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ECOPLANT

Capturing Acid Gases from Air and Combustion Gases

Executive Summary

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Introduction:

During last decades, atmospheric air has undergone alterations in its natural composition mostly due to gas emissions from factories, industrial burners and internal combustion engines running on fossil fuel. As a consequence and because of its inability to become naturally absorbed in the atmosphere, Carbone Dioxide has been and is becoming the dangerously most of the accumulated gas with greenhouse effect responsible for global warming.

Project ECOPLANT was developed in order to eliminate the principal polluting gases such as Carbone Dioxide Acid Gases, Sulfur and Nitrogen oxides and hydrogen sulfide, following a chemical procedure to "clean the atmosphere from those gases, as well as those produced because of combustion in burners and internal combustion engines using fossil fuel, like gasoline, diesel, natural gas, etc., that produce acid gases (CO_2, SO_2 y NO_2), by ingeniously using a diluted solution of Sodium Hydroxide (NaOH), in an absorption equipment with spraying nozzles. This original solution has already been patented worldwide.

In order to carry out the process, gases must be taken from chimneys into an absorber, where the gases are sprinkled with an alkaline solution and react forming saline solution of carbonates, nitrites, sulfites and sulfates, according to the following reactions:

$2\ NaOH + CO_2 \text{----}\rightarrow Na_2CO_3 + H_2O$

$2\ NaOH + 2\ NO_2 \text{--}\rightarrow NaNO_3 + NaNO_2 + H_2O$

$2\ NaOH + SO_2 \text{----}\rightarrow Na_2SO_3 + H_2O$

After that, the alkaline solution with salts is regenerated with Calcium Hydroxide or Magnesium Hydroxide, forming Calcium or Magnesium salts that are insoluble and may be separated by filter; Calcium Sulfite, not very soluble, co-precipitates with Calcium Carbonate; Nitrate and Nitrites remain in solution and can be treated with Ammonium Chloride if it becomes financially interesting. The following reactions take place to produce a very pure Calcium Carbonate:

$Na_2CO_3 + Ca(OH)_2 \text{---}\rightarrow CaCO_3 + 2\ NaOH$

$Na_2SO_3 + Ca(OH)_2 \text{---}\rightarrow CaSO_3 + 2\ NaOH$

$2\ NaNO_2 + Ca(OH)_2 \text{---}\rightarrow Ca(NO_2)_2 + 2\ NaOH$

$2\ NaNO_3 + Ca(OH)_2 \text{---}\rightarrow Ca(NO_3)_2 + 2\ NaOH$

$Ca(NO_2)_2 + 2\ NH_4Cl \text{-----}\rightarrow CaCl_2 + 2\ NH_4NO_2$

$Ca(NO_3)_2 + 2\ NH_4Cl \text{-----}\rightarrow CaCl_2 + 2\ NH_4NO_3$

$CaCO_3$ separated by filter and drying is a fine powder of great whiteness and high purity used in manufacturing paper, paint, inert charge in pharmaceutical products and artisanal figures.

The following reactions take place to produce very pure Magnesium Hydroxide:

$Na_2CO_3 + Mg(OH)_2 \dashrightarrow MgCO_3 + 2\ NaOH$

$Na_2SO_3 + Mg(OH)_2 \dashrightarrow MgSO_3 + 2\ NaOH$

$2\ NaNO_2 + Mg(OH)_2 \dashrightarrow Mg(NO_2)_2 + 2\ NaOH$

$2\ NaNO_3 + Mg(OH)_2 \dashrightarrow Mg(NO_3)_2 + 2\ NaOH$

$Mg(NO_2)_2 + 2\ NH_4Cl \dashrightarrow MgCl_2 + 2\ NH_4NO_2$

$Mg(NO_3)_2 + 2\ NH_4Cl \dashrightarrow MgCl_2 + 2\ NH_4NO_3$

Ammonium Nitrite with an oxidizing agent may be turned into Ammonium Nitrite that can be used as fertilizer.

