FIRST BIO-GAS PLANT OF PAKISTAN

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I built the Pakistan's first Bio-Gas Plant 35 years back. It is still in existence and operation. At that time I did not think it worth introducing on a large scale. Today all out attempts are being made to carry it to every house. Is bio-gas from farm yard manure solution to the gas requirements of rural areas? Some twenty or more years ago, an International Cooperation Administration (predecessor of US-AID) representative visiting me in Tandojam, where I was working with the Government of West Pakistan then, informed me of bio-gas being introduced in some developing countries specially India with help of the American technologists. In the discussion I told him that I could build such a unit and examine its working and produce a report in a few of month's time. I did not have any drawings and neither had he, but I had a complete theoretical idea of working of it. While I was a student in NED Engineering College at Karachi in forties, this college was making what is known as 'Producer's gas' from coal for D.J. College Karachi. I had a good idea of that unit and fully understood its working and therefore, decide to use the same principle for fabricating the proposed bio-gas plant storage unit at Tandojam Agriculture Workshop. I also fully understood fermentation process and built a separate unit for it. We built this unit during the same week and carried out tests and trials over a period of a few years and afterwards gave up the venture as un-economical, cumbersome and impractical, specially as it could not meet country's requirements. This unit, still in existances is being maintained for demonstration purposes. Ten years back the Governor of Sindh saw it working.

Present views of the planners about potential of bio-gas are based on series of mis-information and mis-conceptions. It theorizes that each head of cattle produces 10 million cattle existing in Pakistan will generate gas at approximately 1.666 cubic feet per kilogram of wet manure. This would meet the entire energy requirements fro domestic cooking and lighting of the whole country. There are series of mis-conceptions in this statement, which need special attention of planners:

a) Our cattle being much lighter in weight to the stall fed cattle of the West, does not produce as much excreta as the Western well fed cows do. The urine free matter in the dung of a Western cow would only be 10 lbs and that in our cow about 6 to 7 lbs and not 10 kilograms.

b) Dung from our cow will be more deficient in nitrogen as compared to the Western cow as it gets less proteinous feed, and thus the C/N ratio would be high and productions of gas low.

c) Out of 25 million cattle there is a large number located in Thar Desert and Kohistan of Sindh, Balouchistan, N.W.F.P., Cholistan and mountainous regions of the Punjab. This would probably be 50% of the total cattle. The population in this area is nomadic or semi-nomadic, with small number of permanent settlements and therefore they can not use dung for bio-gas. Of the balance 12.5 million cattle, collect ability of manure is only 50%

as animals graze in the fields during the day. This reduces the amount of cow dung actually available within the country.

d) Of cow dung collectable, a house-hold must have 6 cows, to own a bio-gas plant for their cooking needs Alore. This reduce the number of potential bio-gas owners to only a few, because those owning less animals can not have bio-gas plant.

e) In every village of 1000 population or 160 families, there are expected to be 125 cattle i.e., for every house hold or family there will be 0.75 animal. There would be hardly 2 to 3 families in the village owning 6 animals each. This means only 18 people out of 1000 can have bio-gas for their domestic requirements. This is only rough estimated figure and has to be verified from the latest agricultural census data. In any case at the best, the number of the beneficiaries can not exceed 3% of population of the country.

f) It is said that use of bio-gas would also save foreign exchange and import of petroleum products. This wild statement is based on imagination of urban planners, who think that villagers use Kerosene oil for their cooking needs. They actually use agriculture and forestery waste material s fuel.

g) They argue that since digester improves the nitrogen contents of sludge, the extra nitrogen available would result in less import of urea and millions of rupees will be saved on such improvements.

h) It is theorized that 70% of the fuel used in the villages in Pakistan is cow dung and 30% is fire wood. This may have been true 35 years ago but today every villager knows the value of dung and very little of it is burnt. It is allowed to dry in heaps. Farmers owing orchards and vegetable gardens purchase these heaps of farm yard manure at very attractive prices. Other farmers use it on ordinary crops to improve fertility of soil. The villagers know that it is cheaper to purchase wood and to use it in the hearth, rather than burn farm yard manure. Most of the farmers use cow dung directly into the fields. It needs a survey to find out whether this assumption is based on 60 years old Royal Agriculture Commission's Report, which gave such figures for cow dung mis-use in the kitchens in late twenties.

i) In some experiments, as quoted by some bio-gas fan I they state that, slurry was added to the field crops at a particular rate per day and there was increase in yield of particular crop. This was considered as quantitative as well as qualitative increase in the yield of a particular crop "breseem", which showed increase in yield as well as in nitrogen content. The experiment is simply non-conclusive as the results are not compared with experiments that should have been performed by quantity of manure applied directly to the field, instead of the digester. The two experiments would have given conclusive results. It would also have been worth-while to perform same experiments with different soils, crops and climatic conditions.

