DESIGN OF BIOGAS DIGESTER
(INDIAN TYPE)

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BACHELOR OF ENGINEERING

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JUDUL: **DESIGN OF BIOGAS DIGESTER (INDIAN TYPE)**

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UNIVERSITI MALAYSIA PAHANG
FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled " Design of Biogas Digester (Indian Type) " is written by Mohd Ayub Bin Adnan. I have examined the final copy of this project and in my opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering.

Dr. Agung Sudrajad
Examiner Signature

DESIGN OF BIOGAS DIGESTER (INDIAN TYPE)

MOHD AYUB BIN ADNAN

Thesis submitted in partial fulfilment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2010

SUPERVISOR’S DECLARATION

I hereby declare that I have checked this project report and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature
Name of Supervisor: Dr. Maisara Mohyeldin Gasim
Position:
Date:

STUDENT’S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature
Name: Mohd Ayub bin Adnan
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Date: 24 November 2010

DEDICATION

This report is dedicated God whose guidance, help and grace was instrumental in making this humble work a reality. To my beloved parents, En. Adnan bin Mohamed and Puan Normala binti Sulaiman, family and friends, without whom and his/her lifetime efforts, my pursuit of higher education would not have been possible and I would not have had the chance to study for a mechanical course.

Also to my supervisor, Dr. Maisara Mohyeldin Gasim and to the entire lecturer without whose wise suggestions, helpful guidance and direct assistance, it could have neither got off the ground nor ever been completed.

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ABSTRACT

This project deals with designing and fabricating a biogas digester which is focusing on Indian type. The objective of this project is to design a biogas digester that can produces biogas with specific flow rate. The digester that uses floating roof will produces constant pressure biogas. The specifications for the design will meet the type and specifications of the diesel engine that will run the generator. The fabrication of lab size digester was done by using 200 litres barrel. Biogas, a clean and renewable form of energy could very well substitute (especially in the rural sector) for conventional sources of energy (fossil fuels, oil, etc.) which are causing ecological–environmental problems and at the same time depleting at a faster rate. Utilization of biogas has gained importance in recent years, mainly due to the availability of cheap raw materials and environmental compatibility. Further, with an increase in the cost of petroleum products, biogas can be an effective alternative source of energy for cooking, lighting, food processing, irrigation and several other requirements. In essence, a biogas digester involves anaerobic fermentation process in which different groups of bacteria act upon complex organic materials in the absence of air to produce biogas. The efficiency of anaerobic digestion essentially depends on intensity of bacterial activity, which is influenced by several factors such as ambient temperature, temperature of digester material, loading rate, retention time, pH value of digester content etc. Therefore, for efficient performance of a biogas plant, it is necessary to regulate all the factors suitably. The rate of biogas production also depends on the ambient temperature of a particular region.

ABSTRAK

Projek ini melibatkan merekabentuk dan fabrikasi pencerna biogas yang berfokuskan kepada rekaan Indian. Objektif projek ini adalah untuk mereka pencerna biogas di mana ianya dapat menghasilkan biogas yang kadar alirannya adalah tertentu. Pencerna yang menggunakan atap jenis terapung akan menghasilkan biogas yang tekanannya adalah malar. Spesifikasi rekabentuk akan memenuhi jenis dan spesifikasi enjen diesel yang akan menjalankan generator. Fabrikasi pencerna yang bersaiz makmal adalah dengan menggunakan tong 200 liter. Biogas, di mana ianya merupakan gas yang bersih dan juga merupakan suatu bentuk tenaga yang boleh diperbaharui amat sesuai bagi menggantikan (terutamanya di sektor luar kota) sumber tenaga konvensional (bahan bakar fosil, minyak dan lain-lain) di mana ianya telah menyebabkan permasalahan ekologi alam sekitar dan pada masa yang sama sumber tenaga ini berkurangan dengan kadar yang pantas. Penggunaan biogas telah meningkatkan kepentingannya semenjak tahun-tahun yang lepas, berikutan terdapatnya bahan-bahan mentah yang murah dan persekitaran yang sesuai. Oleh sebab itu, dengan peningkatan kos produk-produk dari petroleum, biogas boleh menjadi suatu sumber alternatif yang efektif bagi memasak, pencahayaan, pemprosesan makanan, irigasi (pengairan) dan lain-lain. Secara dasarnya, pencerna biogas melibatkan proses penapaian *anaerobic* di mana beberapa kumpulan bakteria bertindak ke atas bahan organik kompleks dengan ketidakhadiran udara dan seterusnya menghasilkan biogas. Kecekapan pencernaan *anaerobic* dasarnya bergantung pada intensitas aktiviti oleh bakteria, yang dipengaruhi oleh beberapa faktor seperti suhu persekitaran, suhu bahan di dalam pencerna biogas, tempoh masa penapaian, waktu retensi, nilai pH kandungan di dalam pencerna biogas dan lain-lain. Oleh sebab itu, untuk mendapat prestasi yang cekap dari pencerna biogas, adalah perlu untuk menetapkan semua faktor yang sesuai. Peningkatan pengeluaran biogas juga bergantung pada suhu sekitar bagi kawasan tertentu.

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LIST OF ABBREVIATIONS

Dia.	Diameter
FRP	Fibreglass reinforced plastic
ICE	Internal combustion engine
KVIC	Khadi and Village Industries
No.	Number
PVC	Polyvinyl Chloride
Qty.	Quantity
RMP	Resting membrane potential
UASB	Upflow Anaerobic Sludge Blanket

CHAPTER 1

INTRODUCTION

1.1 PROJECT SYNOPSIS

1.1.1 General Project Synopsis

This project involves designing and calculating a biogas digester which is focusing on Indian type that using floating roof type rather than fixed type roof. This digester could be used by other students or lecturers in order to do some research that relates with biogas. As the Bachelor final year project allocates the duration of one semester, this project only focused on designing the digester that can produces needed amount of mass flow rate.

The project will be funded by student final year project funding, UMP short term project funding as well as sponsorship attained from industrial sponsors in terms of equipments, products and also monetary funding.

1.1.2 Specific Project Synopsis

The project title is Design a Biogas Digester (Indian type). The project involves designing and calculating a digester which is using floating type roof. This type of roof can produces constant pressure biogas which then can be used to run the internal combustion engine (ICE) that will drives generator so that electricity can be generated.

1.2 PROBLEM STATEMENTS

This project will focus on the size of the digester in order to achieve aimed output which is the biogas itself. Lack of biogas industry in Southeast Asia especially in Malaysia, rising of fuel price and plenty of waste (cow dung) lead to a beginning of this project.

For the digester itself, the common digester has a problem regarding the feeding of the manure. The project will use plunger in order to push the manure into the digester.

1.3 PROJECT OBJECTIVES

The objective of this project is to design and fabricate a biogas digester that can produces biogas with specific flow rate. The design is referred to Indian type digester. The digester will produces constant pressure gas.

1.4 PROJECT SCOPES

The scopes that involved in this project are literature review and the design of the digester itself. The literature review is to practice the knowledge and skill of the student that have been gathered before in solving problem using academic research. This project also important to train and increase the student capability to get know, research, data gathering, analysis making and then solve a problem by research or scientific research.

As for the design, it is specified to Indian type that uses floating type roof, so that the digester will keep the biogas pressure constant. The specifications for the design will meet the type and specifications of the diesel engine that will run the generator.

1.5 PROJECT PLANNING

This project is begun with collecting all possible data and information regarding the given title via website, reference books, journal others relevant academic material. It took about three weeks before continue for literature review. All gathered information about biogas will be referred to compile the literature review.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION AND OVERVIEW

Anaerobic treatment is the use of biological processes, in the absence of oxygen, for the breakdown of organic matter and the stabilization of these materials, by conversion to methane and carbon dioxide gases and a nearly stable residue. As early as the 18th Century the anaerobic process of decomposing organic matter was known, and in the middle of the 19th Century, it became clear that anaerobic bacteria are involved in the decomposition process. But it is only a century since anaerobic digestion was reported to be a useful method for the treatment of sewage and offensive material. Since that time, the applications of anaerobic digestion have grown steadily, in both its microbiological and chemical aspects. The environmental aspect and the need for renewable energy are receiving interest and considerable financial support in both Developed and Developing Countries, expanding research and application work in these directions, and many systems using anaerobic digestion have been erected in many countries (Satyanarayan S., 1977).

Anaerobic digestion provides some exciting possibilities and solutions to such global concerns as alternative energy production, handling human, animal, municipal and industrial wastes safely, controlling environmental pollution, and expanding food supplies.

Most technical data available on biogas plants relate primarily to two digester designs, the floating cover and fixed dome models. Promising new techniques such as bag, dry fermentation, plug flow, filter, and anaerobic baffled reactors should be explored to establish a firmer technical base on which to make decisions regarding the viability of biogas technology. Along with this increase in interest, several newer processes have developed, that offer promise for more economical treatment, and for stabilizing other than sewage materials - agricultural and industrial wastes, solid, organic municipal residues, etc. - and generating not only an alternative energy source, but also materials that are useful as fodder substitutes and substrates for the mushroom and greenhouse industries, in addition to their traditional use as organic fertilizers. Other benefits of anaerobic digestion include reduction of odours, reduction or elimination of pathogenic bacteria (depending upon the temperature of the treatment) and the use of the environmentally acceptable slurry.

The technology of anaerobic digestion has not yet realized its full potential for energy production. In most industrialized countries, biogas programs (except for sewage treatments) are often hindered by operational difficulties, high costs of plants and as yet low energy prices. In most Developing Countries, expansion of biogas programs have been hindered because of the need for better economic initiatives, organized supervision and initial financial help, while in other Developing Countries, on the other hand, slow development has been observed, and a lack of urgency, because of readily available and inexpensive non-commercial fuels, such as firewood.

Biogas technology is also potentially useful in the recycling of nutrients back to the soil. Burning non-commercial fuel sources, such as dung and agricultural residues, in countries where they are used as fuel instead of as fertilizer, leads to a severe ecological imbalance, since the nutrients, nitrogen, phosphorus, potassium and micro-nutrients, are essentially lost from the ecosystem. Biogas production from organic materials not only produces energy, but preserves the nutrients, which can, in some cases, be recycled back to the land in the form of slurry. The organic digested material also acts as a soil conditioner by contributing humus. Fertilizing and conditioning soil can be achieved by simply using the raw manure directly back to the land without fermenting it, but anaerobic digestion produces a better material. Chinese workers report that digested biomass increases agricultural productivity by as much as 30% over farmyard manure, on an equivalent basis. This is due in part to the biochemical processes occurring during digestion, which cause the nitrogen in the digested slurry to be more accessible for plant utilization, and to the fact that less nitrogen is lost during digestion than in storage or comporting.