$2\ NH_4NO_2 + O_2 \dashrightarrow 2\ NH_4NO_3$

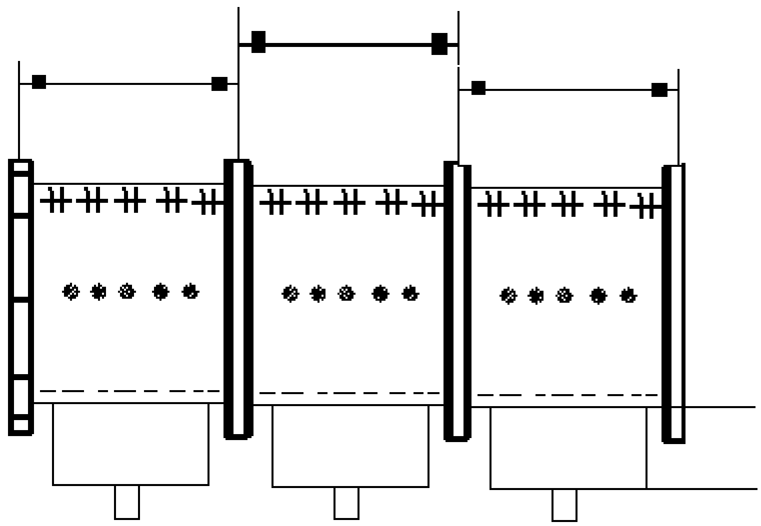
$MgCO_3$ is separated by filter and drying as a fine powder of great whiteness and high purity. It is a fire retardant used in making curtains fabrics, rugs, cigarette paper and paint, mostly used in places near fire; it is also used as inert charge in some pharmaceutical products and, to avoid compacting of table salt with environment moisture.

A similar process can be used with Lithium Hydroxide producing Lithium Carbonate. Application in the manufacture of batteries (Li_2CO_3-Li^+) for electrical cars, solar panels and rechargeable batteries for diverse uses (Lap Tops, PC`s, watches, etc.).

$2LiOH + CO_2 \dashrightarrow Li_2CO_3 + H_2O$

To carry out the Project, a horizontal absorber with modular sections and spaying nozzles for absorption fluid in three rows, one in the upper side of the nozzle and the other two on each side making a 90° with the upper part row, was designed to give flexibility to the process. Optimum dimensions for the designed equipment are 85 cm in internal diameter and 15 nozzles and modules one meter long with 5 ¼ inch nozzles per row, giving a total of 15 nozzles per modular section of the absorber. Gases go from one extreme of the equipment to the other while absorption fluid is fed perpendicularly to the gas flow. Nozzles "pulverizing" the fluid into small drops that increase the mass transference area and producing absorption of gases to be eliminated. Figure 1

Figure 1
Modular Horizontal Absorber



Operating Conditions for the Equipment:

1) Average global speed of the atmospheric air and combustion gases is from 3 to 7 m/sec.
2) Gas and absorber solution temperature is 22°C, even if combustion gases are warm when entering the absorber because they will take the absorber´s temperature solution in a very short while.
3) Gas and absorber solution inlet pressure is 20 manometric mmHg. The absorber is connected to the atmospheric air or to the exit of combustion gases on one extreme, and to the atmosphere for the exit of washed gases on the other, considering 586 mmHg for the Distrito Federal case.
4) Absorber solution will be 80 g NaOH/lt (that is 2 N).
5) Operating liquid flow density will be from 2.7 to 3.4 $\frac{Kg}{m^2 Sec}$, considered optimum industrial operating values.