j) It is assumed that the efficiency of gas production of digester is 100%. In the experimental and properly controlled digester, 68% efficiency could be reached, but this would mean that last the litre of gas may have to be extracted and one may have to keep the original material in digester for 6 months or more. As this is not practical, thus one has to accept efficiency of 20% or so, to get continuous supply in that too much fluctuation.

k) For all practical purposes digestion of manure could not be continued beyond a particular time because the gas production would decrease and thus the digested material has to be removed and replaced by fresh material at frequent intervals.

l) It is difficult to keep a C / N ratio at 30 throughout the period of digestion and therefore the gas production from a particular batch will not be optimum.

m) The variable factors that affect gas production like; pH and temperature, have not been considered.

n) It is assumed that 1 kg of fresh (wet) cow dung manure will give about 1.66 cubic feet of gas per day and this also assumed that our gas cookers are so efficient that about 20 cubic feet of gas is required for cooking and lighting per person per day. This is a figure copied from the Western sources. It is further assumed that if consumption would be 15 cubic feet of gas per B.H.P. per hour. At full load the gas consumption would actually be 70 to 100% more than this figure for a low compression engine.

My findings after carrying out elaborate tests were:

1. Digester fermentation process, leaves various materials in layers, which from top to bottom are:

    a) Bio-gas
    b) Scum
    c) Supernatant
    d) Digested sludge
    e) Organic solids

    The biologically active zone is known as supernatant. The digested sludge in liquid form carries dissolved minerals and chemicals like fertilizers. The un-digested light agricultural wasters form the scum. Some heavy inorganic matter and in-soluble solids deposit at the bottom. To take full advantage of the anaerobic process, digester is to have much longer height as compared to diameter, so as to have adequate length of strata of biological active supernatant zone. Organic solids usually contain sand and silt mixed with manure and it is therefore advisable to drain it periodically. Our design permitted this.

2. The plant needed large quantity of farm yard manure to produce methane gas, and collection of this quantity be labour from fields made the process un-economical. However, if manure was readily available , as was the case at animal husbandry department of Agricultural college near by, the unit could be operated economically provided, there was no other competitive use for the manure.

3. Production of gas was governed by temperatures prevalent. It was started in the month of March with high temperatures during day and low temperature at night. The temperature difference between day and night was of the order of some 25 to 30^{O}F (14 to 16.5^{O}C). At maximum temperatures. This was measured by taking gas out directly from the digester rather than gas holder. It was also found that the production of gas was low in most of the areas in Pakistan, and thus large capacity plant may be required to meet demand during its low production season. We did not carry out tests on heating of digester contents, although it was a simple process.

4. The produce food for six people we required farm yard manure of six buffaloes or ten cows. This was easily available at the livestock section of Agriculture College, but to have manure as fuel fro the population of whole country, we would need as many cattle animals as the number of human beings and also close to their settlements. Unfortunately there is a great dis-proportion in this ratio.

5. The collection of manure was a difficult job and we tried to collect it from the fields where animals grazed during the day time. It would need a full time man working eight hours to collect cow manure for a family of six. The cost of labour was exhorbitantly high, as compared with cost of sui-gas or wood. If farm yard manure were readily available in the house from domestic animals, it would bee a different matter.

6. There was heavy corrosion the of gas container, which had been made from an ordinary steel sheet. It was mainly due to acids and Hydrogen - Sulphide into water held in the container. Though Hydrogen – Sulphide present was in very small quantities but that may have been the primary corrosion agent, we took gas samples three times daily, at eight hour intervals fro analysis. It's average chemical composition was as under:

GAS	**PERCENTAGE**
Methane (CH_4)	48 – 67 %
Carbon Dioxide (Co_2)	31 – 51 %
Oxygen (O_2)	Up to 1 ½ %
Nitrogen (N_2)	1 to 30 %
Hydrogen (H_2)	Up to 1 %
Hydrogen Sulphide (H_2 S)	Less than ½ %

7. Carbon dioxide dissolved in water was probably also a corrosive agent. Though the initial experiments ended in 12 months, we observed after effects over a period of many years and found that even the concrete lining of the digester had been slightly attacked by acid reaction of the contents and most probably by bacteria and Hydrogen Sulphide. The structures therefore were plastered with Sulphate resistant cement and the drum was coated with asphalt to save it from rusting.

