1 - INTRODUCTION

Due to the petroleum crisis in the seventies, several alternative energy sources, so far unfeasible, became more competitive and gained a new impulse towards development and improvement. Of those, we may stress the ones that are more suitable to be used in Brazil such as eolic energy, solar energy, hydro-electric power stations working on small watercourses and alcohol from sugar cane as vehicular fuel. This latter might be the most widespread and well-succeeded alternative energy source in this country which presently has at its disposal a fleet of about five million vehicles fed on this type of fuel. Energy recovery of urban household waste has received scarce financial support from the federal Government by means of investment sources at better conditions. Few, however, were the well-succeeded attempts. Approximately ten small and medium-sized recycling stations and a landfill biogas collection and treatment installation implanted with governmental resources are still working. The relative steadiness of petroleum prices, considering even the late Middle-East warlike conflicts in the beginning of 1991, acts as an inhibitor of the search for renewable energy sources, thus resulting in a progressive diminution of the planet resources and consequently anticipating the great energy crisis foreseen by international organizations to occur in the next thirty years. Obviously this crisis will not affect all countries equally - the Third World and its peoples will suffer a large amount more than the developed countries, which will keep on consuming the still available energy clumsily and carelessly. This explains the small occurrence of serious projects on waste energy recovery in underdeveloped countries. This fact should deserve a major attention from the government at federal, state and municipal levels in the sense of stimulating the development and implementation of new technologies that present at least the following characteristics:

- low investment costs –
- low operational and maintenance costs –
- labor intensive, basically for unskilled laborers –
- high operational efficiency –
- low energy consumption yielding a positive energy balance

Considering urban waste a disposable product, consequence of human activities, there is the need to evaluate the phases of its cycle, on terms of energy maintenance and recovery:
- waste production

The idea is to reduce it progressively, avoiding one way packages, wrappings and containers.

- waste collection

Selective waste collection must be stimulated since it implies an important conception: the citizen's awareness about environmental problems.

- waste treatment

Recycling and composting plants must be geographically decentralized so to reduce transportation costs. They should utilize non sophisticated technologies with the characteristics mentioned above.

- recycling of recovered products

The industrial plants that will transform recovered products into new raw material need to be simple efficient and suitable for the social-economic conditions of the region.

- final disposal

If sanitary landfilling is chosen as the best final disposal system, one must consider the possibilities to recuperate damaged areas and the subsequent recovery and utilization of the biogas, be it for domestic use (cooking, lightening, refrigeration etc.), industrial (boilers and furnaces) or for vehicular fuel. There is no doubt that the energy balance is positive in the first two hypothesis, since there is no need of treatment once the gas can be burned just as it is when it comes out of the well. In case of using the gas as vehicular fuel more expensive installations are needed to purify (remove \( H_2O \) and \( CO_2 \), to compress and to store it, convenient only in very peculiar conditions or when it is strategically important to use an alternative fuel other than petroleum derived. Recovery systems of landfill gas can be extremely simple, operational safety and collection efficiency regarded. Due to storage difficulties that demands high pressure or cryogenic temperature, the biogas must be utilized, industrially or domestic, close to the landfill, since the fuel will be transported through low pressure, high density polyethylene pipes. This kind of energy utilization should be widely stimulated in any city with more than 30.000 inhabitants that possesses a landfill at least eight meters thick, well or badly operated, which has been recently used.

2 - A SIMPLIFIED METHOD FOR LANDFILL GAS RECOVERY

The evaluation of a landfill gas recovery project for urban waste should consider the analysis of two aspects:

- economic feasibility of the system
- energy balance of the process
The economic study of a landfill gas recovery project must take into account current knowledge about the following data:

- **Investments**, that includes:
  
  landfill preparation .
  well systems and collection network .
  purifying and compressing systems .
  distribution systems

- **Operational and maintenance costs**: .