Table 1
Gas density calculated at 0.771 atm, and 22°C for fluids obtained from tables

GAS / LIQUID	DENSITY IN KG / M^3
Carbone Dioxide {CO_2}	1.40
Sulfur Dioxide {SO_2}	2.04
Nitrogen dioxide {NO_2}	1.46
Air	0.922
Combustion Gases	0.983
NaOH 80 g/lt Solution	1080

Table 2
Gas and Fluid Viscosity

GAS OR LIQUID	VISCOSITY IN KG / m.sec
Air	17.8×10^{-6}
Combustion Gases	26.6×10^{-6}
NaOH 80 g/lt Solution	0.0136

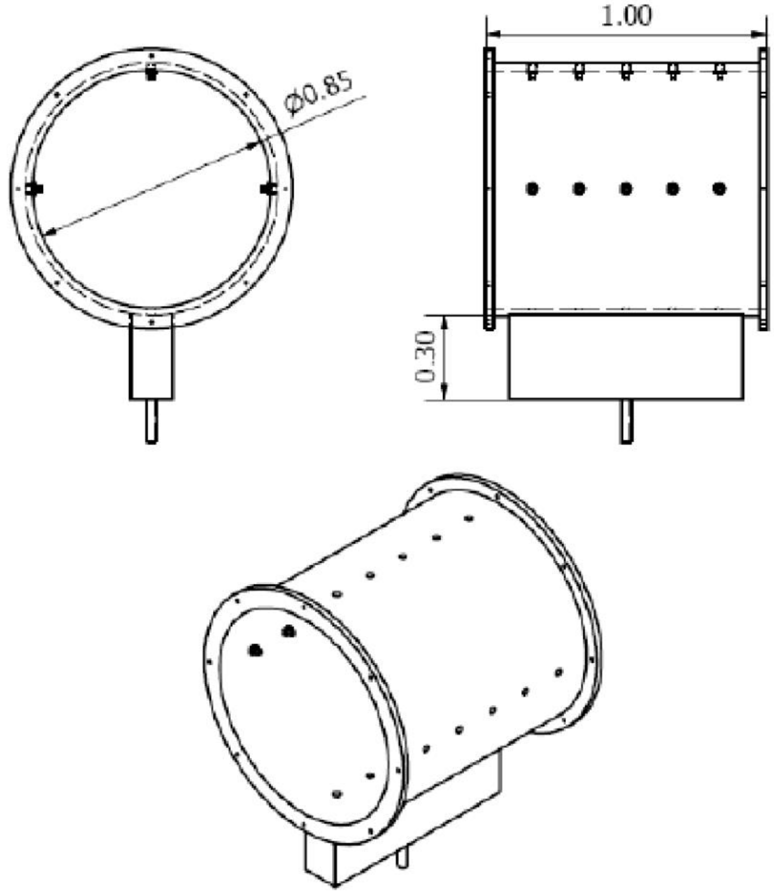
Table 3
Urban Atmospheric Air Composition and Combustion Gases Values and Molecular Weights

Component	Atmospheric Air Composition Average Values (%)	Combustion Gases Composition Average Values (%)	Molecular Weight	Air Molecular Weight	Combustion Gases Molecular Weight
N_2	78.1	79,9	28	21.87	22.37
O_2	20.9	2.9	32	6.69	0.928
Noble Gases	0.9	0.9	40	0.36	0.36
CO_2	0.044	16	44	0.019	7.04
SO_2	0.0045	0.2	64	0.0029	0.128
NO_2	0.0035	0.069	46	0.0016	0.0317
Other Gases (CH_4)	0.048	0.0931	16	0.0077	0.0149
Total	100.000	100.000		28.95	30.87

Optimum gas flow handled by the equipment is from 10,000 m^3 / h and 16% of CO_2 for combustion gases. At that volume flow a 5.47 m long absorber is required, allowing six 1 m coupling sections, having 90 nozzles in use for the 50.07 m^3 / h. of required absorbing solution and nozzle flow would be 0.556 m^3 /h.