8. One of the observations though not quantatively measured was, that gas production was maximum in the month of May, when the temperatures of the order of 113^{O}F (45^{O}C) prevailed throughout the month. Temperatures within digester also were not necessarily uniform. It was maximum in supernatant. At low temperatures gas production was retarded. Beyond a particular high temperature limit, fermentation process is retarded but temperatures are yet a matter of investigation, and some amount of dispute, as some authorities think that gas production is retarded at 58^{O}C and others think that it retards after 69^{O}C. We also checked the calorific value of the gas produced. It varied and was between 300 to 500 BTU per cubic feet. At the time it did not occur to us to measure quantity of gas and its BTU, hour by hour and to plot their cor-relation with prevalent atmospheric temperatures, acidity within the digester and the quality or chemical composition of input manure as well as nitrogen content of slurry in the digester. Even the total time the material was allowed to be digested, would affect the gas production.

9. Later on it became clear to us that the gas production, as well as its calorific value would vary with the age of the manure in the digester and the production probably would be maximum after a certain period of time for each fresh batch of charge. Dry manure produced gas quicker than fresh manure which tended to produce large quantities of Co2 and other inert gases in the beginning. At one stage it was decided to keep adding manure periodically and also removes part of slurry sludge from the digester to find out if this gave an un-fluctuating supply of gas. It worked thought lot of undigested manure had to be discarded. The project was abandoned after one year as far as detailed experiments and observations were concerned.

At that time we never thought that, after some 20 years the Government would make bio-gas production a prestigious project for rural up lift. Of course I had in view, the other alternatives of producing gas from agriculture wastes like leaves, stems, waste grasses and other types of waste materials normally available in the fields. I wanted this to be burnt at a temperature of about 500^{O}C with about 25% moisture content. If the agriculture wastes had less moisture, water in form of steam was to be added to it. In my opinion that was the most practical thing to do, especially as the hydrogen sulphide content in it would be extremely low and as such this gas could easily be utilized in diesel engines and tractors. Diesel engine can not operate directly on that gas or let us call it wood gas or water gas primarily because the compression ratio of diesel engine has to e reduced and fuel injection system has to be replaced by air-gas mixing unit. At that time diesel oil was so cheap that system could not be attractive. It's application however, to the rural areas would have been revolutionary i.e., the whole village could have had a net work of gas supply being operated from a central plant in which instead of wood, agricultural and wood wastes could have been utilized and also power generated.

In mid 70's there came a large scale publicity of bio-gas plants being installed in the Third World countries including India and Pakistan. The Government also encouraged its installation. To day most of the plants so far installed are Government sponsored and subsidised either fully or partially or built on loans easily granted by the Government agencies. The beneficiaries in the rural area are a few big land-holders, who own some farm and milk animals. A family of six would need six buffaloes or 10 cows for daily gas requirement of their kitchen. A village having a population of 1000 souls, does not have 1000 cattle goes out in the fields for grazing and has to walk over a few miles leaving excreta enroute. It is not possible to collect all this farm yard manure and bring it to the village at any reasonable cost. What is collectable is only 50% left over in the house at night time. Thus the farm yard manure available per village, if saved to the last bit, would produce gas for 50-80 people in the whole village, and that would be about 5-8% of actual requirement but unfortunately no body would part with his farm yard manure for use in the digester of somebody else. And this is the end of the story. It has already been stated that on the average 3 house holds having a total of 18 members out of 1000 population can have bio-gas from farm yard manure for use in the digester of somebody else. And this is the end of the story. It has already been stated that on members out of 1000 population can have bio-gas from farm yard manure.

It is only big land owner or big herdsmen who may avail this facility. This is my sincere and earnest opinion, in view of being the builder of first farm yard manure digester or bio-gas plant more than 20 years ago. I have rural background and understand the rural socio-economic set up, as well as availability of farm yard manure and I am still not willing to accept that the application of this technology will be revolutionizing. In the village it is an item of prestige to show something new, clean, mechanical and mysterious to others, who cannot afford it. Of course cleanness, ease of operation and reduction of drudgery are advantages and toiling rural women do deserve sympathy.

It would be interesting to go into technical details of this plant and its working for laymen as well as scientists. Drawings and photographs of my first plant are enclosed with this article. The process consists of fermentation, in which organic material is converted into energy by bacteria. The process need not be limited to farm yard manure. Selected agriculture wastes could also be fermented provided they have enough moisture and there is adequate nitrogen present to support bacterial activity. Bacteria itself is living organism whose body contains Carbo-hydrates and proteins, i.e., C, H_2, N_2 & O_2. In aqueous environments with absence of air, bacteria consumes nitrogen and Carbo-hydrates from the agricultural wastes, multiplies and dies. In the process of dying and decay, nitrates, or nitrous, ammonium compounds and methane gas are produced. Methane would escape into the atmosphere, but its flow to free atmosphere could be checked by trapping it in a holder. The residue in aqueous solution will have more nitrogen than the original, due to decay of bacteria and therefore it gets enriched. It is important that the ratio of carbon to nitrogen should be about 30 for optimum production of methane. It this ratio is more, nitrogen is to be added in form of urea, for production of methane. It had become clear to us that sheep and goat and poultry manure if used directly or added to cow/buffalo manure would increase production of gas by reducing carbon to nitrogen ratio to start with but very soon carbon will be consumed and unutilized nitrogen inform of protein would be left behind. Again if there is less nitrogen than 30 to 1 ratio, the nitrogen will be consumed, leaving un-fermented Carbo-hydrates or carbon. The production of gas will also be slowed down.