In the area of public health and pollution control, biogas technology can solve another major problem: that of the disposal of sanitation wastes. Digestion of these wastes can reduce the parasitic and pathogenic bacterial counts by over 90%, breaking the vicious circle of re-infection via drinking water, which in many rural areas is untreated. Industrial waste treatment, using anaerobic digestion, is also possible.

With the growing significance of this process, it is appropriate to mention some the historical developments which have occurred during the last 100 years of anaerobic digestion. In many cases, this may help to clarify the state-of-the-art at the end of the 20th Century (Satyanarayan S., 1977).

2.2 SHORT HISTORICAL BACKGROUND ON ANAEROBIC DIGESTION

The appearance of flickering lights emerging from below the surface of swamps was noted by Plinius and Van Helmont recorded the emanation of an inflammable gas from decaying organic matter in the 17th Century. Volta is generally recognized as putting methane digestion on a scientific footing. He concluded as early as 1776 that the amount of gas that evolves is a function of the amount of decaying vegetation in the sediments from which the gas emerges, and that in certain proportions, the gas obtained forms an explosive mixture with air.

In 1804 - 1810 Dalton, Henry and Davy established the chemical composition of methane, confirmed that coal gas was very similar to Volta's marsh gas and showed that methane was produced from decomposing cattle manure. France is credited with having made one of the first significant contributions towards the anaerobic treatment of the solids suspended in waste water. In 1884 Gayon, a student of Pasteur, fermented manure at 35°C, obtaining 100 liters of methane per m of manure. It was concluded that fermentation could be a source of gas for heating and lighting. It was not until towards the-end of the 19th Century that methanogenesis was found to be connected to microbial activity. In 1868, Bechamp named the "organism" responsible for methane production from ethanol. This organism was apparently a mixed population, since Bechamp was able to show that, depending on the substrate, different fermentation products were formed. In 1876, Herter reported that acetate in sewage sludge was converted stoichiometrically to equal amounts of methane and carbon dioxide (Patel, V., Madamwar, D., 1994).

2.3 COMPONENTS OF A BIOGAS SYSTEM

Biogas technology is a complete system in itself with its set objectives (cost effective production of energy and soil nutrients), factors such as microbes, plant design, construction materials, climate, chemical and microbial characteristics of inputs, and the inter-relationships among these factors. Brief discussions on each of these factors or subsystems are presented in this section.

2.3.1 Biogas

This is the mixture of gas produced by methanogenic bacteria while acting upon biodegradable materials in an anaerobic condition. Biogas is mainly composed of 50 to 70 % methane, 30 to 40 % carbon dioxide (CO2) and low amount of other gases as shown in Table 2.1.

Table 2.1: Composition of biogas

Substances	**Symbol**	**Percentage**
Methane	CH_4	0-70
Carbon Dioxide	CO_2	0-40
Hydrogen	H_2	5-10
Nitrogen	N_2	1-2
Water vapour	H_2O	0.3

Biogas is about 20 percent lighter than air and has an ignition temperature in the range of 650 to 750 ˚C. It is an odourless and colourless gas that burns with clear blue flame similar to that of LPG gas. Its calorific value is 20 Mega Joules (MJ) per m^3 and burns with 60 percent efficiency in a conventional biogas stove (Lagrange, B. 1979).

2.3.2 Methanogenic Bacteria/Methanogens

These are the bacteria that act upon organic materials and produce methane and other gases in the process of completing their life-cycle in an anaerobic condition. As living organisms, they tend to prefer certain conditions and are sensitive to micro-climate within the digester. There are many species of methanogens and their characteristics vary. The different methane forming bacteria have many physiological properties in common, but they are heterogeneous in cellular morphology. Some are rods, some cocci, while others occur in clusters of cocci known as sarcine. The family of methanogens (Methanobacteriacea) is divided into following four genera on the basis of cytological differences:

a) Rod-shaped Bacteria
i- Non-sporulating, Methanobacterium
ii- Sporulating, Methanobacillus

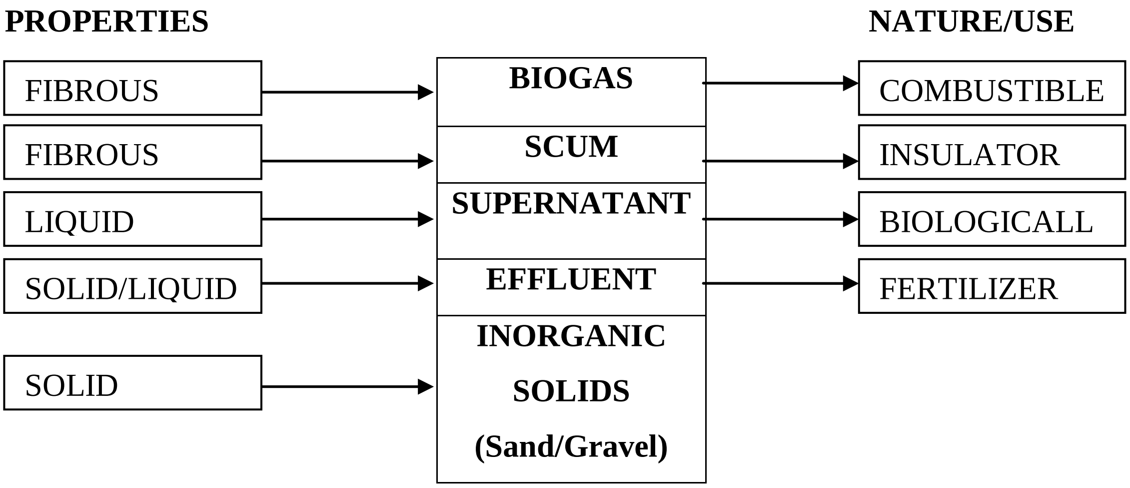
b) Spherical
i- Sarcinae, Methanosarcina
ii- Not in sarcinal groups, Methanococcus

A considerable level of scientific knowledge and skill is required to isolate methanogenic bacteria in pure culture and maintain them in a laboratory. Methanogenic bacteria develop slowly and are sensitive to a sudden change in physical and chemical conditions. For example, a sudden fall in the slurry temperature by even 2°C may significantly affect their growth and gas production rate (Lagrange, B. 1979).

2.3.3 Biodigesters

The biodigester is a physical structure, commonly known as the biogas plant. Since various chemical and microbiological reactions take place in the biodigester, it is also known as bio-reactor or anaerobic reactor. The main function of this structure is to provide anaerobic condition within it. As a chamber, it should be air and water tight. It can be made of various construction materials and in different shape and size. Construction of this structure forms a major part of the investment cost.

Table 2.2: Anaerobic decomposition of organic material in biogas digesters



Source: Lagrange, B. (1979)

Table 2.2 shows the various stages of decomposition and the forms of the material at each stage. The inorganic solids at the bottom of the tank are rocks, sand, gravel, or other items that will not decompose. The effluent is the semisolid material left after the gases have been separated. The supernatant is biologically active liquid in which bacteria are at work breaking down the organic materials. A scum of harder-to-digest fibrous material floats on top of the supernatant. It consists primarily of plant debris. Biogas, a mixture of combustible (burnable) gases, rises to the top of the tank.

The content of biogas varies with the material being decomposed and the environmental conditions involved. When using cattle manure, biogas usually is a mixture of:

Table 2.3: Composition of biogas

Substances	**Symbol**	**Percentage**
Methane	CH_4	54-70
Carbon Dioxide	CO_2	27-45
Hydrogen	H_2	1-10
Nitrogen	N_2	0.5-3
Water vapour	H_2O	0.3
Carbon Monoxide	CO	0-1
Oxygen	O_2	0-1
Hydrogen Sulfide	H_2S	0-1

Source: Lagrange, B. (1979)

The largest, and for fuel purposes the most important, part of biogas is methane. Pure methane is colourless and odourless. Spontaneous ignition of methane occurs when 4-15% of the gas mixes with air having an explosive pressure of between 90 and 104 psi. The explosive pressure shows that biogas is very combustible and must be treated with care like any other kind of gas. Knowledge of this fact is important when planning the design, building, or using of a digester.

2.3.3.1 Types of Digester

There are many types of digesters that commonly use in many countries nowadays. For example, floating roof digester has been invented by Indian and for the fixed roof digester, it has been invented by Chinese.

a) Indian Type Digester

Also known as floating drum digester, the experiment on biogas technology in India began in 1937. In 1956, Jashu Bhai J Patel developed a design of floating drum biogas plant popularly known as Gobar Gas plant. In 1962, Patel's design was approved by the Khadi and Village Industries Commission (KVIC) of India and this design soon became popular in India and the world. In Figure 2.1, the digester chamber is made of brick masonry in cement mortar. A mild steel drum is placed on top of the digester to collect the biogas produced from the digester. Thus, there are two separate structures for gas production and collection. With the introduction of fixed dome Chinese model plant, the floating drum plants became obsolete because of comparatively high investment and maintenance cost along with other design weaknesses. In Nepal, KVIC design plants have not been constructed since 1986 (Lagrange, B., 1979).

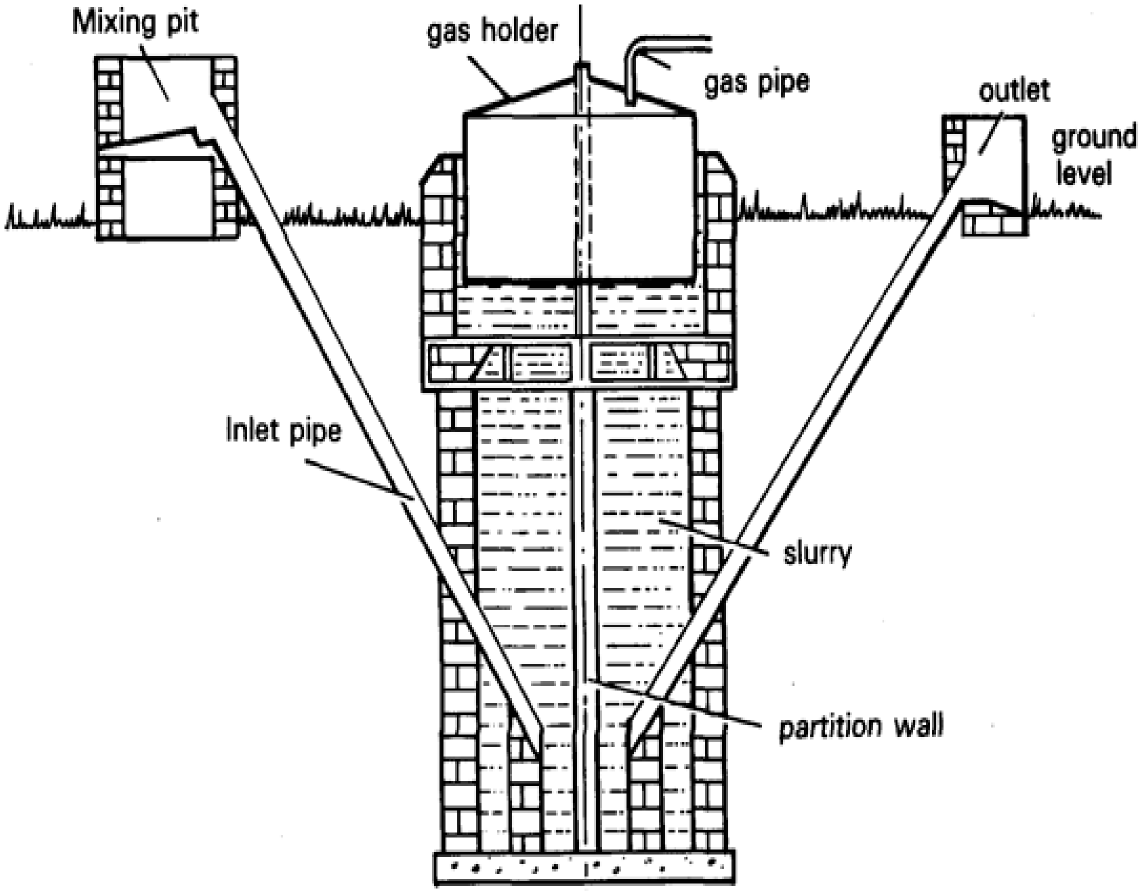


Figure 2.1: Floating roof digester

Source: Lagrange, B. (1979)