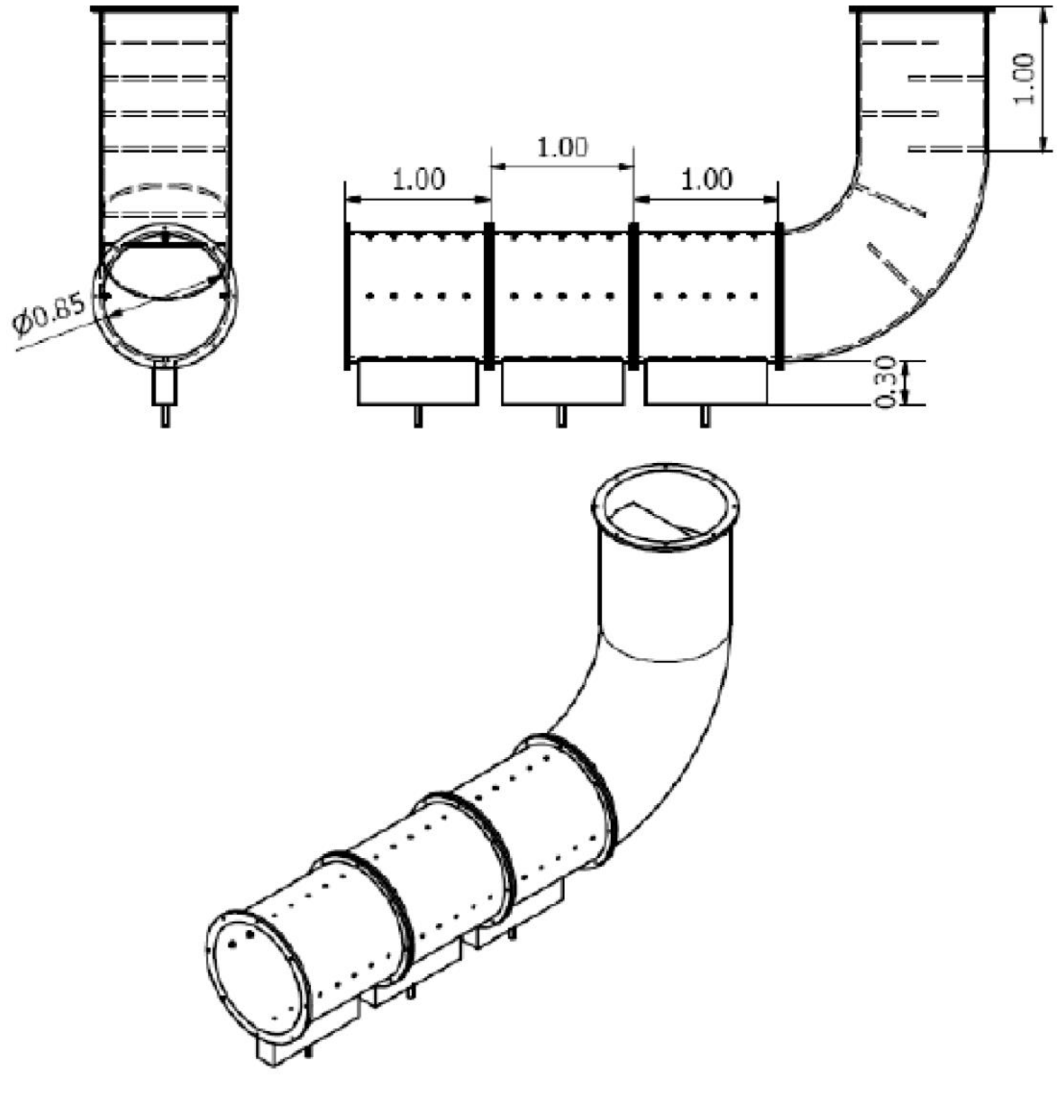
Disposition of absorber sections can be observed in Figure 2.

Figure 2
Absorber Sections and Construction Details



Gas to be treated enters through on extreme of the absorber, driven by a one direction fan and once the acid gases, particles and powder suspended in the air have been captured and/or held by the absorption fluid, the gases exit through the other extreme of the absorber to a chimney changing direction and with deflectors to hold absorption liquid flow for clean gases sent to the atmosphere. See Figure 3.

Figure 3
Horizontal Absorber with Gas Exit



The complete process flow diagram to produce $CaCO_3$ is in Figure 4; Figure 5 has the complete process flow diagram to produce $MgCO_3$, and Figure 6 has the complete process flow diagram to produce Li_2CO_3.