For the optimum production of gas high a temperatures are essential. In the digester of the type we built, irrespective of outside temperatures, the temperatures of water in the digesters were sufficiently high. The pH of digester has also to be high for optimum gas production. If pH goes down below 6.6 methane production is reduced considerably quantities of Co_2 are generated by the digester.

With the digester and gas-holder the following equipment were installed for measurements:

a) Gas holder was so built as to produce a pressure of 1 / 10 lb per square inch, but counter weights were added to lift gas drum in case lower pressure were needed. It could be loaded to increase the pressure.

b) Pressure gauge, manometer and pressure regulator valve to maintain constant pressure of 1/10 lb per square inch or 2.775 inches of water column at the out let. The pressure of Sui-gas domestic supply is ¼ lbs per square inch or 7 inches of water column but as calorific value of bio-gas was low, either nozzles were changed or gas pressure raised by reversing the counter weights i.e., by loading the drum with weights instead of counter balancing it. We preferred to provide nozzles with bigger diameter. To raise pressure a bar could be clamped to the vertical supports, thus causing further movement of drum u.-wards and thereby increasing the pressure. We were not sure of the effects of pressure on the gas production.

c) Gas flow meter.

d) To get gas samples, an aspirator was used to fill ordinary children's rubber balloons. Orstat apparatus were used for measuring percentage of various gauges. The balloons were handed over to Agriculture Research Section of Agricultural College Tandojam. They did the chemical analysis.

e) The pH of material in the digester was measured by pH meter. As soon as pH went over 8.5 more fresh manure was added. At both high and low pH (below 6.7) gas production reduced considerably. Most probably pH value of supernatant is more important than that of other layers, though they usually have same pH value due to mixing of water by gas bubbling through the liquid.

f) Two holes in the manhole were used for inserting a thermometer and a siphon tube to take juices out for measurement of pH or any other examination.

g) Temperature within digester was measured by long glass thermometers. This was not an accurate indicator of temperature, as there was some heat loss between digester and outside atmosphere. All the same when the outside temperatures $30^{O}C$, the digester temperature was $42^{O}C$ and even at night when temperature fell to $22^{O}C$, the digester temperature was well over $39^{O}C$. In this case the gas production had reduced to half or less during the night. In the month of May with outside temperatures reaching $45^{O}C$, digester temperature was $59^{O}C$. One defect with our experiments was that we did not have automatic recorders for pH, temperatures and gas output. Although pressure was kept constant by the floating drum container.

h) The calorific value of the gas could not be measured locally and therefore samples were taken down to Sui-gas Laboratories at Karachi for analysis. The BTU value of gas per cubic feet varied and was between 350 to 550 BTU fro various samples, taken out thrice, at different times, within 24 hours, and varied according to age of manure in the digester. It was also found that the BTU varied according to carbon dioxide content in the gas. We concluded that if there was substantial quantity of fresh water in the gas holder the gas sample taken immediately afterwards, i.e. had lower content of carbon dioxide and therefore high calorific value. Once water became saturated with carbon dioxide the bio-gas samples had more carbon dioxide and lower calorific value. Again in this case, frequent sampling of gas for analysis and its corelation with other factors could have given more scientific information.

i) An externally closed 225 litre drum (459 gallon grease drum) filled with water was used for absorbing carbon dioxide by bubbling through it. It's BTU increased substantially (from 350-550 BTU to 550-750 BTU) due to absorption of carbon dioxide with slightly increased cost of this bubbler. One disadvantage with such type of water scrubber or bubbler was, periodic or continuous replacement of water, as after saturation it did not absorb more gas. After saturation it did not absorb more gas. No attempt was made to remove hydrogen sulphide to decrease its corrosive except what was separate in the bubbler. Hydrogen sulphide could be removed by passing the gas over iron filings. There is a very fast method of removing carbon dioxide by bubbling gas in hydrated lime water but this can only be justified only on a large commercial unit. Special hydrogen sulphide filters can also be incorporated only in highly commercial gas units.

