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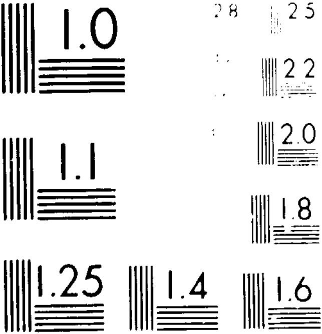
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A BIOGAS POWER STATION IN FOSHAN *
ENERGY FROM NIGHT SOIL

by

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Keywords: Anaerobic Digestion, Night Soil, Electricity Generation

Abstract—A biogas power station has been built in Foshan, Guangdong. It was originally a night soil treatment plant that did not collect any biogas generated. In the year of 1974 it was transformed into a biogas power station with an output of 90 kw. The station has been operating normally for 4 years. Successful experiences have been acquired in the aspects of leak-proof and anti-corrosion on the walls of gas domes of the digesters, gas storage with balloons, automatic overflow to minimize pumping, and making attachments in easy ways.

INTRODUCTION

Nowadays, countries in all parts of the world are paying full attention to the expicitation of energy sources and studying them on a large scale. Energy via bioconversion is an important one of the available energy sources. Scientists of many countries have made wide studies in this field. In rural areas of our country anaerobic digestion has been studied, tested and popularized for years. More than 7 million rural digesters have been built since 1972, and they have brought about excellent results—better solving of the fuel supply problem for commune members, providing more and better fertilizer and improving the sanitary condition of the countryside. In many places biogas is utilized to drive motors and generate electricity. Studies on biogas production from urban industrial and domestic waste water, as well as biogas utilization to generate electricity, are also being carried on.

The Foshan Environmental Sanitary Management Agency, together with this institute, had studied the anaerobic digestion of night soil and the utilization of biogas to generate electricity. And then we transformed the original Junqiao Night Soil Treatment Plant into a biogas power station with an output of 90 kw. The plant began to work in the summer of 1974, and has been operating normally for 4 years. Although the said power plant is very small, its success provides new experiences for the treatment of urban waste water and for the building and operating of commercial biogas power plants.

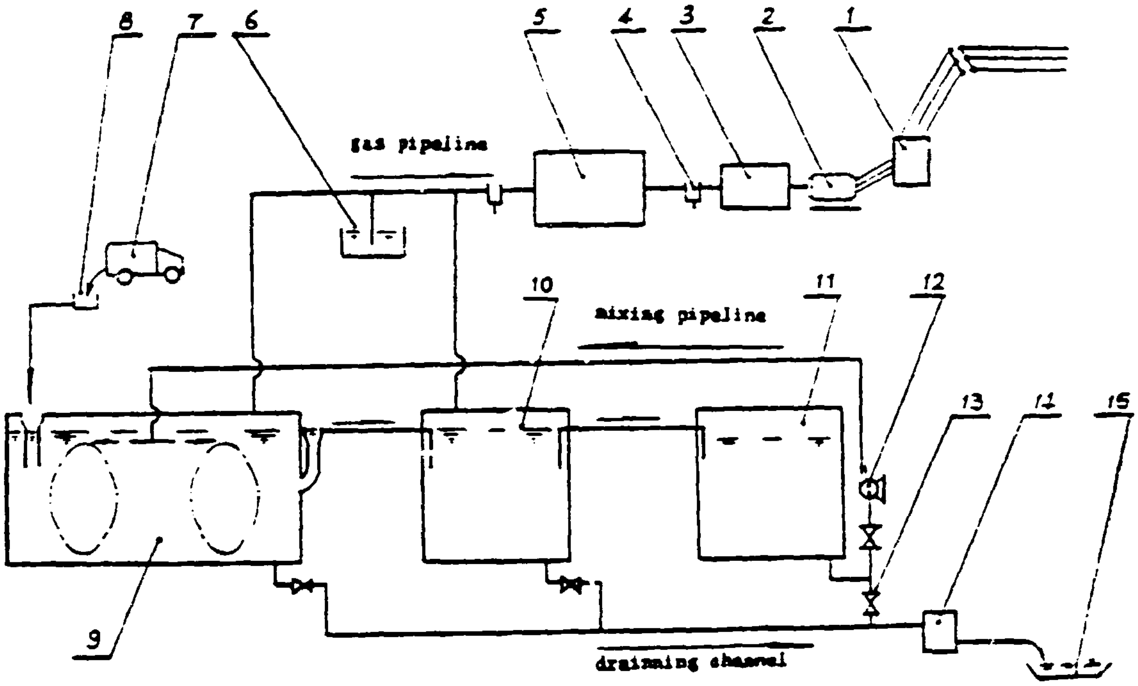
Biogas power plants are different from other power plants. As one biogas power plant was built, three plants were functioning at the same time: a power plant, a fertilizer plant and a waste water treatment plant. Hence the building of such plants is a matter of great realistic importance.