Figure 4
Flow Diagram
CO_2 Absorption from Air or Combustion Gases Producing $CaCO_3$

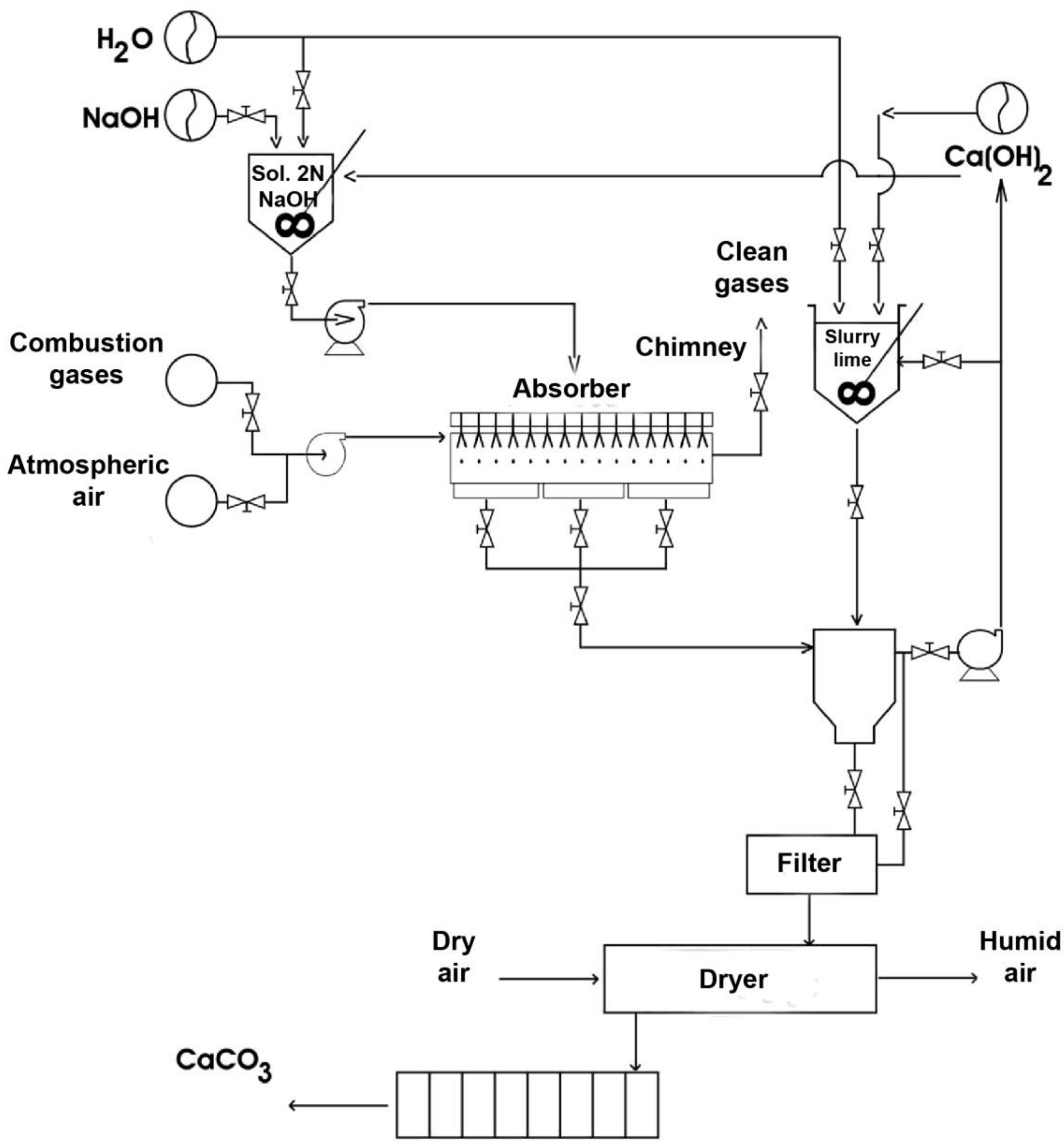


Figure 5
Flow Diagram
CO_2 Absorption from Air or from Combustion Gases Producing $MgCO_3$