The waste is fed into the digester via the inlet pipe and undergoes digestion in the digestion chamber. The temperature of the process is quite critical. Methane producing bacteria operate most efficiently at temperatures between 30 - 40°C or 50 - 60°C and in colder climates heat may have to be added to the chamber to encourage the bacteria to carry out their function. The product is a combination of methane and carbon dioxide, typically in the ratio of 6:4. Digestion time ranges from a couple of weeks to a couple of months depending on the feedstock and the digestion temperature. The residual slurry is removed at the outlet and can be used as a fertilizer (Lagrange, B., 1979).

b) Chinese Type Digester

A fixed dome biogas digester was built in Jiangsu, China as early as 1936, and since then considerable research has been carried out in China on various digester models. The water pressure digester was developed in the 1950s. In one variation, the displaced effluent flows on to the roof of the reactor, enabling the roof to withstand the gas pressure within more easily.

In terms of absolute numbers, the fixed dome is by far the most common digester type in Developing Countries. This reactor as in Figure 2.2 consists of a gas-tight chamber constructed of bricks, stone or poured concrete. Both the top and bottom of the reactor are hemispherical, and are joined together by straight sides. Some new structural Considerations have been published lately. The inside surface is sealed by many thin layers of mortar to make it gas tight, although in the old type digesters gas leakage through the dome was often a major problem. This was changed in the new Chinese type of design. The digester is fed semi-continuously (i.e. once a day), the inlet pipe is straight and ends at mid-level in the digester. There is a manhole plug at the top of the digester to facilitate entrance for cleaning, and the gas outlet pipe exits from the manhole cover.

The gas produced during digestion is stored under the dome and displaces some of the digester contents into the effluent chamber, leading to gas pressures in the dome of between 1 and 1.5 m of water. This creates quite high structural forces and is the reason that the reactor has a hemispherical top and bottom. Construction material and technique is selected at the site (e.g. brickwork, lime-mortar, cement-mortar, concrete cast-in-place, etc.) to keep costs low. A brick dome may be constructed on an umbrella-shaped framework or a concrete cast-in-place digester used (Lagrange, B., 1979).

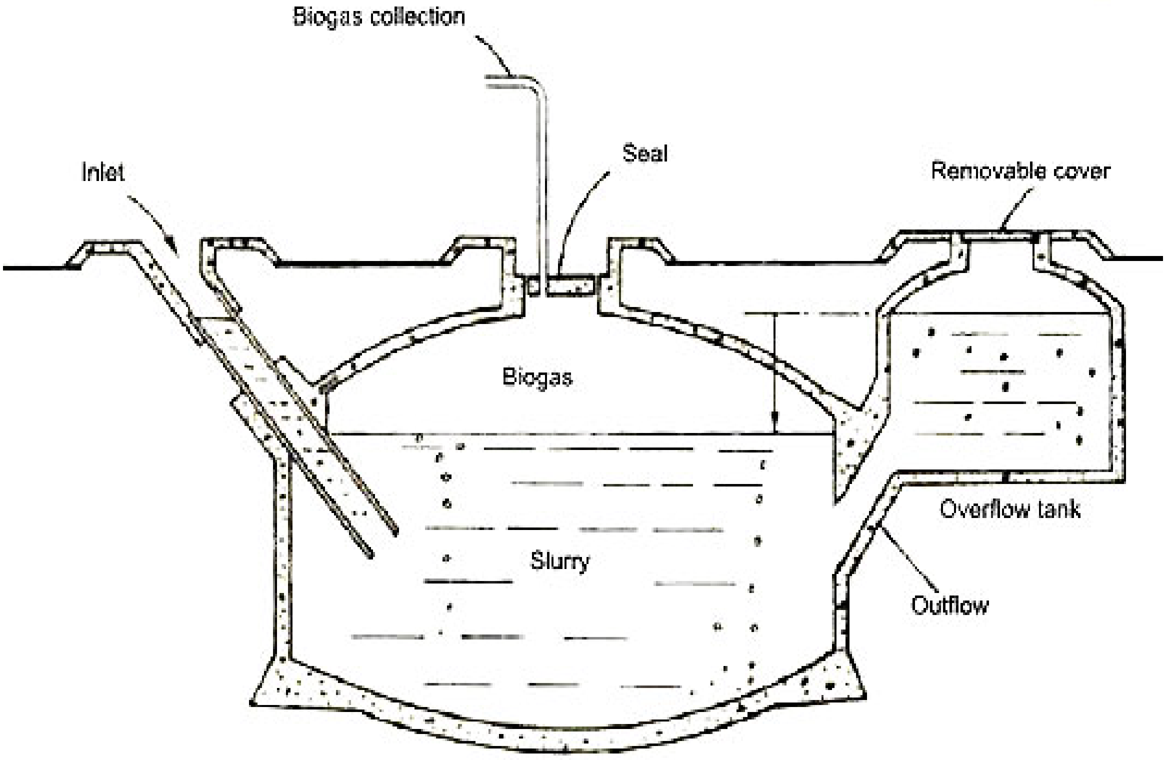


Figure 2.2: Fixed dome digester

Source: Lagrange, B. (1979)

c) Batch Digester

By referring to Figure 2.3, one of the most successful biogas programs using batch systems has been that of Maya Farms in the Philippines. Using a 1:1 dilution of swine manure (12.5% total solids, 10.0% volatile) and a residence time of 30 days at around 30°C, average volumetric efficiencies of around 1.0 % were obtained. This was achieved with seed inoculums of 20% by weight of the total digester slurry, which resulted in maximum gas production rates. By using more than 30 reactors extensively, emptying and recharging one each day, a constant supply of biogas is ensured.

As evident from the description of anaerobic digestion up to now, the "Batch" system is inefficient, but cheap to build.

Considerable interest has been shown in "dry" fermentation, a process which Jewell et al. have worked on for a number of years. They found that fermentation can proceed at total solids concentrations up to 32%. With grass mixed with manure at 25% total solids and 35°C, using a manure inoculums of 30% by weight, they obtained volumetric gas productions of 0.79 l\l\d over 60 days, which increased to around 3.0 l\l\d at 55°C. They concluded that such a reactor would have to be started only once a year. The unloading and use of the digested slurry can therefore be planned in advance.

The stage of development of "dry" fermentation and the process parameters need further work and research. However, even at this stage it appears to be a viable technology, and its gas production rates are competitive with semi-continuously fed reactors (Lagrange, B., 1979).

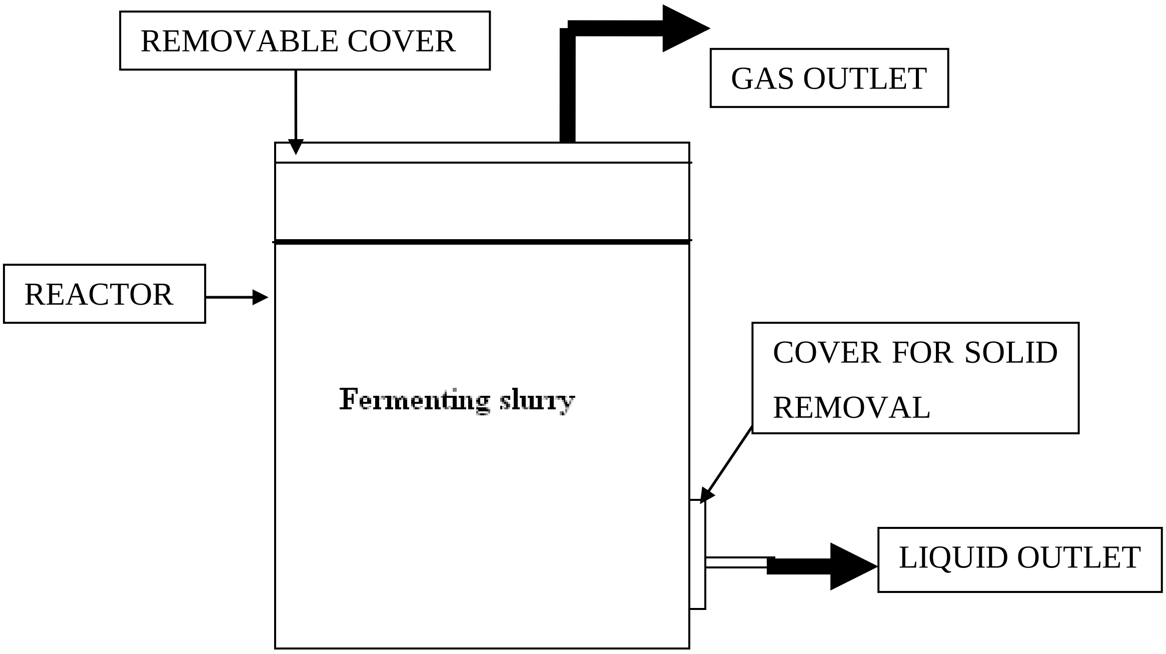


Figure 2.3: Batch digester

d) Bag Digester

The basic design originated in Taiwan, China, in the 1960s, due to problems experienced with brick and metal digesters. The original material used, a Neoprene coated nylon, was expensive and did not weather well. In 1974 a new membrane, RMP, was produced from the residue from aluminium refineries. It was inexpensive and has a life expectancy of up to 20 years. Due to its availability, Polyvinyl Chloride (PVC) is also starting to be used extensively, especially in Central America. The membrane digester is extremely light (e.g. a 50 m^3 digester weighs 270 kg), and can be installed easily by excavating a shallow trench, slightly deeper than the radius of the digester.