TECHNOLOGICAL PROCESS

As the original Junqiao Night Soil Treatment Plant was to treat night soil and provide fertilizer for sanitary and agricultural purposes, while projecting the technological process, we had to consider the original sanitary and agricultural demands, the construction characteristics of the original treating tanks as well as the local conditions. We tried our best to minimize the reconstruction work, simplify the equipment, convenience the operation and economize the investment. In regard to the digestion process, we made it similar to that of three-stage septic tanks and kept the sludge overflowing automatically from feeding to discharging. The flow sheet of this biogas power plant is shown in Fig. 1.

The raw sludge of night soil is sent to the station by tank trucks every night. After releasing from tank trucks to the feeding basin, the raw sludge runs into the digesters through the channels and the inlets. At the same time, an equal volume of digested sludge overflows from the outlets on the other side of the digesters into the sedimentation tanks. Similarly, an equal volume of supernatant overflows from the sedimentation tanks into the storage tanks. Every morning the digested liquid in the storage tanks flows automatically into the fertilizer boats through valves, drainning channels and a measuring box. When the precipitate in the sedimentation tanks accumulates to a certain extent, it is released periodically, and flows into the fertilizer boats, too. The digested liquid and the precipitate are all sent to the countryside for fertilizer.

Axial flow pumps and pipelines form the stirring equipments. The digested liquid is pumped from the storage tanks to the nozzles of the 'T' tubest submerging below liquid level of the digesters through the pipelines and dividing into two currents, gushes out from the said nozzles to dash against the scums floating on the surfaces of the contents in the digesters. Thence two eddies are formed in every digester and the contents in digesters are well mixed.



1. Switch board	2. Generator	3. Combustion engine	4. Water seal valve
5. Balloon	6. Safety valve	7. Tank Truck	8. Feeding Channel
9. Digester	10. Sedimentation Tank	11. Storage Tank	12. Mixing Pump
13. Stop-Valve	14. Measuring Box	15. Fertilizer Boat	

Fig. 1. FLOW SHEET OF JUN QIAO BIOGAS POWER STATION

The biogas generated from the digesters flows into two storage balloons and then to the combustion engines. There are water seal valves, which are specially designed, among the digesters, balloons and the engines. The electricity generated by the combustion engine-generator sets is sent to the local power grid through switch boards.

EQUIPMENTS

1. DIGESTERS.

The digesters are transformed from the original rectangular treatment tanks. There are 28 digesters in this power station with a volume of 47 cu.m. each, and the total volume of the digesters is 1316 cu.m. The bottoms and roofs of the digesters are made of concrete and the walls are made of bricks. Ceramic pipes produced locally are used as inlet and outlet pipes of the digesters while PVC pipes as biogas pipelines. In order to prevent any possible gas leakage from the digesters, the inner surfaces of the gas domes are well coated with three layers: the first layer is of common cement mortar, the second layer is of cement mortar mixed with 5% (to cement by weight) of polyvinyl acetate latex and the third layer is of cement paste mixed with 10% (to cement by weight) of polyvinyl acetate latex. Furthermore, bituminous painting is used as anti-corrosion coating on the cement paste layer. It has been verified through operating practice of late years that the anti-leakage and anti-corrosion results of these coatings are excellent and no leakage has been found. This is also a successful experience of preventing gas leakage on a large surface of concrete structure without any need of lining plastic or metal plate. The diagram of each digester is shown in Fig. 2.