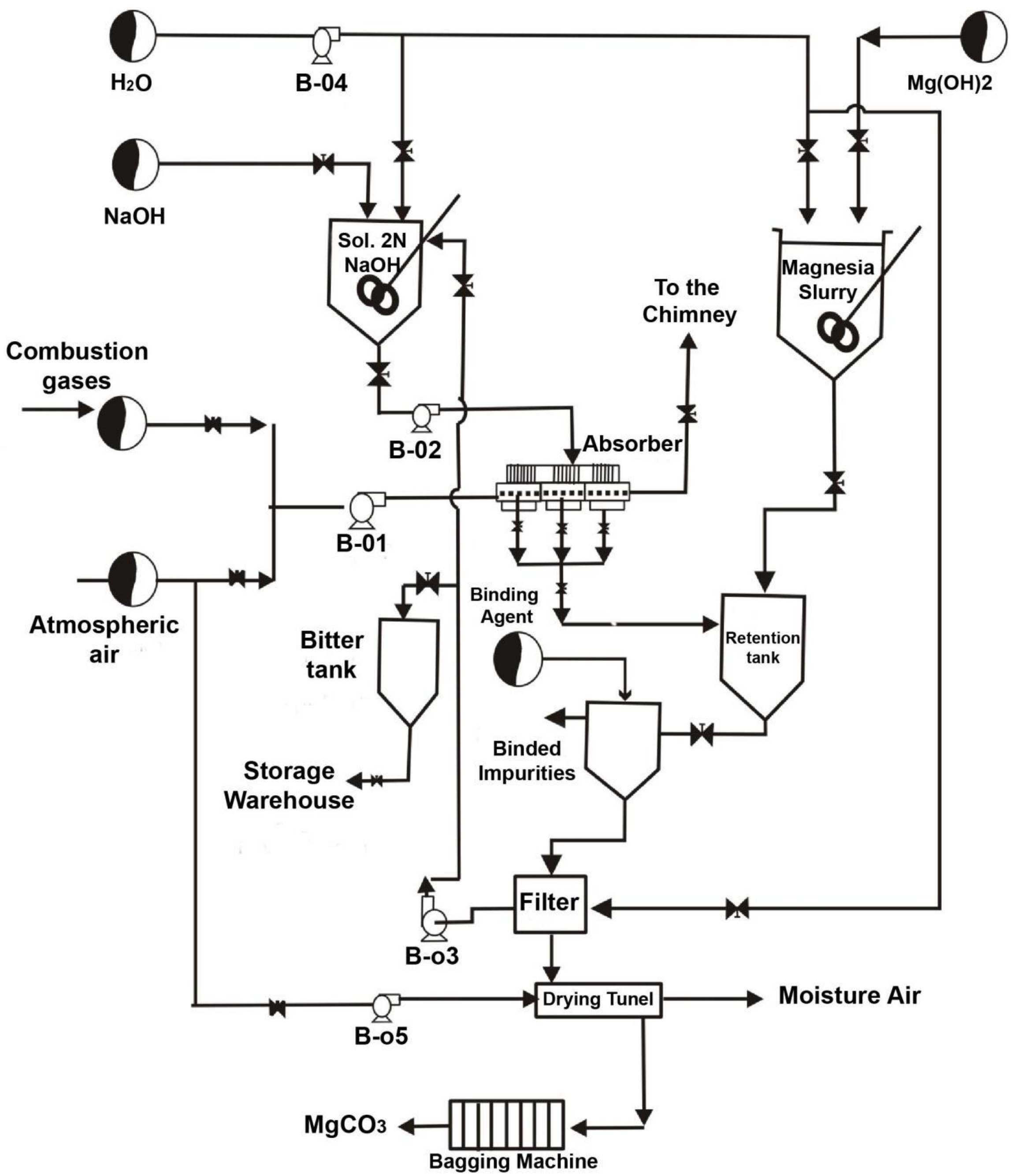