The Taiwanese evolved the bag digester as in Figure 2.4 primarily to treat swine manure, which is also the most common substrate in Korea and Fiji. Due to its low cost and excellent durability, the Chinese have also started producing these digesters, and claim that the cost is as low as \$25 to \$30 per m^3. Depending on the availability of the plastic, a rapid expansion in the use of bag digesters is expected in China, and in time it may replace the fixed dome as the preferred type in China.

Typical retention times in bag digesters, for swine waste, vary from 60 days at 15° -20°C, to 20 days at 30° - 35°C. One advantage of the bag is that its walls are thin, so the digester contents can be heated easily if an external heat source, such as the sun, is available. The Chinese have found that average temperatures in bag digesters, compared with dome types, are 2° - 7°C higher. Hence specific yields can be from 50 - 300% higher in the bag (0.235 - 0.61 volumes of gas per volume of digester per day). Park et al. also found this to be true in Korea, and obtained specific yields varying from 0.14 in winter (8°C) to 0.7 in summer (32°C) for swine manure.

The RMP or semi-plastic digesters in China are commonly batch type digesters. They are filled with straw and manure and operated for 6 - 8 months. Discharging is easy because the RMP gas-holder can simply be removed. Even when cracks in the wall occur, it does not affect gas production. The film is fixed with bricks in a water jacket and seals the digester completely. The RMP material is also used as a gas barrier, for pipes and hoses and for many other applications outside the biogas sector. At present there are about 50,000 RMP digesters of over 10 m^3 operating in China (Lagrange, B., 1979).

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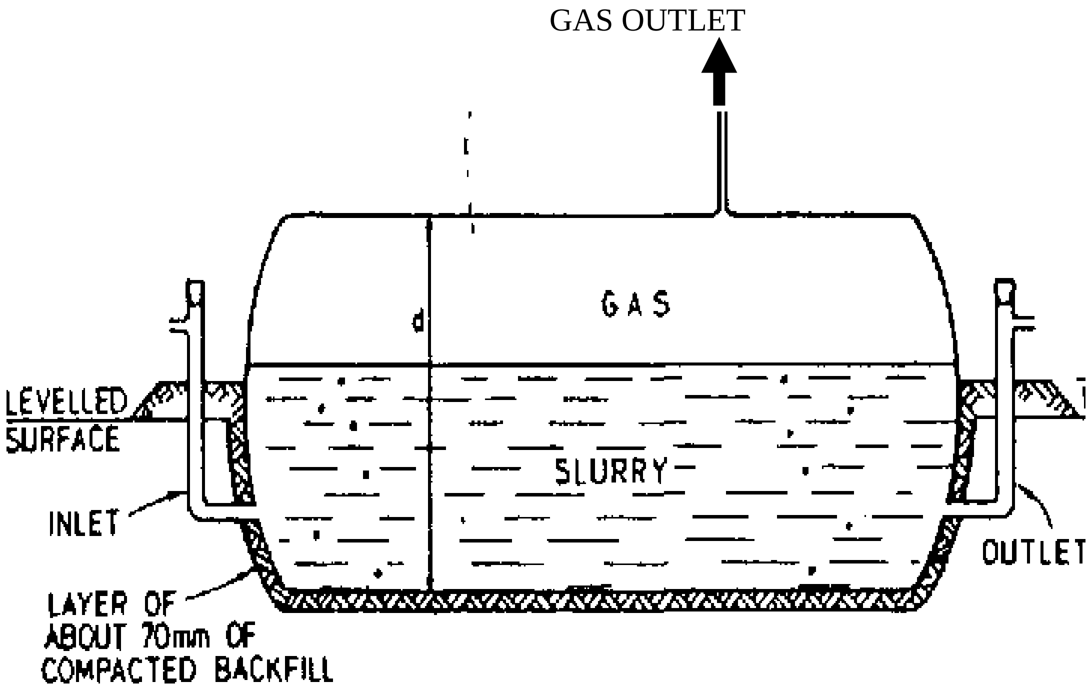


Figure 2.4: Bag digester

Source: Lagrange, B. (1979)

e) Plug Flow Digester

The plug flow digester is similar to the bag digester. It consists of a trench (trench length has to be considerably greater than the width and depth) lined with concrete or an impermeable membrane. The reactor is covered with either a flexible cover gas holder anchored to the ground, concrete or galvanized iron (GI) top. The first documented use of this type of design was in South Africa in 1957. A typical plug flow reactor consists of a trench lined with either concrete or an impermeable membrane (see Figure 2.5). To ensure true plug flow conditions, the length has to be considerably greater than the width and depth. The reactor is covered with either a flexible cover gas holder, anchored to the ground, or with a concrete or galvanized iron top. In the latter type, a gas storage vessel is required. The inlet and outlet to the reactor are at opposite ends, and feeding is carried out "semi-continuously, with the feed displacing an equal amount of effluent at the other end (Lagrange, B., 1979)

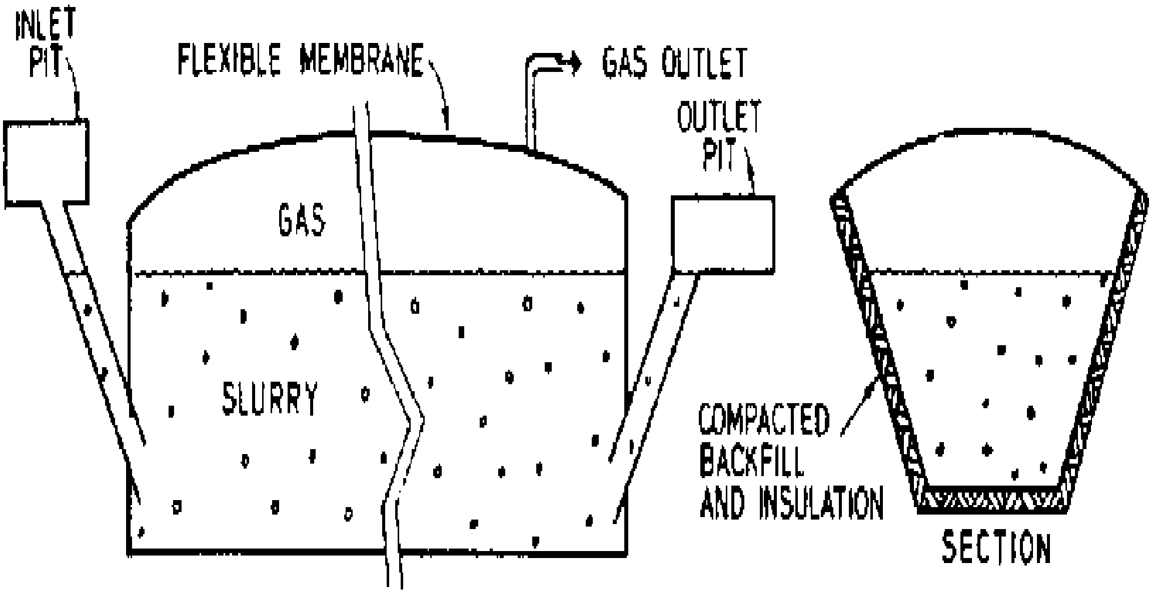


Figure 2.5: Plug flow digester

Source: Lagrange, B. (1979)

f) Anaerobic Filter

This type of digester as in Figure 2.6 was developed in the 1950's to use relatively dilute and soluble waste water with low level of suspended solids. It is one of the earliest and simplest type of design developed to reduce the reactor volume. It consists of a column filled with a packing medium. A great variety of non-biodegradable materials have been used as packing media for anaerobic filter reactors such as stones, plastic, coral, mussel shells, reeds, and bamboo rings. The methane forming bacteria form a film on the large surface of the packing medium and are not carried out of the digester with the effluent. For this reason, these reactors are also known as "fixed film" or "retained film" digesters (Lagrange, B., 1979).

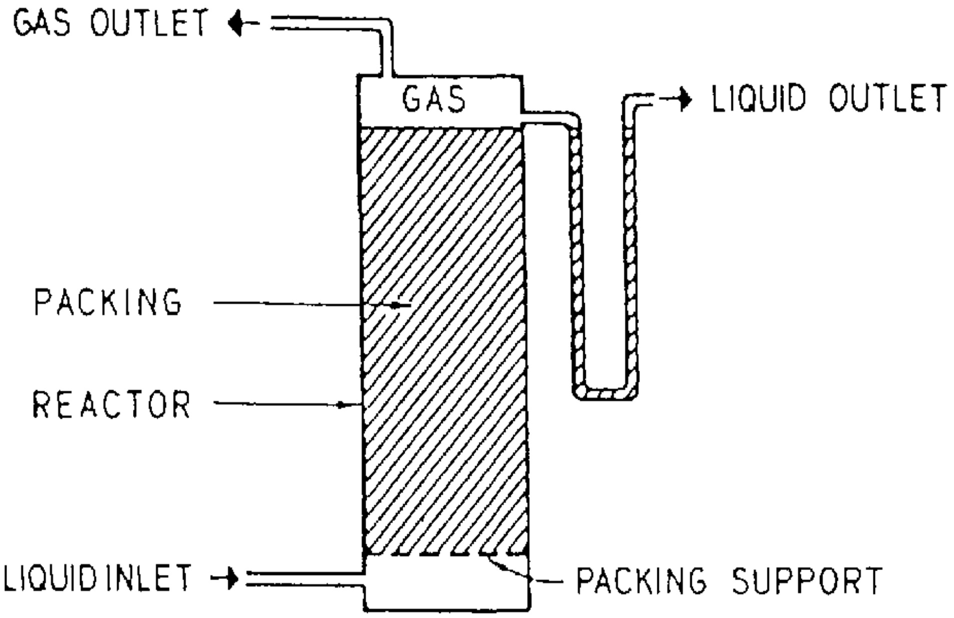


Figure 2.6: Anaerobic filter

Source: Lagrange, B. (1979)

g) Upflow Anaerobic Sludge Blanket

This UASB design was developed in 1980 in the Netherlands. It is similar to the anaerobic filter in that it involves a high concentration of immobilized bacteria in the reactor. However, the UASB reactors contain no packing medium, instead, the methane forming bacteria are concentrated in the dense granules of sludge blanket which covers the lower part of the reactor. The feed liquid enters from the bottom of the reactor and biogas is produced while liquid flows up through the sludge blanket. Many full-scale UASB plants are in operation in Europe using waste water from sugar beet processing and other dilute wastes that contain mainly soluble carbohydrates. Such reactor has not been experimented in Nepal. There are also other designs of anaerobic reactors which are of less interest in the context of Nepal due to their limited utility. Reduction in investment cost using alternative construction materials has been one of the main driving forces in the development of new designs. In an effort to achieve this objective, use of bamboo, plastics and other such cheap construction materials have also been tried with varying degree of success. However, all such reported success stories are yet to take the form of implementation programmes in a mass scale (Trujillo D, Perez JF, Cerebros FJ.1993).