  operation and maintenance of the plant .
  gas quality monitoring

- **Selling price of the product**

If the biogas selling price for the ordinary consumer is higher than the verified production cost (capital cost + depreciation + operational and maintenance costs), the system will be economically feasible and its implementation recommended. Under this configuration, the lower investment, operational and maintenance costs, the higher economic results of the installation and the sooner amortization of the investment. In the same way will the energy balance vary: the less energy consumed to make the gas ready for use, the more positive will the energy balance of the installation be. Both these considerations motivated the development of extremely simple technologies which are capable of making landfill gas utilization much more profitable to urban communities. To have them well described one should divide the whole system into the following subsystems:

a) **landfill preparation**

A waste landfill does not need to be projected to serve as gas producer. Actually, even an open dump is suitable for a recovery installation, once it has received a sufficient quantity of waste (about 100,000 tons, which is the amount produced by a 50,000 inhabitants city in nine years) and is disposed with an eight meters thickness, at least. A cover made of a low permeability material with a minimum thickness of 40 cm should be provided in order to prevent the gas from escaping to the atmosphere. Before that, collection wells must have already been provided so to avoid an increase of internal pressure in the landfill, what could provoke underground migration of the gases. This caution keeps the gases from reaching sewage networks or buildings foundations, what may mean serious problems for the population.

b) **well perforation**

Depending on the thickness of the waste layer, the drilling may be done whether manually or not. The utilization of manual drills with the maximum diameter of eight inches is rather feasible. This kind of equipment is ordinarily used for drilling artesian wells of water in non rocky soils, reaching a maximum depth of 20 meters. Drilling into waste demands greater
efforts, for the drill's extremity usually meets pieces of wood, rubber, cloth or stone, being then necessary to make use of cutting instruments to bust these blockages through percussion. The holes must go through all the waste thickness, or till it reaches the water layer, whatever comes first. There is no risk for the hole to be closed, for the interweaving of the several materials composes a stiff structure that prevents this unwanted fact from occurring. Another inexpensive way of drilling is making holes with the help of percussion equipment operated by electric or explosion motors, also utilized for artesian wells perforation. In this case, it is possible to open holes of greater diameters at a maximum of 14 inches; however, care must be taken to pressure-wash its inner walls in order to facilitate the gases migration. Distance between wells may vary from 15 to 60 meters, depending on the gas production of the landfill or on the necessity of applying negative pressure on the collection network to increase production, when there is the chance of interference to occur between wells.

c) well installation

Before installing the pipes network and the rest of the accessories for the well functioning it is necessary to light a flame on the hole to check whether there is gas or not. If there is gas, it will suddenly burn and it is recommended not to stay near the well. The flame will run off, since there is no oxygen renewal in the hole. Once the presence of the gas has been confirmed, stones slightly smaller than the hole diameter should be put into it on them will the four-inches PVC tube rest. This tube has to have its lower end obliquely cut and must also be pierced with a half-inch drill. The number of piercing on the tube must be the greater possible - since it does not affect the tube structure - from its inferior end till one meter below the ground surface. Its superior extremity should be 50 cm above the ground. The tube must be placed into the hole and centralized, then the space between the external surface of the tube and the well's walls is filled with gravel, up to a height of 50 cm below the ground level. This last space (from the top of the gravel heap to the ground itself) must be fulfilled with well compacted clay of low permeability so to avoid atmospheric air income when the system is under negative pressure.

d) network installation

The kind of tube to be utilized will depend on the amount of negative pressure applied on the wells. If it is small, up to 50 mm of water column, even a garden hose may be used. In other cases, it is recommended the use of flexible tubes with diameters adequate to the gas flow (maximum of 4"), made of PVC or any other resistant material. The pipes must be buried at a minimum depth of 40 cm beneath the clay layer that covers the landfill, and it has to be disposed an the shape of a fish skeleton, with a main manifold linked to each well, that should be equipped with condensation drains. Ideally, the wells must also have a valve to control the gas flow, an outlet for taking samples and a bore plate for calculating the flow.

e) exhaust/compression of the gas

The several manifolds have to be connected to the exhausters/blowers which apply variable negative pressure on the wells and compression on the final conduction line to the installation which will make use of the gas. A simple air compressor can be occasionally used to perform
this function, as we will see further on. The compressor can store the gas in its own reserve, one taking the care of reducing its inner pressure.