Our measurements also showed that output of gas varied between 5 to 8 cubic feet per kilo of 100% dry farm yard manure and 1.66 to 2.0 cubic feet per kilo of fresh manure. But the manure available at times had more than 50% moisture. This comparatively a poor efficiency of about 20% as accessed theoretically, as we did not have a suitable calorimeter to know the exact heat content in farm yard manure. Again 5 to 8 cubic feet per kilo of dry farmyard manure is only equivalent to 2.0 to 4.5 cubic feet of Sui-gas in urban areas is 2.5-3.5 MCF or 2500-3500 cubic feet per month for a family of 6. This means at least 1 ton of dry farm yard manure was required per month or 1 mound per day. One mound of dry farm yard manure means 4 to 8 gunny bags, each of which is meant for 100 kilo-grams of grain. One advantage of our two stage digester and gas holder was that we could cut off gas holder and get gas directly from the digester. Because of its larger capacity, minimum volume could be utilized for fermentation if also used as gas container; otherwise up to 90% of it could be used for fermentation.

Handling of farm yard residue posed a serious problem, because it was no longer a solid but sludge. This sludge had high nitrogen content as examined by the Agriculture Research Section at Tandojam with Kjeldahl apparatus, but handling of it was too cumbersome to be considered as a practical proposition for transporting it over long distances. By allowing it to dry into a cake or powder form, some nitrogen was lost and purpose of enriching it with nitrogen was lost.

Our bi-gas unit was for batch process and not for continuous flow digestion and as such gas production and its quality was into uniform. The manure was changed every 30 days. Alternatively 33% manure was changed every 10th day. When farm yard manure was first put into the digester, gas produced was carbon dioxide. After nearly two weeks operation gas production started. It took several hours or even days specially when digester re-charged with manure before gas production reached its original peak, but with each tapering down of productions were variable, primarily due to state of raw material and sludge, although other factors like pH and temperatures were constant. We therefore thought that the best solution to this problem was to have a number of small digesters connected to the same gas holder in this way each one of batch holders could be utilized to the last litre of gas and any one of them could be disconnected for refilling. Since for a couple of week's, digester would produce only carbon dioxide, which from a batch digester could easily be allowed to escape to atmosphere as it accumulated. Being anaerobic process it cannot be have an out let to atmosphere only at the time of releasing gas.

We worked out a correlation between the daily gas production and capacity of digester. For a daily 10 cubic feet of gas production, digester must have a capacity of 20 cubic feet. Our digester unit had a full capacity of about 130 cubic feet, and gas holder could also store about same quantity of gas to meet emergencies. We could therefore always tap 100 cubic feet or more of gas a day without trouble, and even 150 cubic feet was possible. Intermittently it could give more than 200 cubic feet if stored gas was also utilized. How ever, the digester some times was used directly and therefore it was filled only to half of its capacity with manure. In this case, therefore, it produced only about 60 cubic feet of gas daily in May and about 30 cubic feet in January, the coldest month of the year. The gas holder when used. Gave full capacity of gas production, provided the digester was filled to a minimum of 60-70% of its capacity.

An interesting experiment was to use banana stems in the digester. These were first crushed by a sheet metal roller to get rid of as much water as possible and then were put into the digester along with urea. The $C.N_2$ ratio of dry matter (as accessed by drying sample in a furnace was maintained as 1.30. It worked though with a considerable time lag but this type of fermentation of wastes was costly as compared to Sui-gas although at that time urea was highly subsidised, and gas prices too were also very low.

Human excreta. Between 1967 and 1970 I had used human excreta from Hyderabad town on my farm. We used to pick up two tractor trailler loads of excreta and dump it under mango trees. Since its manual handling was a problem we used tipping trailler with front-end loader for this purpose. Human excreta are very rich in nitrogen and it can be mixed with straw and other nitrogen deficient agricultural wastes to produce large quantities of gas.

Our experiments could not define correctly the loading rate per cubic of digester space. At one stage we thought of having small 225 litre digester made from empty oil drums and use them as experimental digesters, but our initial experiments showed that bio-gas from manure is not as solution to the national problem. We therefore carried out no further experiments. The municipal sewage plants operating in the western countries are loaded at the rate of 0.5 to .2lbs of dry waste matter per cubic feet of the digester space per day. Assuming the digesting time of 60 days, this would mean approximately 6 lbs of material per cubic feet. This also meant that almost 75 percent of the space had to be occupied by the waste material but with high volumes, the detention period is increased. It is always preferable to load the digester to less than 50% of its volume and keep adding fresh matter to it, rather than allowing it to be filled up, this will give better and more uniform rate of gas production per unit quantity of manure.