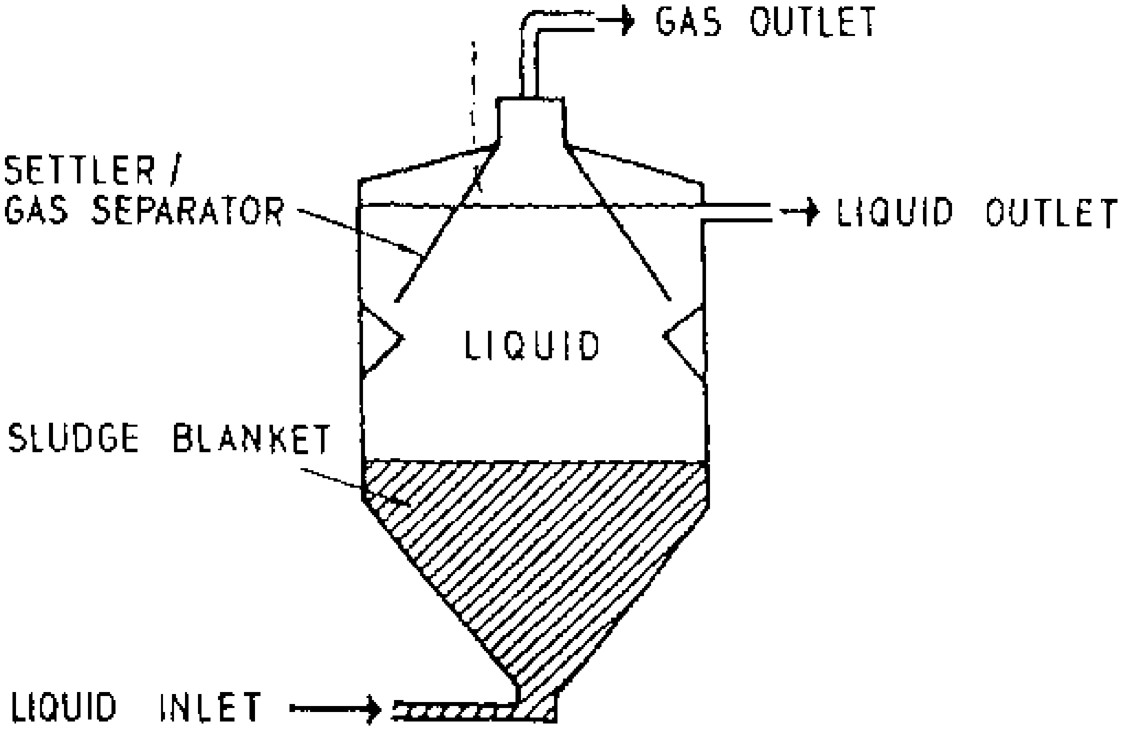


Figure 2.7: Upflow anaerobic sludge blanket

Source: Trujillo D, Perez JF, Cerebros FJ (1993)

By referring to the previous types of digesters, the Indian type digester is the one which will produce constant pressure of biogas due to the uses of floating roof.

2.4 INDIAN TYPE DIGESTER

In India, the history of biogas technology has developed since 1937. In 1950, Patel designed a plant with a floating gas holder which caused renewed interest in biogas in India. The Khadi and Village Industries Commission (KVIC) of Bombay began using the Patel model biogas plant in a planned program in 1962, and since then it has made a number of improvements in the design.

The Floating Dome digester is disseminated by KVIC and workshops recognized by KVIC. Those most commonly constructed are of 6 and 8 m^3 gas production capacity. The digester is designed for 30, 40 and 55 days' retention time: the lowest time applies to the hot southern States, the highest to the cooler northern States. Construction costs vary according to ambient temperatures, for which partial compensation is allowed for by subsidies. The main material fed is cattle manure. At community plant level, nightsoil is digested in a mixture with cattle dung, and at large farm level other types are being introduced, to digest materials such as water hyacinth. The drum was originally made of mild steel, until fiberglass reinforced plastic (FRP) was introduced successfully, to overcome the problem of corrosion. Nearly all new digesters are equipped with FRP gas-holders.

The cost of a mild steel gas-holder is approximately 40-50% of the total cost of the plant. FRP gas-holders are 5 - 10% more expensive than the steel drum.

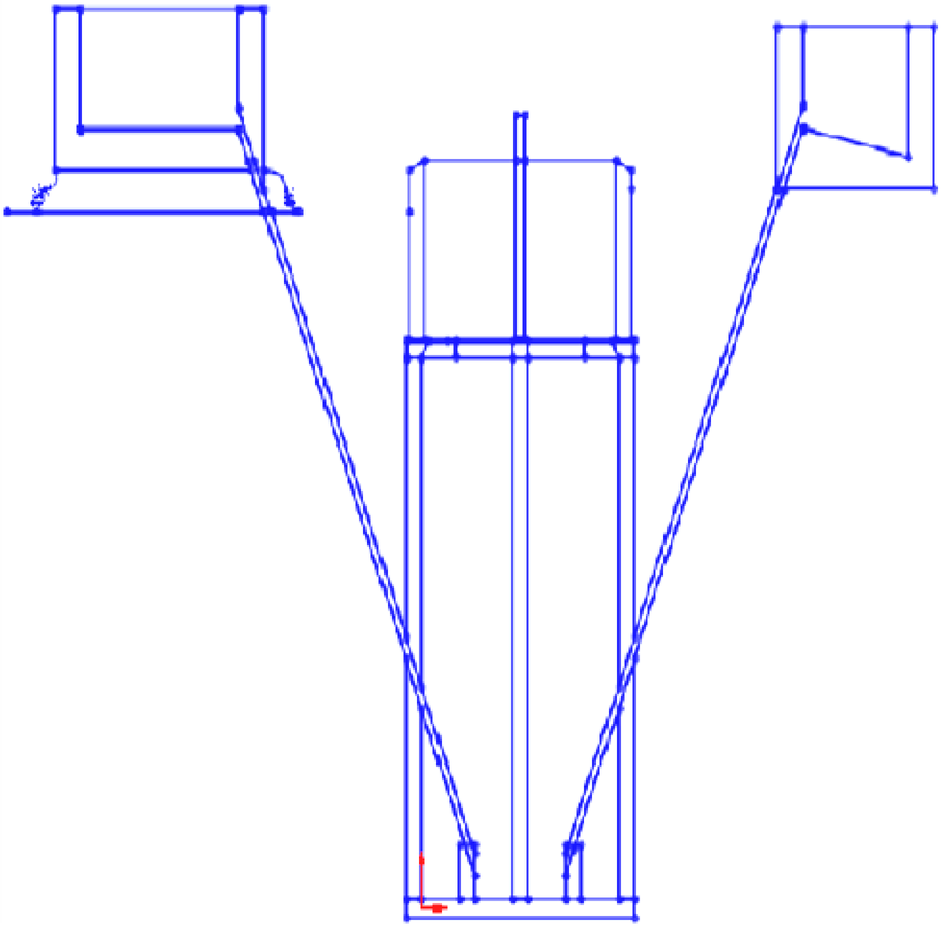


Figure 2.8: 2-cubic meter digester (SolidWorks drawing)

The figure shows the rough sketched of the 2-cubic meter of biogas digester. The digester is Indian type which is using floating roof. The floating roof can produces constant pressure of biogas that then will be used to generate the internal combustion engine (ICE). The design presented here is most useful for temperate or tropical climates. It is a 2-cubic meter plant that requires the equivalent of the daily wastes of four-six cattle.

This digester is a continuous-feed (displacement) digester. Relatively small amounts of slurry (a mixture of manure and water) are added daily so that gas and fertilizer are produced continuously and predictably. The amount of manure fed daily into this digester is determined by the volume of the digester itself, divided over a period of 30-40 days. Thirty days is chosen as the minimum amount of time for sufficient bacterial action to take place to produce biogas and to destroy many of the toxic pathogens found in human wastes.

2.4.1 Problems

Problems on dimension, feeding and construction occurred regarding designing and fabricating this biogas digester.

a) Dimension

The design must meet the mass flow rate of the biogas which is 94.1536e-9 kg/s. It is hard to calculate or find the right dimension which can produce the amount of required mass flow rate. This digester will produces biogas that then will be used to run the ICE. As for decision, 2-cubic meter digester is used as for reference.

b) Feeding

The design of the digester needs manual pouring of manure. To feed the digester, there are many ways including by piston, which is manually handled by manpower, electric motor pump, extruder, and so on. The pressure inside the digester assumed to be very high and it is hard to force by hand. So, the design of the digester is modified to meet the ease of use.

c) Construction

The construction of this type of digester is costly as it uses floating roof type. This roof is made of mild steel which the cost is nearly 60 percent of the total construction. It is very important to find the right contractor which can give lowest price to construct the digester in terms of materials cost (Deshpande CV, Satyanarayan S, Kaul SN.,1998).

CHAPTER 3

DIGESTER DESIGN

3.1 INTRODUCTION

Biogas digester is a physical structure, commonly known as the biogas plant. Since various chemical and microbiological reactions take place in the digester, it is also known as bio-reactor or anaerobic reactor. The main function of this structure is to provide anaerobic condition within it. As a chamber, it should be air and water tight. It can be made of various construction materials and in different shape and size (Lagrange, B., 1979).

The different size of digester will affect the volume of the produced biogas itself. The input mass flow rate of the gas that needs to run the ICE is the output of the biogas from digester.

The design of the digester is focussing on 2-cubic meter as it will produce the closest value of mass flow rate of biogas compared to other different volume of digester. Designing the digester is using SolidWorks software which the size of the cap holder is 2-cubic meter.