2. GAS HOLDERS.

There are two gas holders in this plant, with a volume of 120 cu.m. each. Actually, they are two balloons made of PVC film with a thickness of 0.28 mm. Characteristics of the balloon holder are stated as follows:

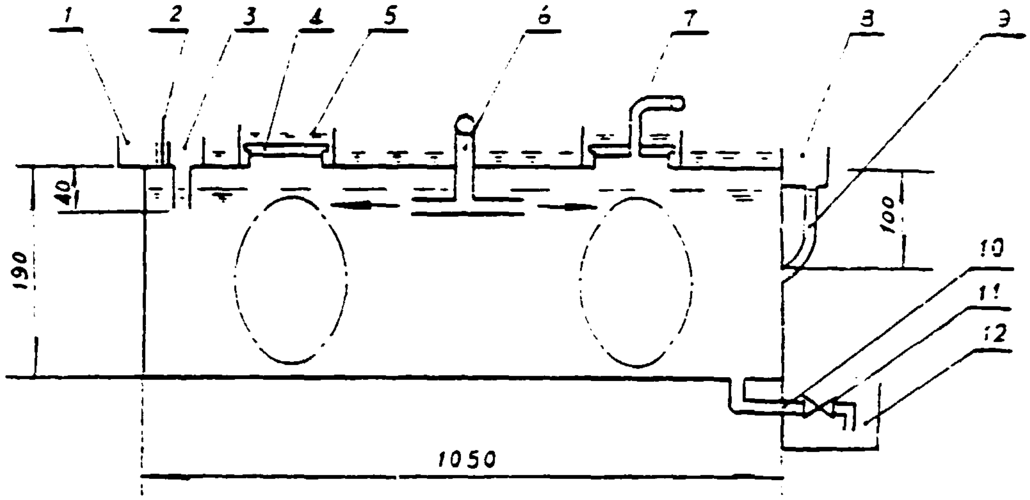
a. The whole gas system kept in an extremely low pressure below 1 mm. water column till the balloons are full of biogas. Even when the balloons are filled, the highest pressure of the whole gas system will be kept at 3 cm. water column by the safety valves. Consequently, the demands on construction of the digesters are limited. The digesters are very easy to be built with common materials and by ordinary methods. For example, the roofs of the digesters in this plant is made of concrete with a thickness of only 5 cm.

b. The materials making the balloons are cheap and easy to obtain. The balloons can be made simply and installed conveniently. The two balloons, having a total volume of 240 cu.m., cost only RMB 900 yuan. Comparing with a floating cover, having a same volume, which would cost as high as 25,000 yuan and still would be difficult to be manufactured and installed.

c. As the pressure of the gas system is very low, it is easy and cheap to make absolutely reliable stop valves and safety valves. (See Fig. 3, water seal valves and Fig. 4, safety valves.)

The balloons should be kept in rooms. The floors, walls and roofs of the rooms should be smooth and clean to avoid grinding through the balloons by sharp things, such as sand. There is no any other requirement besides this. On the contrary, in our case, the floating covers require water tanks of the same volume, because all digesters have their own concrete roofs and no floating covers should be allowed to float directly on top of the digesters. It is obvious that to build a water tank is more difficult and expensive than to build a usual room for the balloon.

At first, we simply joined the openings of the gas pipelines to the balloons, but it did not take very long before we found that the films adjacent to the outlets would stick



1. Feeding Channel 2. Sluice Board 3. Inlet 4. Removable Cover 5. Manhole
6. Mixing Pipeline 7. Gas Pipeline 8. Overflow Channel 9. Outlet
10. Discharging Pipe 11. Discharging Valve 12. Drainning Channel

Fig. 2. DIAGRAM OF DIGESTER

the opening of the gas pipelines and cut the pipelines off due to the suction of the engines. In order to prevent this we inserted the gas pipelines through the balloons from the inlets to the outlets and drill holes on the tubes of the gas pipelines, thus make them like flutes within the balloons.

3. WATER SEAL VALVES AND SAFETY VALVES.

Owing to the exceptionally low pressure of the gas system, we have designed two kinds of special plastic valves (water seal valves and safety valves) which possess many advantages—the producing material being easy to obtain, simple manufacturing, being convenient to operate, being cheap and reliable, no abrasion, and anti-corrosion.

The water seal valve is shown in Fig. 3.