The plant shown in the attached drawing and consists of:

i. Digester pit, 98 inches outside diameter 78 inches internal diameter, chamber 67 inches high with 5 inches roof at the top and 18 inches cast iron man hole used in sewerage systems. The man hole was made air tight by a rubber packing between frame and the cover. For making this cover to withstand inside gas pressure, a steel clamp was firmly fitted on tip of the cover by bolts and tightened. The other end of clamp was fixed on the roof. It was tested with compressed air at 4 bars. The man hole, had two holes one for insertion of thermometer and the other for checking level of water and sludge and siphoning out juices fro pH and other tests. To charge the digester with manure, man hole had to be removed. It was also used for removing the scum. An outlet pipe from near the ceiling led to the gas container drum. The pipe line had a gas regulator, flow meter and shut off valves. This arrangement besides maintaining a constant or desired pressure in the line, was also used for bypassing the container and supplying gas to burner direct or via gas scrubber or bubbler, fro improving the calorific value of gas, if required, by removal of carbon dioxide. A 4 inches pipe at the bottom was meant to remove sludge.

SLUDGE, Nitrogen contents of the sludge varied all the time. It is twice as rich as in raw manure of cow/buffalo and is ordinarily as high as 3.5 percent for chicken manure and could even go upto 8 percent. Where did this extra nitrogen come from? This question has not been properly explained. There appears to be fixed ammonia in the plants, which ordinarily is not separatable and therefore is not shown in Kjeldahl process. Bacteria consumes the fixed nitrogen and on its own decay forms ammonia (NH_3). This extra nitrogen production is considered a great advantage of bio-gas plants.

Is sludge more useful to the agricultural plants than ordinary manure? Animal dung used in the field releases nitrogen from manure slowly and therefore nitrogen does not go into ground but is able to give benefit to crops for 2 to 3 years. In my opinion the fixed nitrogen also is released in the process and therefore the benefits from extra nitrogen produced become a myth, unless the synthesis them into protein (nitrogen compounds). Since nitrogen in the sludge is mostly in the form of ammonia it would get lost, if exposed for long to the atmosphere. It therefore should be utilized in the liquid form as quickly as possible.

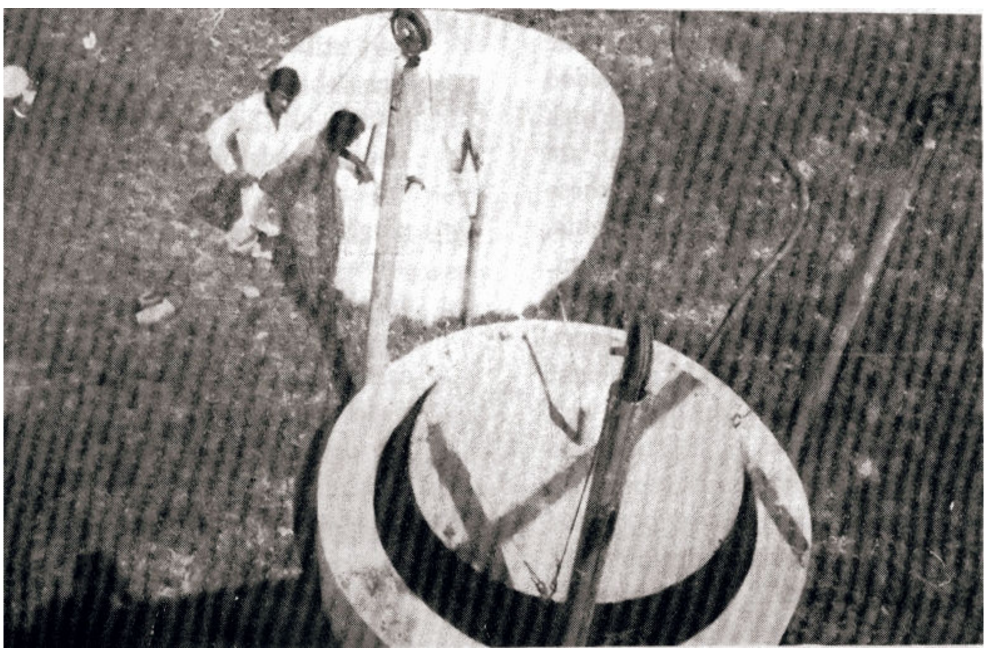
Organic manure has another important advantage. Organic material is soil conditioner. This material when worked into soils produces porous space, improves aeration and allows quick extension of plant root system. Sludge from digester mostly in liquid form does not have ability of adding humus to the soil. There is also a serious disadvantage in applying this sludge in clayey soils of rice area of the Northern-Western Sindh. In such areas sludge can retard growth of plants. Sludge however can help to make soils acidic and thereby help better absorption of phosphates. Sludge if mixed with scum would help some what as scum is undigested fodder material, but the amount of organic matter put in the digester would always be higher than that taken out, thus the disadvantage of depriving the soil of organic matter would always be there.