3.2 PLANT DESIGN

3.2.1 Preconstruction Considerations

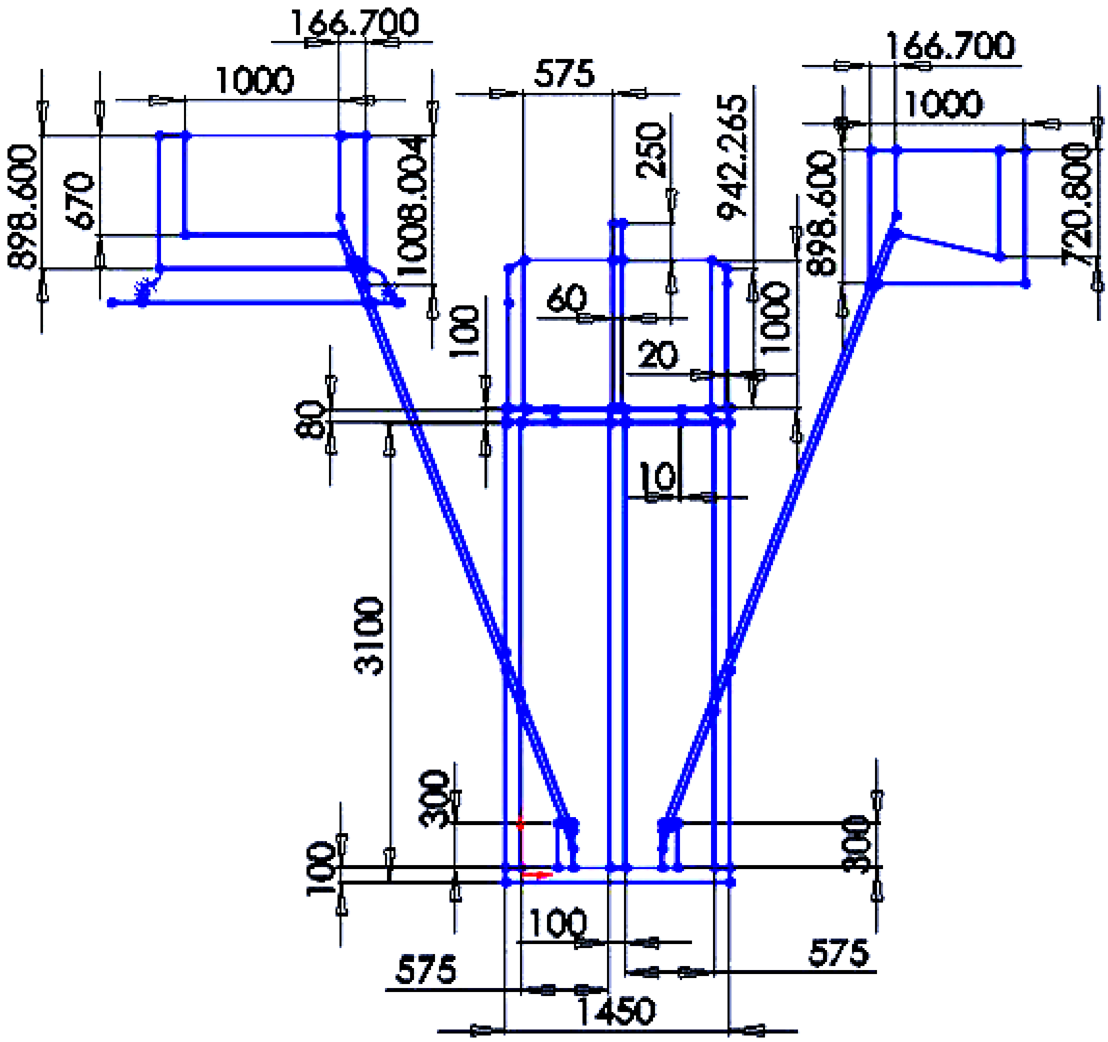


Figure 3.1: 2-cubic meter digester (SolidWorks drawing)

The design is most useful for temperate or tropical climates. It is a 2-cubic meter plant that requires the equivalent of the daily wastes of four-six cattle. This digester is a continuous-feed (displacement) digester. Relatively small amounts of slurry (a mixture of manure and water) are added daily so that gas and fertilizer are produced continuously and predictably. The amount of manure fed daily into this digester is determined by the volume of the digester itself, divided over a period of 12-14 days.

Twelve days is chosen as the minimum amount of time for sufficient bacterial action to take place to produce biogas and to destroy many of the toxic pathogens.

The reactor is fed semi-continuously through an inlet pipe, and displaces an equal amount of slurry through an outlet pipe. When the reactor has a high height, diameter ratio, a central baffle is included to prevent short circuiting.

Most of the KVIC type digesters are operated at ambient temperatures, so that retention times depend on local variations. Typical retention times are 30 - 40 days in warm climates, such as Southern India, where ambient temperatures vary from 20° - 40°C, 40 - 50 days in moderate climates, such as the Central and Plains areas of India, where minimum temperatures go down to 5°C, and 50 - 80 days in cold climates, such as the hilly areas of Northern India, where minimum temperatures go below 0°C.

Typical feedstock is cattle dung, although substrates such as agricultural residues, night soil and aquatic plants have been used. Cattle manure, generally about 20% solids, is diluted to 10% total solids before feeding, by adding an equal quantity of water. The daily average gas yield varies from 0.20 to 0.60 volume of gas per volume of digester ratio in cold to warm climates (Brush, B.S., Taylor, J.E., 1992).

3.2.2 Sizing of Digester

Designing a properly sized digester to obtain the maximum biogas production per unit of reactor volume is important in maintaining low capital construction costs. The digester should be sized to achieve desired performance goals in both winter and summer, and must be large enough to avoid “washout.”

Design goals could be maximal gas production with minimal capital investment, achieving pollution control and reduction of pathogens, or simply the production of a reasonable amount of gas with a minimum of operational attention. The uses of the slurry after the digestion process is a critical consideration since the main income to the plant can come from that material. The differences in uses also determine the digestion retention time. Criteria must be established, prior to design, since not all goals can necessarily be achieved with a single design.

Table 3.1 shows the comparison between gas plant type and estimated specifications. The design of the 2-cubic meter of gas plant type was chosen because it gives the closest value of mass flow rate that will run the internal combustion engine.

Table 3.1: Measurements for a number of simple gas plant

Gas Plant Type (Model)	No. Of Animals	1:1 Water and Dung Per Day (kg)	Volume of Well for 42 Days Digesting (m^3)	Size of Well Dia. and Depth (m)	Size of Gas Cap Dia. and Height (m)	G.I Sheet for Gas Cap (m^2)	No. of Bricks	No. of Bags Cement (50kg)	Qty. of Sand (m^3)	Gas Produced Per Day (m^3)	Sun Dried Fertilizer Produced Per Day (kg)
2 m^3	4	80	3.5	1.25x3	1.15x1	4.5	2800	22	9	2	4-8
3 m^3	6	120	5	1.5x3.4	1.4x1.25	9	3200	25	12	3	6-12
4 m^3	8	160	7	1.5x4	1.5x1.5	9	4000	28	12	4	8-16
5 m^3	10	200	8.5	1.7x3.5	1.6x1.5	10.5	4000	30	14	5	10-20
7.5 m^3	15	300	13	2x4	1.9x1.5	12.6	5200	32	16	7.5	15-30
10 m^3	20	400	17	2.2x4.3	2.1x1.5	14.3	6400	35	18	10	20-40

Source: Satyanarayan S. (1977)

3.2.3 Digester Feedstocks

The physical and chemical state of a material feedstock used for anaerobic digestion is initially determined by its source. The feedstock may be a clear liquid, a suspension of solids in a liquid, or a "solid" - a material with less than 70 - 80% water content. Various digester systems have been designed to treat these physically different forms of feedstock. Sometimes physical and chemical problems may be solved by modifying the feed. These modifications may allow the original type of digester to be used, or they may be such that a different type is needed (Satyanarayan S., 1977).

3.3 MATERIALS

a) Baked bricks, approximately 2800
b) Cement, 22 bags (for foundation and wall covering)
c) Sand, 12 cubic meters
d) Clay or metal pipe, 20cm diameter, 10 meters
e) Copper wire screening (25cm x 10 meters)
f) Rubber or plastic hose
g) Gas outlet pipe, 3cm diameter
h) Pipe, 7.5cm diameter 1.25 meters (gas cap guide)
i) Pipe, 7cm diameter, 2.5 meters (center guide)
j) Mild steel sheeting, 32mm to 1.63mm, 1.25 meters x 9 meters long
k) Mild steel rods, approximately 30 meters (for bracing)
l) Waterproof coating (paint, tar, asphalt, etc), 4 liters (for gas cap) (Satyanarayan S., 1977).

3.4 CONSTRUCTION

3.4.1 Prepare Foundation and Walls

a) Dig a pit 1.5 meters in diameter to a depth of 3.4 meters.
b) Line the floor and walls of the pit with baked bricks and bound it with lime mortar or clay. Any porousness in the construction is soon blocked with the manure/water mixture.
c) Make a ledge or cornice at two-thirds the height (226cm) of the pit from the bottom. The ledge should be about 15cm wide for the gas cap to rest on when it is empty.
d) Extend the brickwork 30-40cm above ground level to bring the total depth of the pit to approximately 4 meters.
e) Make the input and output piping for the slurry from ordinary 20cm clay drainpipe. Use straight input piping. If the pipe is curved, sticks and stones dropped in by playful children may jam at the bend and cannot be removed without emptying the whole pit. With straight piping, such objects can fall right

through or can be pushed out with a piece of bamboo.

f) Have one end of the input piping 90cm above ground level and the other end 70cm above the bottom of the pit.

g) Have one end of the output piping 40cm above the bottom of the pit opposite the input pipe and the other end at ground level.

h) Put an iron or wire strainer (copper screening) with 0.5cm holes at the upper end of the input and the output pipes to keep out large particles of foreign matter from the pit.

i) Construct a center wall that divides the pit into two equal compartments. Build the wall to a height two-thirds from the bottom of the digester (226cm). Build the gas cap guide in the center top of the wall by placing vertically a 7cm X 2.5 meters long piece of metal piping.

j) Provide additional support for the pipe by fabricating a cross brace made from mild steel (Satyanarayan S., 1977).

3.4.2 Prepare the Gas Cap Drum

a) Form the gas cap drum from mild steel sheeting or galvanized iron sheeting of any thickness from .327mm to 1.63mm.

b) Make the height of the drum approximately one-third the depth of the pit (1.25-1.5 meters).

c) Make the diameter of the drum 10cm less than that of the pit (1.4 meters diameter).