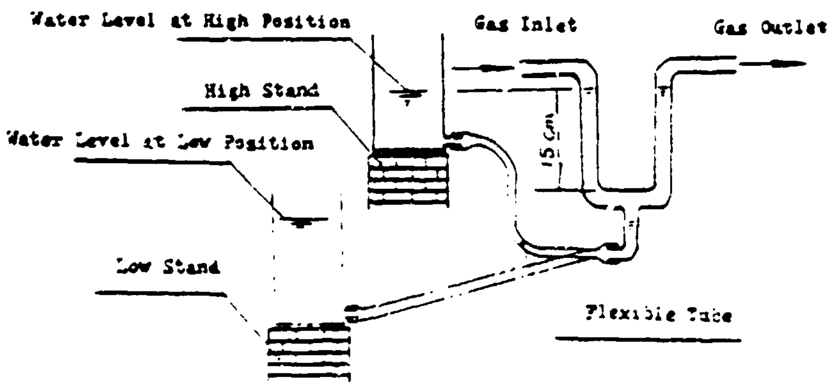


Fig. 3. WATER SEAL VALVE

A plastic tube is bent into the shape of the letter U. A water seal valve is formed by means of connecting the bottom of the 'U' and a pail with a flexible tube. Two stands have to be built for the pail, one of them is low and the other is high. When the pail is put on the higher stand, the water flows from the pail to the U-tube, thus the water level raises to a height about 15 cm. over the bottom of the U-tube and the valve is closed to cut off the pipeline. When the pail is put down on the lower stand (as shown with dotted lines in Fig. 3.), the water flows from the U-tube to the pail, thus the water level drops to a height below the bottom of the U-tube and the valve is open to make the pipeline through.

The safety valves are designed to guarantee the safety of the digesters and the balloons. The principle is similar to that of the water seal valves. The safety valves are formed simply by connecting several branch pipes to the gas pipelines and submerging the openings of the branch pipelines into water about 3 cm. below the water surface (as shown in Fig. 4.). When the balloons are filled, the pressure of the gas system gradually increases till it reaches 3 cm. water column and then the biogas gets out from the openings mentioned above and keeps the pressure unchanged (at about 3 cm. water column), and prevents the balloons from breakage.

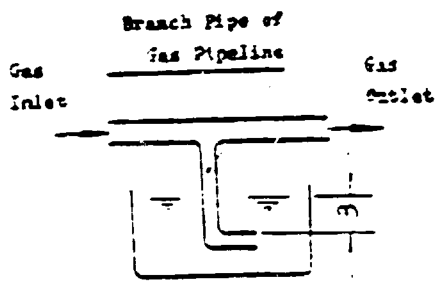


Fig. 4. SAFETY VALVES

4. INTERNAL COMBUSTION ENGINE-GENERATOR SETS.

There are two sets of generators in the station. One is a Diesel engine-generator set rating at 50 kw, the other is a gas engine-generator set rating at 40 kw. Both sets are ignited by spark plugs. The Diesel engine has been reconstructed, the fuel oil injection system has been dismantled; spark plugs are used in place of the nozzles; a distributor, and a mixer (Fig. 5.) for gas were placed in the air inlet, an ignition coil and a storage battery were added. After the reconstruction, the Diesel engine gives good result. There is no need to reconstruct the gas engine.

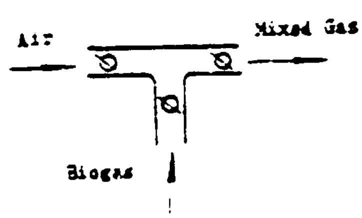


Fig. 5. GAS MIXER

OPERATION AND DETERMINATION

1. FEEDING AND DISCHARGING.

The feeding of night soil is 60 tonnes per day and the discharging of digested night soil to fertilizer boats is of the same quantity. Owing to the large quantity of lavatory water, the content of dry material in night soil is merely around 2%, and volatile solid is about 1.7%, so the fluidity of night soil is good. Furthermore, we properly utilized the terrain by building the digesters upon the highest spot to keep the discharging outlet higher than the water level of the river at any time so that the sludge overflows automatically from feeding to discharging without pumping. Thus made the cost of construction low, the operation easy, and the local power consumption drops down (to 6% of the total power generated), while net output increases.

2. DIGESTION AND GAS PRODUCTION.

According to the design, the detention time of night soil is 22 days in the digesters.