f) utilization of the gas

The gas recovered from waste landfills can be used, without going through any kind of treatment, for cooking, lightening, refrigeration and heating; industrially, in boilers and furnaces and in stationary explosion motors Otto cycle - that can put other equipment and even an energy production generator into action. After the removal of the C0₂ and the reduction of the moisture rate, the gas can be compressed to 220 atmospheres and utilized in vehicles, as it will be described in the next item. Gas treatment and compression require high investments as the operation and maintenance of the installation demands skilled laborers and elevated resources. Thus, it is strongly recommended the adoption of gas recovery and utilization without any treatment - be it for domestic or industrial use - through simplified technologies, therefore, of a low cost. one should be reminded that the biogas utilization offers small risk once the installation is well-aired or in open air. Then, in any occasional leaking, the gas, lighter than air, will be dispersed an the atmosphere.

3 - THE PURIFICATION AND COMPRESSING PLANS FOR BIOGAS USE IN VEHICLES

Comlurb - Cia. Municipal de Limpeza Urbana (Municipal Public Cleansing Company) is the public company responsible for solid wastes management in the city of Rio de Janeiro, Brazil, which includes domestic waste collection (6.000 ton/day), street and beaches cleansing, operation of four transfer stations, three recycling and composting plant and three controlled landfills. Comlurb used to possesses, before contracting part of its services with private companies, a workforce of about 15.000 employees including 150 college graduates, a fleet with more than 1,200 vehicles such as collecting trucks, transfer trailers, dumping trucks, dempster trucks, tractors, front loaders, small trucks etc. with a monthly fuel consumption rate of 800000 its of diesel oil, 30000 its of gasoline and 50000 its of alcohol. After the oil crisis of the seventies, the Brazilian Government has encouraged and subsidized researches for alternative energy solutions, specially those originated from activated wastes, with the purpose of reducing diesel and gasoline consumption, both in urban and road transportation. In the state of Rio de Janeiro, Comlurb working together with CEG (Gas Company of the State of Rio de Janeiro) pioneered the biogas recovery technology development of waste landfalls. In 1977, Comlurb implemented the biogas collection project in the Caju landfill; the biogas was transported through a 4 km long pipeline to the CEG gas plant - located in São Cristovão, a city section - and added to naphtha gas and posteriously to natural cracked gas, in order to be distributed to the residential quarters of the city, by the company's distribution network. In ten years of operations the CEG system recuperated about 20 million cubic meters of raw biogas, with 5.800 Kcal/m3 heat capacity, that was combined to the gas produced by the plant (4.200 Kcal/m³ heat capacity), without any kind of treatment whatsoever. In fact, the operational costs of the system were extremely low (just one pumping equipment with a 2 hp blower, operated by three technical experts), thus confirming the excellent viability of the program. In 1980 Comlurb engineers started to work on studies aiming at the biogas utilization in their vehicular fleet; a detailed project for the collection, purification, compressing and supplying unit was developed and finally in 1985 the works were initiated; the installations are still in operation.
3.1 - Characteristics of the Caju landfill The Caju landfill is located by the Guanabara bay shore, 8 km away from Rio de Janeiro downtown. It was installed in 1935, at a time when the collection of wastes was still done by animal-traction vehicles. The landfill operated until 1977 when it was closed; it was considered one of the major landfills in the city. During its operational existence there was no control whatsoever over the quantity or quality of the wastes. In reality, it was an open dump, with irregular land cover and had received about 30 million cubic meters of waste. Today the Caju landfill has spread out in an area of about one million square meters, totally covered by irregular layers of clay. Its highest spot stands about 20 meters above the sea level. The gas collection system occupies an area of approximately 250,000 m² and is located in the areas last filled. One can come to the conclusion that not only the high tier of organic materials existing in Rio de Janeiro waste, but also the high pluviometric and insulation rates constitute the ideal conditions for obtaining a high production of biogas, even if the landfill has received no treatment directed to a future processing of the wastes at all. Twelve years after its closure, the landfill gas production is still at acceptable levels although only a quarter of the total landfill area is being utilized.