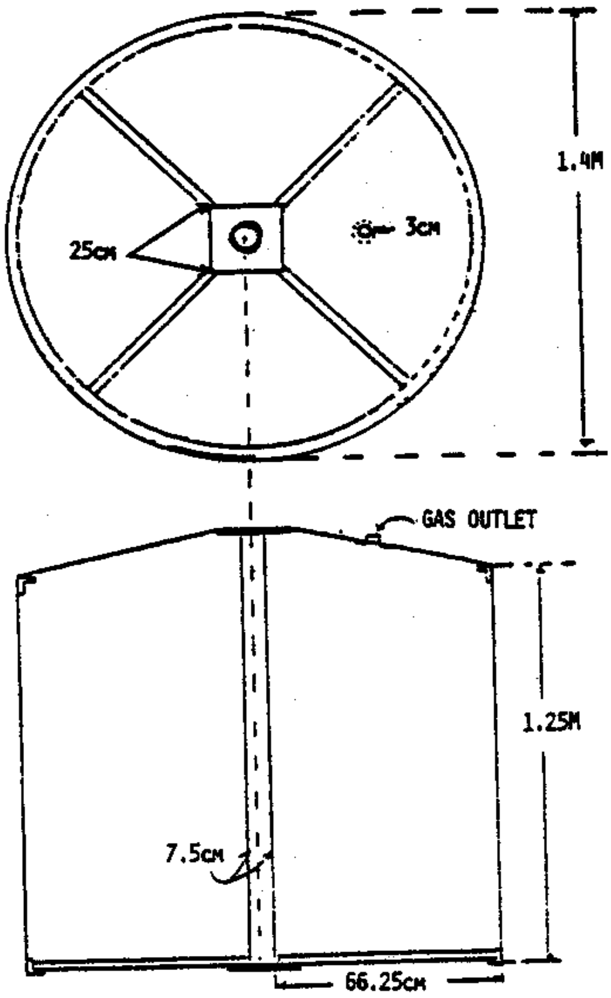


Figure 3.2: Biogas plant cap

Source: Satyanarayan S. (1977)

d) Using a flange, attach a 7.5cm pipe to the inside top center.

e) Fix the lower end of the pipe firmly in place with thin, iron tie rods or angle iron. The cap now looks like a hollow drum with a pipe, firmly fixed, running through the center.

f) Cut a 3cm diameter hole, as shown in Figure 5, in the top of the gas cap.

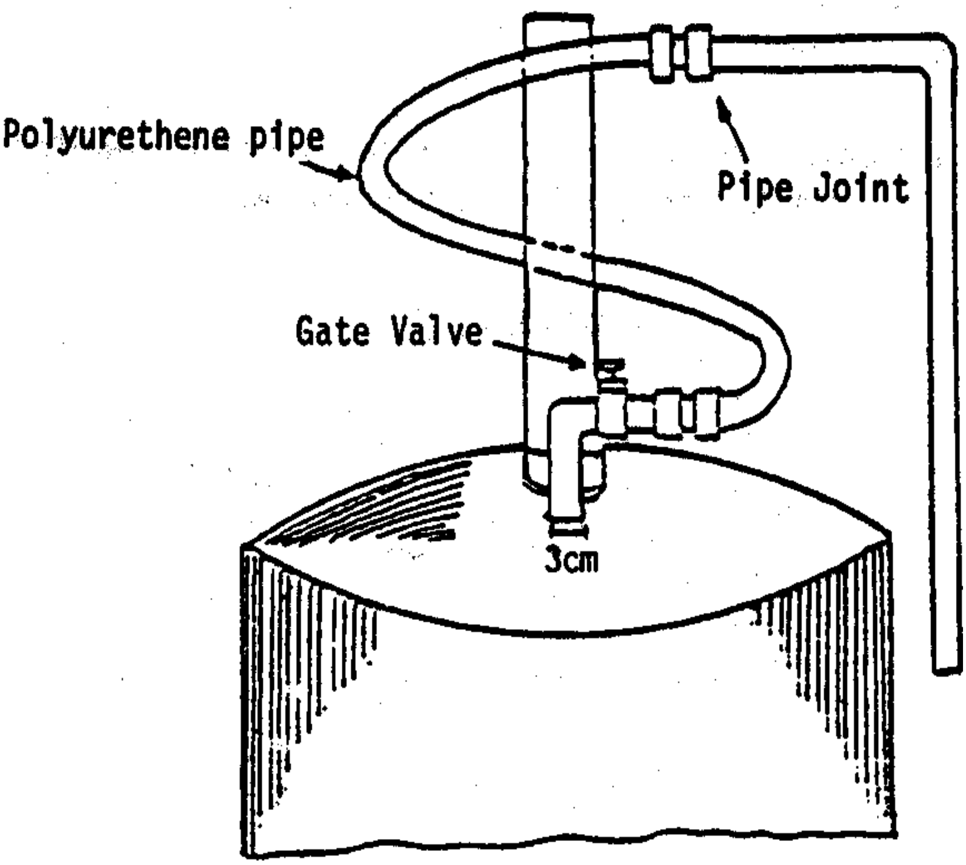


Figure 3.3: Piping on gas cap

Source: Satyanarayan S. (1977)

g) Weld a 3cm diameter pipe over the hole.

h) Fix a rubber or plastic hose long enough to allow the drum to rise and fall to the welded gas outlet pipe. A valve may be fixed at the joint as shown.

i) Paint the outside and inside of the drum with a coat of paint or tar.

j) Make sure the drum is airtight. One way to check this is to fill it with water and watch for leaks.

k) Turn the gas cap drum so that the outlet pipe is on top and slip the 7.5cm pipe fixed in the gas cap over the 7cm pipe fixed in the center wall of the pit. When empty, the drum will rest on the15cm ledges built on either side. As gas is produced and the drum empties and fills, it will move15cm ledges built on either side. As gas is produced and the drum empties and fills, it will move

l) Attach handles to either side of the drum. These don't have to be fancy, but they will prove very helpful for lifting the drum off and for turning the drum.

m) Weld a 10cm wide metal strip to each of the tie rod supports in a vertical position. These "teeth" will act as stirrers. By grasping the handles and rotating the drum it is possible to break up troublesome scum that forms on the slurry and tends to harden and prevent the passage of gas (Satyanarayan S., 1977).

3.4.3 Prepare Moisture Trap

Place a jar of water outside the pit and put into it the end of a downward projection of the gas pipe at least 20cm long. Any moisture condensing in the pipe flows into the jar instead of collecting in the pipe and obstructing the passage of gas. Water then overflows and is lost in the ground. Remember to keep the jar full or the gas will escape. An ordinary tap when opened lets the water escape. Whether using the water jar or tap, do not let the length be greater than 30cm below ground level or it becomes too difficult to reach (Satyanarayan S., 1977).

3.4.4 Prepare the Mixing and Effluent Tanks

Build or improvise a mixing tank to be placed near the outside opening of the inlet pipe. Likewise, provide a container at the outlet to catch the effluent. Some provision may also be made for drying the effluent as the plant goes into full production (Satyanarayan S., 1977).

3.5 OPERATIONS

In order to start up the new digester, it is necessary to have 2 cubic meters (3000kg) of manure. In addition, approximately 15kg of "seeder" is required to get the bacteriological process started. The "seeder" can come from several sources:

a) Spent slurry from another gas plant.
b) Sludge or overflow water from a septic tank.
c) Horse or pig manure, both rich in bacteria.

d) A 1:1 mixture of cow manure and water that has been allowed to ferment for two weeks.

Put the manure and "seeder" and an equal amount of water into the mixing tank. Stir it into a thick liquid called a slurry. A good slurry is one in which the manure is broken up thoroughly to make a smooth, even mixture having the consistency of thin cream. If the slurry is too thin, the solid matter separates and falls to the bottom instead of remaining in suspension; if it is too thick, the gas cannot rise freely to the surface. In either case the output of gas is less.

When filling the pit for the first time, pour the slurry equally into both halves to balance the pressure on the thin inner wall, or it may collapse. Mix 60kg fresh manure with 60kg water and add it to the tank every day.

The advantage of this model is that since the daily flow of slurry goes up the first side, where the insoluble matter rises, and down the second, where this matter naturally tends to fall, the outgoing slurry daily draws out with it any sludge found at the bottom. Thus having to clean out the pit becomes a comparatively rare necessity. Sand and gravel may build up on the bottom of the digester and will have to be cleaned from time to time depending location.

It can take four to six weeks from the time the digester is fully loaded before enough gas is produced and the gas plant becomes fully operational. The first drumful of gas will probably contain so much carbon dioxide that it will not burn. On the other hand, it may contain methane and air in the right proportion to explode if ignited. Empty the gas cap and let the drum fill again. At this point the gas is safe to use (Wate SR.,1982).

3.6 LAB SIZE DIGESTER-DESIGN AND FABRICATION PROCESS

A 200 litres water barrel has been used in order to replace the 2-cubic meter digester. The digester consists of inlet and outlet piping which was made of PVC and the gas cap which is floating roof type was made of zinc. The partition wall will circulate the slurry to the outlet piping as the new cow dung will be poured daily was made of aluminium.

Figure 3.4: 200 litres water barrel

3.6.1 Fabrication Process

The fabrication process begins with cutting out the top surface of the barrel approximately 0.865m (length) from the bottom of the barrel with using grinding machine. To make the inlet and outlet hole that will fit with PVC socket, the barrel will be drilled first before continuing with grinding process so that 4" diameter hole can be made. The centre of the hole to the bottom surface of the barrel is 5".

Figure 3.5: One of the two 4" hole

A 58cm x 53cm x 4cm partition wall is made of aluminium and the process involves cutting the sheet metal by using shear cutting machine and bending machine. To tie up the wall to the barrel together, blind rivets have been used. Although it will leaves gap between the wall and the barrel, fibreglass compound and silicone were used in order to seal the gap.

Figure 3.6: Fabricating a partition wall

Figure 3.7: Welding process

The next step is fabricating a 0.89m³ gas cap which was made of zinc. A rectangular 185cm x 33cm zinc sheet metal was bent to a circular shape and metal inert gas (MIG) welding machine is used to weld it. The same material then is cut into circular shape which will be used as a top cover and welded together to form a gas cap. The centre of the gas cap cover then is drilled by using ½" hole saw and ½" PVC pipe and hose adapter are then attached to the hole. There is also ½” ball valve that is placed between the hose adapter and the gas cap surface.