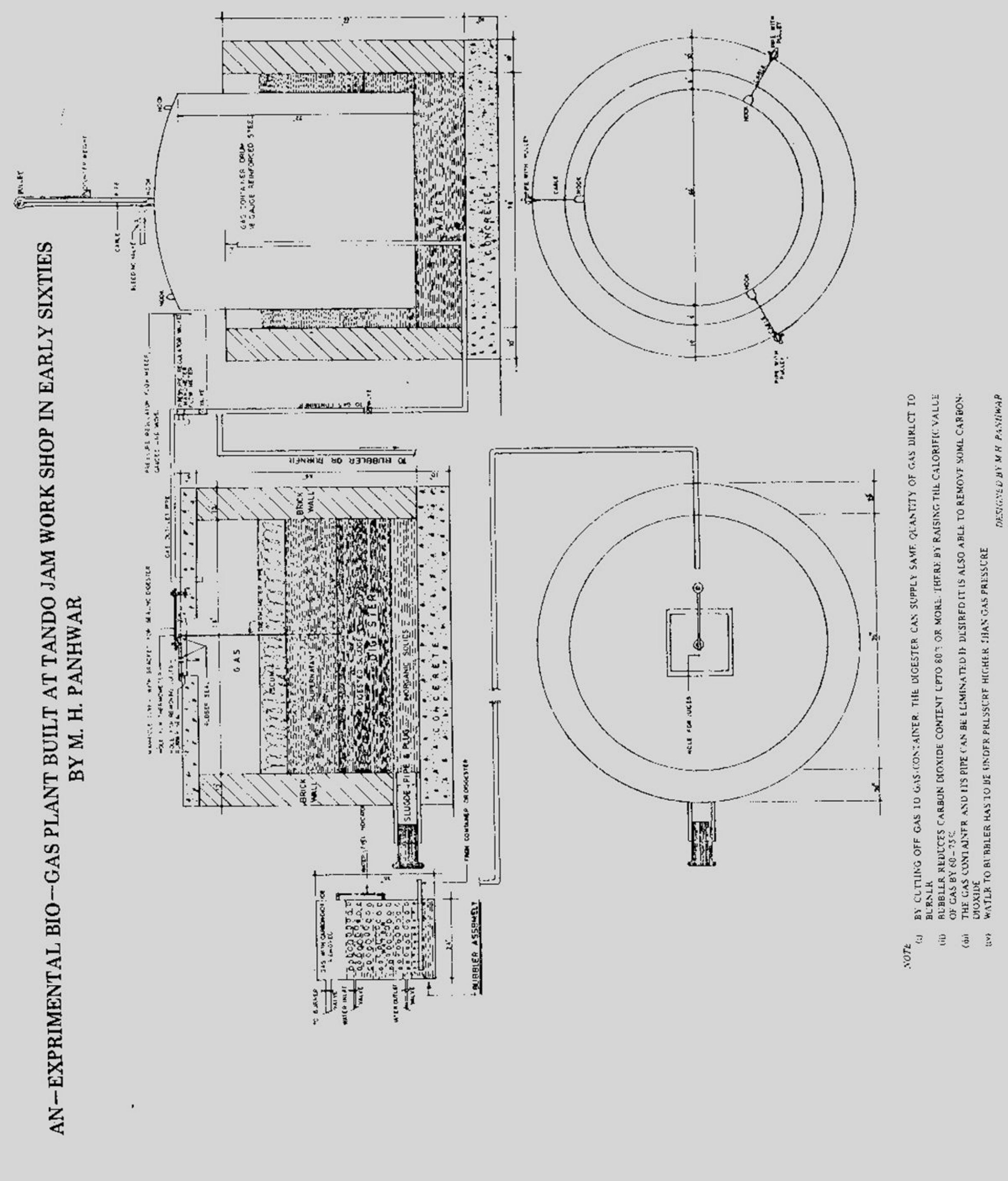
ii. *Gas Holder.* It consists of another circular container over ground pit or well which has been 96 inches outside diameter, 78 inches internal diameter and 72 inches deep. Along its periphery stand three two inches diameter steel pipes 120 inches above the ground level and buried 24 inches above the ground level and buried 24 inches in concrete foundation under the ground. On the top of thee pipes are three pulleys of 4 inches diameter. The three pipes and pulleys are meant to support the inverted gas drum. Drum itself is 66 inches diameter 72 inches high and its total weight inclusive of books, fittings and welded joints etc. is 342 lbs. It has three hooks 120^{O} spaings along its top edge and are supported on pipes and pulley. From these pulleys are suspended three counter weights, which take-up part of the load of the drum. The inverted drum floats on water in the pit and gas pressure on it would be difference between its own weight minus counter weight divided by the diameter of the drum and comes to 0.2 lbs per square inch. There is a great flexibility in adjusting constant pressure of the gas. We needed a pressure of about 0.25 PSI. By is own weight drum could develop only 0.1 i.e., about $2/5^{th}$ of required pressure. This meant keeping 513 lbs weight on the drum. Alternatively a steel bar was clamped between two vertical pipes and as clamp stopped further movement of the gas holding drum, the pressure rose. Water on which the drum floats removes some of the carbon dioxide, but once saturated it absorbs only small quantities lost by water exposed to atmosphere. A gas valve on the top is used to bleed out the gas or allow in the air in case the drum is to be removed. The drum was quoted with bitumen when installed more than 20 years ago and was repaired only once about 6 months back when its bottom portion showed signs of wear. The drum could be loaded at hooks to increase pressure of gas inside. To let in the gas from the digester to the container, a gas pipe was installed. It is 68 inches above the level of water. The container can hold gas at any desired pressure by either counter weights or loading the drum at the hooks.