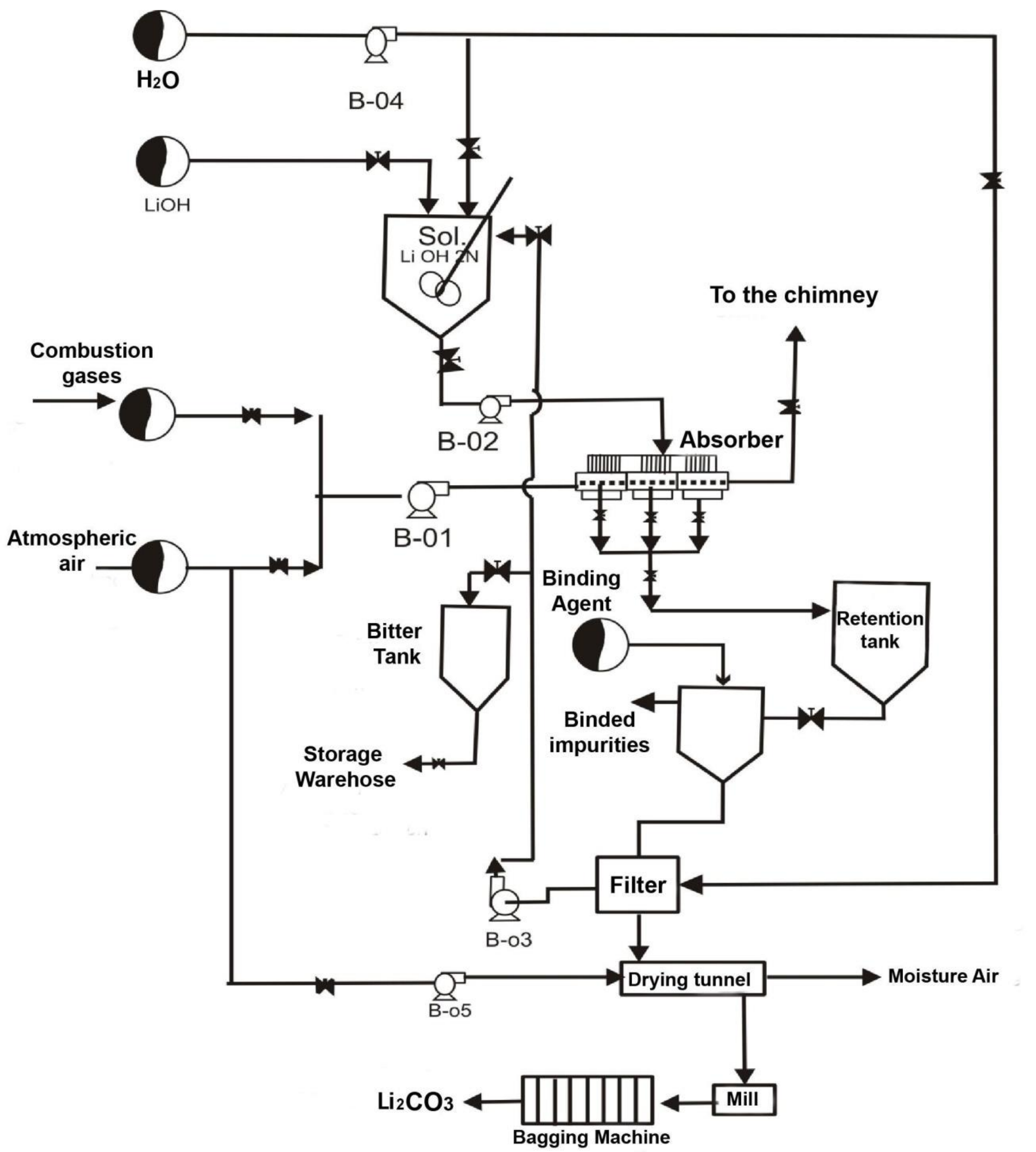