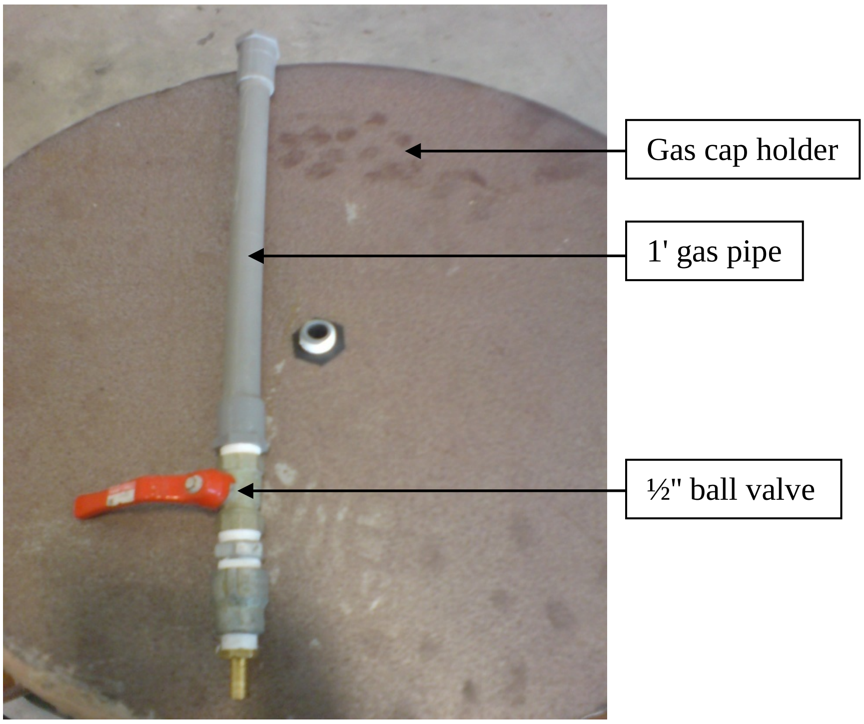


Figure 3.8: Gas cap holder and gas pipe

To form an inlet and outlet piping system, two pieces of 3' x 4" PVC pipe was used with 4" x 90˚ elbow socket and also 4" x 45˚ elbow socket. The 90˚ elbow is used for the inlet pipe while 45˚ elbow is used for the outlet. A PVC gum then is used to attach the connection between the elbow and the PVC pipe.

Figure 3.9: PVC elbow and glue

As for the last step in fabrication process, the gas cap is sprayed with antirust colour that will prevent from rust because the digester will be leaved outside the lab under sunshine. The digester then is ready to be poured with cow dung and also water and it will be leaved for fermentation process.

Figure 3.10: Spraying process with anti-rust

Figure 3.11: Pouring cow dung

Figure 3.12: Leaved for fermentation process

CHAPTER 4

RESULTS AND DISCUSSION

4.1 ESTIMATED RESULTS

There are problems occurred regarding collecting data for the biogas as the slurry will took 12-14 days to be fermented and only one digester that has been used. Besides, monsoon season nowadays will effects the growth of bacteria as it will decrease the ambient temperature.

Table 4.1 shows the estimated results for gas production as the use of various types of dung.

Table 4.1: Estimated results for various types of dung

Types of Dung	**Gas Production Per Kg Dung (m^3)**
Cattle (cows and buffaloes)	0.023-0.040
Pig	0.040-0.059
Poultry (Chickens)	0.065-0.116
Human	0.020-0.028

Source: Zhao, X.H. (1985)

Figure 4.1 shows that for a given capacity, a digester under controlled temperature provides a significantly larger biogas production compared to a digester without controlled temperature.

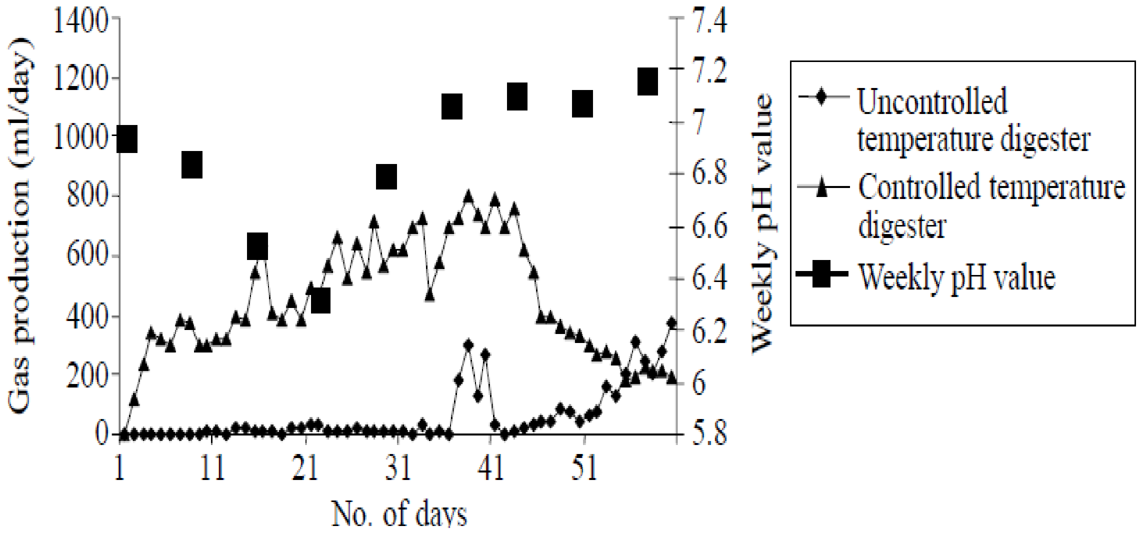


Figure 4.1: Effect of pH value and temperature on biogas production

Source: Zhao, X.H. (1985)

4.2 DISCUSSION

A critical analysis of literature reveals that there is a strong possibility to enhance the biogas production under field conditions. Use of certain inorganic, organic additives seems to be promising for enhancing biogas production. Among different types of biomass (plant and crop residues) used as additives, some have been found to enhance the gas production manifolds. Besides, by stirring the mixture and increasing the surrounding temperature can effected the growth and activeness of the bacteria that acts upon the slurry. Different types of dung will give different volume of produced biogas itself.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

For the conclusion, the project to design and fabricate a biogas digester which refers to Indian type was achieves the objectives successfully. Biogas technology has significant potential to mitigate several problems related to ecological imbalance, minimizing crucial fuel demand, improving hygiene and health, and thus, resulting in an overall improvement in the quality of life in rural and semi-urban areas.

Biogas obtained by anaerobic digestion is a type of bacterial degradation of organic matter that occurs in the absence of oxygen and produces primarily, methane and carbon dioxide. It is evident from the above discussion that efficiency of anaerobic digestion essentially depends on intensity of bacterial activity, which is influenced by several factors such as ambient temperature, temperature of digester material, loading rate, hydraulic retention time, pH value of digester content etc. Therefore, for efficient performance of a biogas plant, it is necessary to regulate all the above factors suitably. The rate of biogas production also depends on the ambient temperature of a particular region.

This project has achieved the objective which was to design a biogas digester which refers to Indian type digester that will produce specific amount of flow rate and at the same time fabricated a lab size digester.

5.2 FUTURE WORK

The produced biogas will be used to run the diesel engine and the digester can be improved by using metal barrel as it can be welded to prevent from leaking. The enhancement of produced biogas can be done by adding different type of additives. Practical aspect of using pure microbial culture as additives should be looked into, in view of certain problems especially human health and ecodynamics. Further techno-economics of using additives on daily basis needs to be worked out by further extensive experimentation at field level.

Recirculation of effluent slurry on daily basis and stirring of the digester's contents by using simple techniques for enhancing biogas production seems to be quite viable under rural conditions. Keeping various parameters within the desired range also improves gas production but the practical difficulty lies in maintaining and monitoring these regularly.

It is a crucial point which needs due consideration since a slight change in pH or temperature could otherwise result in reduction of gas production. Similarly formation of volatile fatty acids beyond a particular range hinders the methane production. Loading rate and solid concentration should be properly balanced and continuously maintained.

REFERENCES

This thesis is prepared based on the following references;

Adeoti, O., Ilori, M.O., Oyebisi, T.O., Adekoya, L.O., 2000. Engineering design and economic evaluation of a family-sized biogas project in Nigeria. Technovation 20, 103–108.

Brush, B.S., Taylor, J.E., 1992. Technology adoption and biological diversity in Andean potato agriculture. Journal of Development Economics 39, 365–387.

Deshpande CV, Satyanarayan S, Kaul SN. Bioenergy production through biomethanation—a new approach. Encology 1998;12(3):23–8.

Lagrange, B. (1979) "Biomethane 2: Principles - Techniques Utilization". EDISUD, La Calade, 13100 Aix-en-Provence, France.

Patel, V., Madamwar, D., 1994. Anaerobic digestion of a mixture of cheese whey, poultry waste and cattle dung: a study of the use of adsorbents to improve digester performance.Environ. Pollut.86(3), 337–340.

Satyanarayan S. Performance of lab digesters receiving mixed feed of cattle dung and night soil. National Environmental Engineering Research Institute (NEERI) internal report, Nagpur, India, 1977.

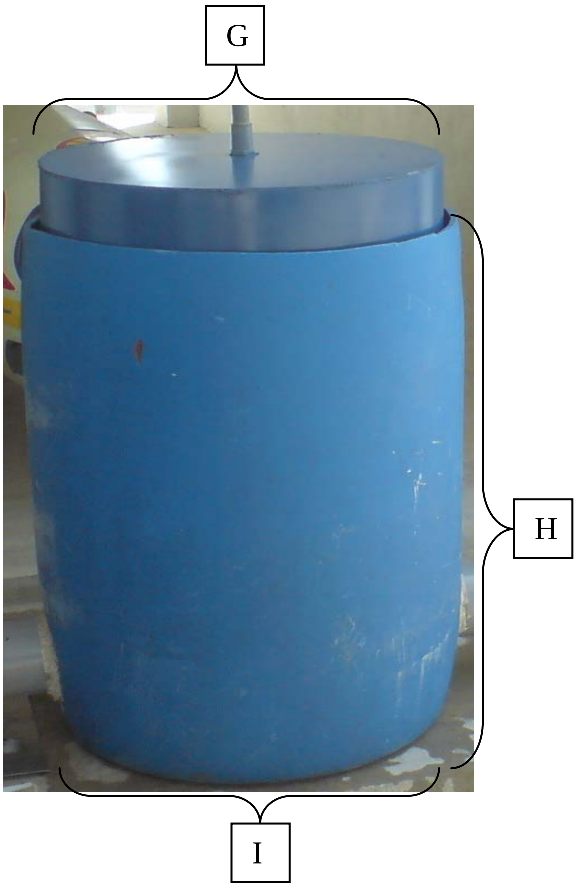
Trujillo D, Perez JF, Cerebros FJ. Energy recovery from wastes: anaerobic digestion of tomato plant mixed with rabbit wastes. Bioresource Technology 1993; 45(2):81– 3.

Wate SR. Studies on anaerobic digestion process as applied to organic matter in presence of some additives. PhD thesis, Nagpur University, Nagpur, India, 1982.

Zhao, X.H. (1985) In: Anaerobic Digestion 1985. China State Biogas Assoc., Beijing, China, pp. 701-710.

APPENDIX A

DIMENSION OF DESIGN



DESCRIPTION

A= 1' x ½" PVC pipe and ½" ball valve for gas pipe
B= 3' x 4" PVC pipe for inlet piping
C= 4" x 90˚ PVC elbow
D= 4" x 90˚ PVC elbow
E= 3' x 4" PVC pipe for outlet pipe
F= 4" x 45˚ PVC elbow
G= 0.185m dia. x 0.33m height for gas cap
H= 34" (0.865m) height
I = 22" dia.