3.2 - Project description The original project can be outlined through the subsystems of collection, transportation, purification, compression, supply and conversion of the vehicles, as follows:

3.2.1 - Collection and transportation subsystem In previously selected landfill areas, twelve test pits were drilled with 2" diameters and at the average depth of 15 m. The flow was measured by means of a flowmeter and the gas composition was analyzed through ORSAT lab equipment. The original project had foreseen the drilling of eight wells with 70 cm diameter and the average depth of 15 m, in sites considered adequate by the prospective studies. The drilling equipment used was "Benoto", but it proved to be expensive and difficult to be moved around. At that time, it was estimated that each well should yield an average of 60 Nm³/h, thus totaling 480 Nm³/h, enough to feed the two specified compressors (225 Nm³/h of raw gas each). In 1987 seven other wells were drilled but only three were connected to the collection network, due to the fact that the others hit water pockets and turned unyielding. The small number of productive wells has limited the unit operations to only one compressor, the other acting as a standby. –

Technical specifications of the collection and transportation systems.

Collection pipe

This pipe is a PVC tube of 4" diameter, class 20, perforated with 1/2" bores in its length, as many as possible, without compromising the structure of the pipe. The tube is not perforated in the upper part, 3 m from the ground.

Wells

The wells of the first stage were drilled with 70 cm diameter with "Benoto" equipment, at the average length of 15 meters.
Installation

After the collection pipes were placed into the drilled wells, the space between the well's walls and the pipe was filled with gravel #3 up to three meters from the ground. The finishing of the well's ends was made with special clay with low rate of permeability (K<10^-7), in the shape of an inverted cone trunk at ground level, the smaller base resting on the gravel backfilling.

Complements

All productive wells have a masonry wall protection, an outlet with a valve for gas sampling, a flow control with a bore plate, a flexible tube for connecting the gas pipeline and a flow control and locking valve. A siphon also protected by masonry walls was installed after each well for the removal of condensation in order to avoid its accumulation in the lower parts of the tube, what would certainly restrict the gas flow.

Collection and transportation network

The pipeline for the gas transportation were made with high density polyethylene tubes, type Dutoflex PN4, of 2", 3" and 4" diameters. The tubes were placed in ditches opened by backloaders, with the average depth of 40 or 80 cm while under the streets, and then filled with dirt.

3.2.2 - Compression and purification subsystems

Compression units

Two Sulzer five stages compressors manufactured in Brazil with 225 Nm3/h capacity each, working in a parallel operation and driven by two 100 hp engines. Before reaching the compressor, the raw gas runs through two steel wool filters for the removal of H2S, with condensation drains and input pressure not over 2.000 mm of the water column. After the second stage, with a pressure of 14 Kg/cm2 and with the flow rate of approximately 225 Nm3/h, the biogas is sent to the scrubbing tower for the removal of C02, going back to the third stage with only 5% of this gas. The biogas is then compressed by the fourth and fifth stages, with a 200 Kg/cm2 pressure and a flow rate of approximately 160 Nm3/h.

Water regeneration tower

The scrubbing water is regenerated in the regenerating concrete tower with a suction fan at the top. The C02 is naturally released into the atmosphere through the air thrust in counterflow with the water sprayed by sprinklers.

Control panel

The control panel is extremely simple, fixed to an outside wall of the compression house, including among others a series of components, explosion and weather proof.
3.2.3 - Biogas high pressure storage subsystem

The system comprehends 20 chromium-molybdenum cylinders, with 80 its hydraulic capacity as 220 Kg/cm3 pressure. The cylinders interconnected by manifolds are assembled in three sets (two sets with seven cylinders and one set with six cylinders). The sets compose the unit installed in an open and airy area, isolated from the compression house. Its discharge system is manual (waterfall type) that allows a fast filling for the vehicles (one at a time, by differential pressure).

3.2.4 - Filling subsystem.