Figure 6
CO_2 Absorption from Air or from Combustion Gases Producing Li_2CO_3



Operating conditions for the processes of capturing Co_2, SO_2 and NO_2 From Combustion Gases.

There are three basic processes under the same technology, producing different carbonates: $CaCO_3$, $MgCO_3$ and Li_2CO_3. Reactives, inputs and materials required in each of the processes are concentrated in Table 4

Table 4
Operating Conditions for an Industrial Facility to Capture Acid Gases (CO_2, SO_2 and NO_2) from Combustion Gases

Reactives, Inputs and Material Flow	$CaCO_3$ Process	$MgCO_3$ Process	Li_2CO_3 Process
Volumetric Flow for Gases to be treated	10,000 m3 / h	10,000 m3 / h	10,000 m3 / h
Volumetric Flow for Absorption Liquids	50.08 (sol. 80 NaOH g/lt)	50.08 (sol. 80 NaOH g/lt)	51.71 (Sol. 48 LiOH g/lt)
Mass Flow for Absorption Alkali	4.006 Ton NaOH / h	4.006 Ton MgCO3 / h	2.482 Ton LiOH /h
Process Water	1.5 m3/h	1.5 m3/h	1.5 m3/h
Slurry Flow at 20%	16.505 m3/h (Magnesia slurry)	12.936 m3/h (Magnesia slurry)	–
Earthy Alkaline Mass Flow	3.706 ton Ca(OH)2/h	2.905 Ton Mg(OH)2/h	–
Carbonate output Flow	4.944 ton CaCO3/h	4.153 Ton MgCO3/h	3.659 Ton LiCO3/h
Average Gas Temperature	22oC	22oC	22oC
Average Gas Pressure	0.771 atm	0.771 atm	0.771 atm
Required Electric Power	15.0 Kw	15.0 Kw	10.25 Kw

Installation Cost

The estimated costs and profits for a 10,000 m^3/hr process ECOPLANT are as follows:

Table 5

Comparative pro-forma Finances for a Minimal Industrial Plant *
(10,000 m^3/hr)

CONCEPT	$CaCO_3$ PROCESS	$MgCO_3$ PROCESS	Li_2CO_3 PROCESS
Basic Equipment	USD 301 410	USD 308 040	USD 259 900
Installation Cost, Piping, Accessories, Tools and Auxiliary Equipment	USD 120 560	USD 123 210	USD 103 960
Working Equipment Cost (WEC)	USD 421 970	USD 431 250	USD 363 860
Deferred Assets	USD 139 260	USD 142 310	USD 120 070
Working Capital (operating a week)	USD 139 470	USD 1 010 820	USD 3 902 100
Contingencies	USD 54 860	USD 56 060	USD 47 300
Total Investment	USD 755 560	USD 1 640 440	USD 4 433 330
Fixed Costs (1st Year)	USD 305 670	USD 519 440	USD 1 179 530
Variable Costs (1st Year)	USD 6 467 990	USD 46 550 620	USD 179 615 740
Expenses (1st Year)	USD 6 773 670	USD 47 070 070	USD 180 795 270
Income (1st Year)	USD 7 457 490	USD 174 736 070	USD 224 080 060
Gross Margin (1st Year)	USD 683 820	USD 127 665 990	USD 43 284 790
Net Income (1st Year)	USD 396 610	USD 74 046 270	USD 25 105 180
Internal Return Rate (ROI)	46.76%	66.86%	64.96%
Equilibrium Point (1st Year)	30.89%	0.41%	2.65%
Investment Return Time	23 months	10 days	2 months
Annual Carbonate Production (Tons)	38 207	32 094	28 276
Production Cost (/Ton)	USD 195	USD 1 469	USD 6 395
Market Price (Intl.)	USD 400	USD 6 404	USD 9 500
Total CO_2 Absorption (Tons / year)	16 800	16 800	16 800

*Certified high quality products
*Prices in USDlls (USD)

As it can be observed, the three processes, one producing $CaCO_3$, another $MgCO_3$ and the last one Li_2CO_3 with the same ECOPLANT technology, are profitable and produce excellent return on investments.

Main conclusion:

- Practically total elimination of acid gases, greenhouse effects and hydrogen sulfide acid content.

- Great financial benefits from carbonates market.