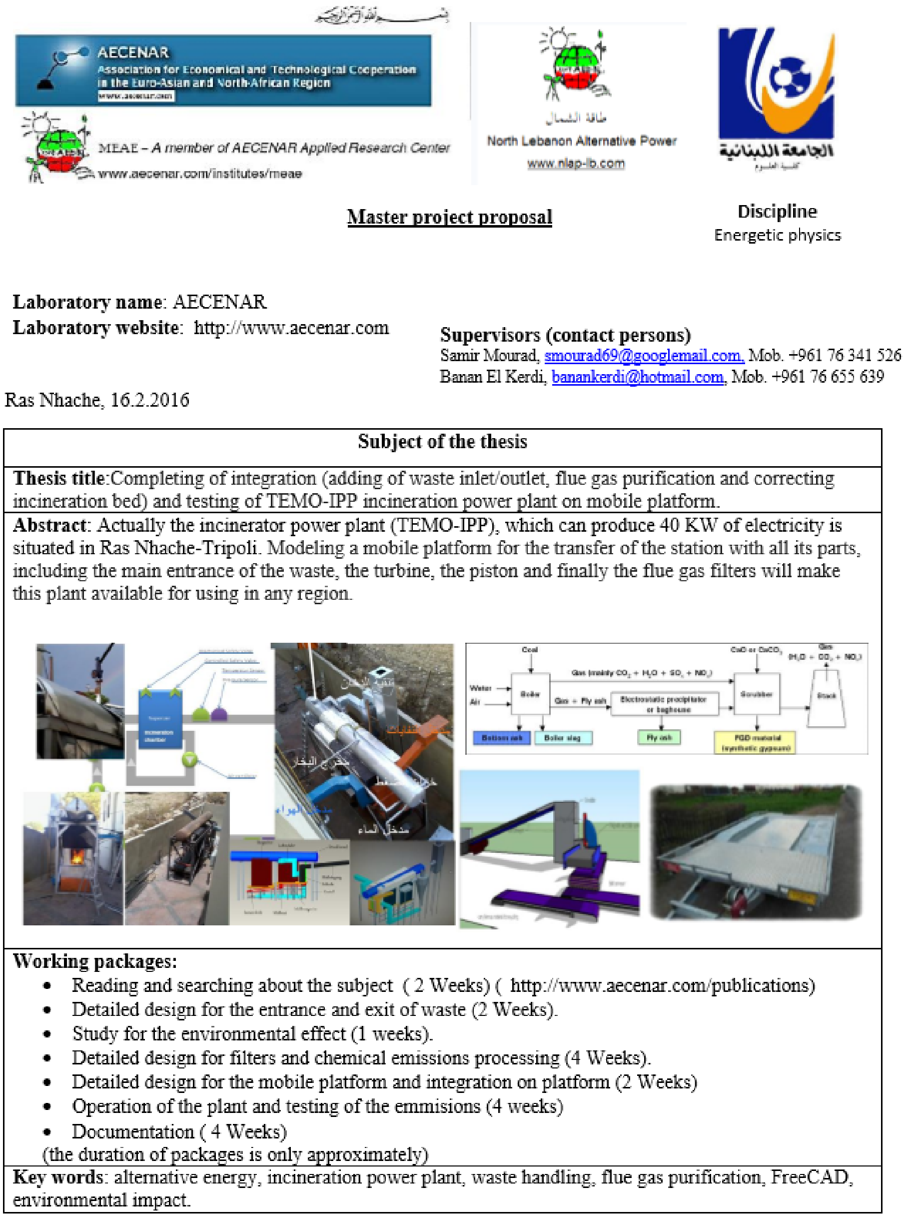


Technical specification

Components Measured:	Nitrogen Oxide (NOx), Sulphur Dioxide (SO2), Carbon Dioxide (CO2), Carbon Monoxide (CO), and Oxygen (O2)
Principle of Measurement	Chemiluminescence measurement for Nox, Non-Dispersive Infra Red Absorption (SO2, CO2, CO)
	Galvanic cell measurement for O2
Repeatability	±0.5% F.S. (Nox:>100 ppm; CO:>1000 ppm
	±1.0 F.S. (other components and ranges)
Linearity	±2.0% F.S.
Drift	±1.0% F.S. per day
	±2.0% F.S. per day for SO2
Response Time	45 seconds (moving average from inlet is 10 sec)
	Only SO2: 240 seconds with selective moving average of 10 sec or 30 sec.
Sample Gas Flow Rate	Approximately 0.4 SLPM
Ambien Humidity	<85% R.H.
Ranges:	NOx: 0-25/50/100/250/500/1000/2500ppm
	SO2: 0-200/500/1000/3000 ppm
	CO: 0-200/500/1000/2000/5000ppm
	CO2: 0-5/10/20 vol%
	O2: 0-5/10/25 vol%
Display	Measured value (3 or 4 digits) active, range, flow rate

HORIBA

E: technical information about Horiba PG250



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طاقة الشمال
North Lebanon Alternative Power
www.nlap-lb.com

الجامعة اللبنانية

Master project proposal

Discipline
Energetic physics

Laboratory name: AECENAR
Laboratory website: http://www.aecenar.com

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Ras Nhache, 16.2.2016

Subject of the thesis

Thesis title:Completing of integration (adding of waste inlet/outlet, flue gas purification and correcting incineration bed) and testing of TEMO-IPP incineration power plant on mobile platform.

Abstract: Actually the incinerator power plant (TEMO-IPP), which can produce 40 KW of electricity is situated in Ras Nhache-Tripoli. Modeling a mobile platform for the transfer of the station with all its parts, including the main entrance of the waste, the turbine, the piston and finally the flue gas filters will make this plant available for using in any region.

Working packages:
- Reading and searching about the subject (2 Weeks) (http://www.aecenar.com/publications)
- Detailed design for the entrance and exit of waste (2 Weeks).
- Study for the environmental effect (1 weeks).
- Detailed design for filters and chemical emissions processing (4 Weeks).
- Detailed design for the mobile platform and integration on platform (2 Weeks)
- Operation of the plant and testing of the emmisions (4 weeks)
- Documentation (4 Weeks)

(the duration of packages is only approximately)

Key words: alternative energy, incineration power plant, waste handling, flue gas purification, FreeCAD, environmental impact.

F: Master thesis