Central Filling Unit for vehicles

The Central filling unit is located close to the biogas purification unit. The gas transportation pipelines are made of steel, as well as the valves, fittings and other accessories, compatible with the operational pressure of 220 Kg/cm2. The twenty filling stalls were designed to allow a slow filling, except for one stall destined to fast supply located next to the high pressure central filling unit.

Decentralized filling units

One of the greatest problems about the utilization of a gaseous fuel for vehicular use is the high price of its transportation in high pressure cylinders, to make possible the decentralization of the supplying, once it would be impossible to build a network pipeline throughout the city that could reach the Comlurb garages, where the vehicles of its fleet are concentrated. Thus, two forms of decentralized filling were designed and implemented:

- Filling through differential pressure

Five sets of 24 steel cylinders with 80 its of hydraulic capacity, pressure of 220 Kg/cm3 were built and placed in four horizontal superimposed runs, each formed by six cylinders. The cylinders are nested in a rigid steel structure, with lifting devices and safety transportation by Dempster or Brooks trucks.

- Decentralized filling unit

This unit was constructed in one of Comlurb garages that shelters about 20 light vehicles and 100 heavy ones; this station is capable to fill seven vehicles at the same time. The project has foreseen the installation of a booster compressor with 30 Nm3/h capacity with the purpose of transferring gas from the cylinder sets to the filling points.

3.2.5 - Vehicles conversion subsystem

The conversion of all vehicles engines to purified biogas was executed by Comlurb engineers in the workshop located in the purification unit. Basically, the conversion system consists of two parts: High pressure gas storage using special cylinders
manufactured from seamless steel tube, closed by hot spinning process. The Choice of the cylinders' diameter, quantity and length, depends on the type of vehicle to be converted and on the autonomy desired. The gas is stored at a pressure of 220 Kg/cm² in the high pressure cylinder and released through the excess valve in steel tubes to the charger valve which, when open, allows the gas to reach the pressure reducer. The pressure is reduced from 220Kg/cm² to atmospheric pressure in three stages and then the gas is released to the mixer as required by engine suction. A mixer is specially designed for every type of carburetor in order to allow a correct and homogeneous mixture. The original supply of gasoline or alcohol to the engine is interrupted by means of a solenoid valve. The selector switches selects the desired fuel to be used. A water circuit coming from the engine block, in the case of a water-cooled engine, passes through the reducer heating it up, so to avoid freezing or low temperatures, and then returns to the radiator. Due to its peculiarities, diesel cycle engines cannot be run on gas only, therefore, diesel fuel can only be partially substituted; there always is the need for some diesel oil to allow spontaneous flame and to cool the injectors. The usual ratio to prevent engine damage is 70% methane and 30% diesel fuel.

3.2.6 - Civil work and electric substation

All the civil works considered the area adjustment and were built on the Caju waste landfill, designed within the context of an economical criteria aiming a rational occupation of the area. It includes the following buildings:

- Operational Control Unit

This is the building where administration offices, laboratory (ORSAT), lockers, bathroom, cafeteria and warehouse are installed.

- Industrial Area

This area is located near the Operational Control Unit where the substation, compressors, scrubbing and regeneration towers are installed.

- Central Filling Unit

Located next to the industrial area with shaded parking lot for the vehicles, including circulation area.

- Vehicles conversion workshop

This building is very simple and equipped with all the necessary tools for vehicles conversion to purified gas utilization. Furthermore, in this workshop the maintenance of all converted vehicles is performed, such as pressure reduction valves repair, engine tuning, high pressure cylinder cleansing etc.
3.3 - Alterations and modifications on the original project

- the use of new technology

The continued operation of the biogas purification unit and the need to expand the system has propitiated the development of new technologies aimed chiefly at the reduction of the costs of landfill gas prospecting and collection and of converting kits maintenance.