Foshan is situated in the south of Guangdong Province, having a subtropical climate. High temperature period is very long there—about 8-9 months. In this period, the range of temperature of the contents in the digesters is about 25-30°C. In consideration of the speciality of climate and the difficulty of recoustruction, no heater and insulator are built so far. When the content temperature is 30°C, the average daily gas production rate is 0.3 cu.m. per cu.m. volume of tank and the total gas production is about 400 cu.m. per day without stir. When it is stirred continuously, the gas production rate increases considerably, up to 0.55 cu.m. per cu.m. volume of tank per day, and the daily production attains about 720 cu.m. To compare with the case without stir, the production increases by 80%. In winter, the lowest temperature of the contents drops to about 14°C, and the gas production decreases to a half of that in summer.

3. GAS ANALYSIS.

The composition of biogas produced without stir is: CH_4 71-72.5%, CO_2 26-27% and a small amount of H_2S, CO, etc. The data of analysis show that agitation has nothing to do with the composition of biogas produced.

4. GAS CONSUMPTION ON ELECTRICITY GENERATING.

According to our determination to the gas engine-generator set, one cubic meter of gas at 40°C may provide 1.5 kwhr. of electricity, i.e., one cu.m. of gas in standard state provides 1.73 kwhr. of electricity. The total heat efficiency is 24.3%.

5. SANITATION EFFECT.

The expertise of Foshan Epidemic Prevention Center (in Table 1.) shows that the effect of parasite eggs sedimentation in digesters of this station is quite well. It is the same as in the three-stage septic tank. The death percentage of parasite eggs is relative to the detention time of night soil in the digesters. But the value of coli-bacillus is far from the criterion of harmlessness.

TABLE 1. SANITATION EFFECT

Sampling Parts	Number of Parasite Eggs	Parasite Eggs Removal	Die-off Parasite Eggs	Value of Coli-bacillus
Inlet of Digester	396	0%	38.75%	10^{-3}
Sedimentation Tank	116	70.7%	62.8 %	10^{-4}
Outlet of Storage Tank	31	92.2%	68.06%	10^{-3}

6. THE FERTILITY OF THE SLUDGE.

In order to check the change of the fertility before and after fermentation (represented by nitrogen, phosphorous and potassium) to provide a reference datum for the agricultural section, we sent the samples to the Guangdong Institute of Soil and Fertilizer for analysis. The results are shown in Table 2.

TABLE 2 CONTENTS OF N, P, K IN RAW SLUDGE AND DIGESTED LIQUID

Sample	Total Nitrogen	Ammonia Nitrogen	P_2O_5 g/l	K_2O g/l
Raw sludge	1.049	0.620	0.512	0.340
Digested liquid	1.009	0.860	0.204	0.340

As shown in the above table, the content of ammonia nitrogen increases about 40% after digestion, but there is little change in total nitrogen and total potassium. The reason why the total phosphorous reduces so obviously is that part of phosphorous is in state of insoluble compound exists in the precipitate, and the amount of precipitate in the digested liquid is very little.

7. THE EXPERIMENT ON USING WASTE HEAT TO MAKE NIGHT SOIL HARMLESS.

Biogas, after generating electricity, releases a large amount of waste heat. According to our calculation, burning one standard cu.m. of biogas from this station will release 4,600 kcal. of waste heat after generating electricity. Hundreds of cu.m. of gas are consumed in Junqiao Power Station every day. Therefore, a great amount of waste heat can be utilized. Recently, we have made some experiments on using waste heat to heat raw night soil to make it harmless, and have brought about some expectant results. The night soil, passing through a heat exchanger, may be heated up to 60°C with waste heat, and then the die-off of parasite eggs is 100% while the value of coli-bacillus is 0. These results attained the standard of harmlessness. This experiment is still going on for the time being.

DISCUSSION

1. Agitation may increase the gas production and shorten the detention time. The power for agitation is 2.8 kw. and daily electricity consumed is about 67.5 kwhr. It means that 44.8 cu.m. of biogas is required every day, that is only one seventh of 320 cu.m. of biogas increased from agitation. Obviously, continuous stirring of the fermenting content is favourable.

2. When a digester is cleaned, a very thick scum layer could always be found. In the scum layer there is still much organic matter which has not yet been utilized. The scum not only occupies the volume of the digester but also hinders gas production. This problem has to be solved. There is a possibility to obtain a better result, if a pressure pump is used to rush the scum and stir the digesting content.

3. The preliminary results of the experiment shows that the using of waste heat from gas engine to make night soil harmless is available. In addition, heated raw night soil may elevate digester temperature and thus increases gas production.

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