iii. *Scrubber or bubbler.* Once we found that carbon dioxide content in the bio-gas was 35 – 50% as compared to 47-67% of methane we were greatly concerned. By change of water in the gas container, some carbon dioxide was definitely removed, but large part still was there and therefore a bubbler was fabricated from a used oil drum. Three fourth of this was filed with water and gas was allowed to bubble through it by means of an ordinary 1 inch gas pip 18 inches long plugged at the end and having series of small holes along its length to allow gas to escape and bubble through water. If burners did not use large quantity of gas, 90% are even more of carbon dioxide was removed in the bubbler. Water was allowed to flow in and out from the drum. It was supplied by an over head tank about 10 feet high. To conserve water, water valve was opened and closed along with the gas value supplying the burner.

Though there is much publicity given to such type of digesters, but in view of low efficiency of gas production, its, low BTU value, and difficulty in handling of sludge, its design is to improved and use of materials other than manure also investigated. The cost of labour to collect farm yard manure and transportation to the digester would be too high to encourage its use for such purposes, specially for running gas engines, unless the plant is put in cattle colonies near large urban centres or large animal husbandry farms. In my opinion production of wood or water gas from agricultural waste and wood or waste by heating and hydrogenising it at $500^{O}C$, is more useful for the rural areas of Pakistan. Such units could also run small diesel engine and can be installed on tractors. They will consume one maund (37.2 kg) of agricultural waste having about 25% water contents to run a 50 HP tractor.

There can yet be another important application of bi-gas in the country. All big towns have cow/buffalo colonies, for supply of milk to the city population. There may accumulate large quantities of farm yard manure in these colonies although it usually is purchased by farmers for direct use in fruit and vegetable crops. It is priced at about 750 to 1000 rupees per truck load, and usually 3 to 4 months old farm yard manure is directly applied to the fields. However, there may be some surplus of manure occuring during certain periods of the year i.e., when manure is not being the crops. At this stage the farm yard manure could be converted into bio-gas. A yearly survey needs to be done in connection with the availability of surplus manure. Based on this a plant may be put up for gas production. Such a gas could be utilized for diesel engines and power generation, provided the economics justify it. Much will depend upon the present market rate of farm yard manure. There is a fear that indiscriminate production of bio-gas at these cattle colonies may simply increase farm yard manure rates and come in the way genuine farmers, as sludge is difficult to transport and use properly in open fields.




AN–EXPRIMENTAL BIO–GAS PLANT BUILT AT TANDO JAM WORK SHOP IN EARLY SIXTIES
BY M. H. PANHWAR
GAS
BRICK WALL
CONCRETE
SLUDGE PIPE & PLUG
DIGESTER
TO BUBBLER OR BURNER
BUBBLER ASSEMBLY
NOTE
(i) BY CUTTING OFF GAS TO GAS-CONTAINER, THE DIGESTER CAN SUPPLY SAME QUANTITY OF GAS DIRECT TO BURNER
(ii) BUBBLER REDUCES CARBON DIOXIDE CONTENT UPTO 80% OR MORE. THERE BY RAISING THE CALORIFIC VALUE OF GAS BY 60–75%
(iii) THE GAS CONTAINER AND ITS PIPE CAN BE ELIMINATED IF DESIRED IT IS ALSO ABLE TO REMOVE SOME CARBON-DIOXIDE
(iv) WATER TO BUBBLER HAS TO BE UNDER PRESSURE HIGHER THAN GAS PRESSURE
DESIGNED BY M H PANHWAR