Drilling and installation of the wells

In the first phase of the project the wells were drilled with the Benoto equipment used for building the great civil works foundations at very high cost, both operational and installation wise. On account of these difficulties, when the second phase of the project was initiated a more economical and fast solution for the drilling of wells was taken in consideration. It was decided that a more conventional and simple equipment normally used to drill artesian wells was to be used. This equipment consists of a steel drill of 12" diameter that works by alternate percussion and rotating movements. From time to time, the drill is removed from the well and the material resulting from the percussion is mixed with water and taken from the well through a steel tube equipped with a check valve in its lower end. When the drilling is finished the well walls are cleaned with a high pressure spray to facilitate the gas migration.

Evaluation of the well's productivity

One of the greatest difficulties for the implementation of the project consists of the evaluation of the productivity of a newly-installed well, not only regarding the quantity but also the quality. It is very important to obtain these information, because it is only after the confirmation of the good characteristics of the well that it will be connected to the collection network. The nonexistence of electric energy in the landfill makes it a lot more difficult to operate; then, the following system, simpler and inexpensive, was developed. - a flexible hose, installed on the edge of the well, is connected to a domestic vacuum cleaner at the suction side. To the other end of the vacuum cleaner another flexible hose is attached, and then a flowmeter. In the outlet of this flowmeter fittings were installed. The flexible hose outlet of smaller diameter was connected to the carburetor of a small 5 hp engine originally fueled by gasoline. Coupled to the flowmeter outlet a steel tube, flame resistant, of 30 cm diameter was installed, just in case it was necessary to burn the gas. The combustion engine was installed to actuate a small 2 KVA generator which would provide electric power for the vacuum cleaner. The process is initiated by starting the engine with gasoline, the generator belt is tightened and the vacuum cleaner is turned on. It starts sucking up the gas whose flow is measured by the flowmeter. Part of the gas at the flowmeter outlet is derived to the combustion engine and after a short operating period it has its gasoline supply cut and starts to operate with biogas only. Through engine acceleration that affect the generator's rotation, therefore the vacuum cleaner, one can evaluate the well production at different suction pressures.

Biopack

Together with a company that manufactures domestic waste compactors, a portable skid mounted system was built; this system can be hauled by tractors or front loaders over the
landfills and is designed to purify, compress and store the gas at high pressures, allowing also vehicular filling. The set consists of the following equipment:

- VW engine - 1300 cc, adapted to raw biogas use
- 20 KVA generator coupled to the VW engine
- precompressor of 10 Nm3/h (normal cubic meter per hour) at 10 kgf/cm², driven by electric engine
- high pressure compressor of 7 Nm³/h at 200 Kgf/cm³ pressure
- scrubbing tower to remove CO₂ from the gas
- gas regeneration tower consisting of a fibercement water tank
- water pump and water circulation closed circuit - four high pressure cylinders with 40 lts of hydraulic capacity each.
- hose for filling up the vehicles The set has operated satisfactorily, but still needs two gas wells
- one to feed the VW engine and another for the purification system.

The only disadvantage that makes its operation not very attractive is the low purified gas production (7 Nm³/h). If the operational regime is one of 16 hours a day, the system would be capable to fill up only eight vehicles of the VW van type and, even so, very slowly. The power generated by the generator set largely exceeds the power consumed by the system's equipment. This way, one could use a larger compressor that would supply the system without changing its basic characteristics that is autonomy, compactfullness and ability to move around easily.

#### 3.4 - Investment and Operational costs

The necessary investments to implement the project were extremely scarce due to the following reasons: - The project developed by Comlurb engineers was designed to be the simpler and more operational possible, utilizing material and equipment exclusively available in the Brazilian market; - The most expensive item of the project is the high pressure compressor, manufactured by Sulzer. The units acquired by Comlurb were the first manufactured in Brazil, and perhaps this fact influenced the equipment's price which was rather low (US$ 66,000,00 - today it is US$ 150,000,00); - No works were executed in the Caju landfill regarding its preparation for the project, nor there was any investment on utilities (electric power, water, communications), already available in the site.

#### 4 - THE NATAL EXPERIENCE

#### 4.1 - Introduction
Natal is the capital of the State of Rio Grande do Norte, located in the northeast of Brazil, about 2,800 km away from Rio de Janeiro. It is a littoral city of around 600,000 inhabitants, with a great tendency for the touring industry. The city produces approximately 500 ton of urban waste per day, of an elevated rate of organic matters, dumped in a controlled landfill located near a large sand dune, from where the covering material is taken. Because of the high percentage of organic matters in the waste and the high pluviometric rates of the region, a great potential for gas production has been verified. In 1983 the city administration decided to assign an elaboration of a project on the utilization of this gas that should include, in three stages: - a communitary kitchen for the low-income
residents of the community, installed next to the landfill; - a gas distribution network directly connected to the 150 habitations of the community, whose resident's majority used wood collected from the landfill as fuel for cooking; - a gas feeding link to a boiler in a cashew nut industrialization factory, capable of replacing the one on use which fed on timber that was becoming progressively scarce in the region. This project had its investment costs estimated in US$ 50,000 and was presented to a federal development agency so to obtain the necessary resources, but it was not approved once the value was considered too small. Even though the Natal administration decided for the implementation of the communitary kitchen by its own resources, what came to happen in 1986.

4.2 –Project description

4.2.1 - Wells installation Six production wells were perforated with manual drills of 6" diameter and average depth of six meters (the waste layer was about seven meters deep), one 20 meters apart from the others. 4" PVC perforated pipes were placed into the wells and the space between them and the well walls filled with gravel. Well-compacted clay of low permeability covered the top of the gravel heap up to ground level. The upper end of the pipes came up to 80 cm above the ground surface, being then reduced from 4" to 3/4".

4.2.2 - Network installation 3/4" PVC hoses, flexible and transparent of domestic use were employed for the gas transportation. The six well hoses were linked to a connection from were another hose of 1" diameter conducted the gas to the compressor, 70 meters away from the landfill.

4.2.3 - Gas suction and compression For the suction of the gas from the; wells and posterior compression for the burners, a 2 hp air-compressor normally used for painting vehicles, with a 150 lts stock was utilized. The pressure regulator normally operated in 150 psi (pound/square inch), was readjusted to 3 psi, thus allowing gas storage in the compressor stock. In its outlet a valve was installed aiming to reduce pressure to 660 mm of the water-column, the recommended rate for the feeding of the burners.

4.2.4 - Manifold and burners The link from the pressure reducer valve to the manifold was done by a flexible PVC hose of the same diameter (1 1/2"). The manifold, made of galvanized steel, goes through the 19 boxes with a half-inch outlet for each burner controlled by a small valve to open or close gas feeding. The burners are the same of industrial stoves and were installed under a concrete top with a hole in the center for the flames to go through, with iron bars disposed in a way to support pans and pots.

4.2.5 - Civil construction The shelter under which the communitary kitchen is placed is a simple masonry building covered with ceramic roofing plates, where there is a small room at the back that keeps the compressor and, at the front, the one-meter-wide boxes with the concrete tops. The building is surrounded in its whole perimeter by a wall with a gate, through which the user's entry is controlled.

4.2.6 - Kitchen utilization The communitary kitchen has its functioning controlled by the employees of the municipality owned cleansing company. Its working period is restricted from 11h to 14h on daytime and from 16h to 19h nighttime. It has been utilized by a large section of
the community, specially by the ones with the lowest incomes, that do not have stoves fed on liquefied petroleum gas (LPG) at their disposal.

5 - CONCLUSION

The experiences performed by Comlurb and by Natal municipality have proven the perfect technical feasibility of the utilization of the gas generated in the landfills. They have also shown that excellent levels of yield can be reached with the use of simple technologies without compromising the quantity and the productivity of the system, viabilizing an energetic alternative available in the surroundings of all urban conglomerates, specially those of the Third World. It is very important that we stress that the implementation of any project on landfill gas recovery, wherever in the world, must be preceded by careful studies of its feasibility; local peculiarities should be evaluated in order to determine the technologies to be used and whether the project is viable both economically and strategically. But one thing is for sure: the waste landfill gas is an energy source that cannot be left aside for it is, generally, much more economic than any other fuel currently available, provided that the consumption sites are near the landfills.