CONSTRUCTION AND EVALUATION OF A COWDUNG GAS PLANT FOR HOUSEHOLD FUEL

By

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I INTRODUCTION

Sound Home-Management has been defined by Gross and Crandall (1954)[1] as a mental process through which the home-maker plans, controls, and evaluates effectively the use of family resources, human and material, to achieve family goals with maximum satisfaction. Time and energy are important resources. The quality of the managerial abilities of an individual therefore depends on the efficiency with which she uses these resources.

Among the many managerial responsibilities of a home-maker, cooking and serving food for the family involve a major part of her time, energy and creative skills. The time taken for cooking is influenced by the type of equipment and fuels used for cooking. The fuel used should be such that it makes cooking a joyful enterprise.

Since ancient days, people are using wood, charcoal and coal as fuels. Until a century ago, wood was the only fuel used for home heating. Even today wood is the household fuel for a large majority of families. The National Council of Applied Economic Research (1959)[2] has estimated that the total annual consumption of fire wood in India is 55.5 million tonnes of coal equivalent, of which a quarter is utilised in the urban areas and the rest in rural areas. An indispensably adjunct to firewood is dried cowdung which is used as a fuel, depriving the farmer a valuable manure.

According to Patel and Patankar (1965)[3] about 172.26 million tonnes of cattledung which constitute 31.14 percent of the total cattledung available in India are being wasted as fuel in the form of cattledung cakes.

The fact that combustible gas can be produced from decaying organic waste, marshes, swamps and farm yard manure has been known, from 1778. Any organic material in the absence of oxygen will produce a gas known as methane because of anaerobic fermentation according to, Acharya (1957)[4].

Construction of cowdung gas plants would give gas for fuel purposes. At the same time, the residue which has rich furtiliser value due to high nitrogen content could be used for crop production. The Installation of cowdung gas plants is possible only where dairy units are available. The manure available after gas production is roughly estimated to be 40 percent more than that is available from compost pits.

In an agrarian country like India where more than 83 percent of the people live in agriculture the need for improving the schemes of animal husbandry is important since animal husbandry is an integral part of a sound system of diversified agriculture. Among the several schemes of animal husbandry, importance has been given for cattle improvement which exceeds the provision made in all the three plans put together amounting to Rs 132 crores (Rs 22 crores in the first five year plan, Rs 56 crores in the Second Five Year Plan. and Rs 54 in Third Five Year Plan).

The census of 1961 has calculated that the cattle population in India is 17.6 million, which constitutes roughly two thirds of the total livestock. The production of cattledung thus available in the country is wasted being burnt in the form of cakes due to lack of an alternate fuel at present.

The country is in need of fuels which will help to conserve the abundance of forest wealth and resources. Good manures are also found essential for increasing the agricultural production. Adequate Scientific data on the construction and efficiency of cowdung gas plants are not available. Therefore this study has been undertaken to find out the cost, materials and methods involved in constructing a gas plant for household use, to utilise the cowdung for a dairy with eight cows with the following specific purposes.

1. To construct scientifically a gas plant that would produce gas adequate to meet the needs of a family of six.

2. To evaluate the constructed gas plant and find out the efficiency of the gas by comparing it with the performance of kerosene.

It is hoped that the results of the study would stimulate the homemakers towards installation of cowdung gas plants and making use of gas produced for cooking and household purposes and also to utilise manure of rich fertiliser value for improving home food production.

II REVIEW OF LITERATURE

The available literature has been reviewed under the following headings:

A. Sources of Heat Energy

B. Factors Affecting the Combustion of Fuel

C. Need for Substitution of Fuel In India

1. For a community.

2. For a house.

D. Cow Dung Gas Plant.

1. Principle of its working

2. Factors affecting the gas production

3. Uses of the Cowdung gas plant.

E. Studies Conducted on Cow Dung Gas Plant.

A. Sources of Heat Energy

The original source of energy available to man is from the sun in the form of heat. The chief sources of heat controllable and usable by man according to Avery (1960)[5] are (1) chemical reaction (which includes the burning of fuels) (2) electrical energy and (3) mechanical energy.

1. Fuels

Stowell et al[6] have defined fuel as the substance which produces heat when the various elements combine chemically with oxygen in the air to burn and give heat with the exception of hydrogen gas. All fuels are chemical compounds of hydrogen and carbon with sometimes the addition of sulphur and few are incombustible substances. Fuel as per Encyclopaedia[7] Britanica is used to produce heat by combustion in air. Osborn (1929)[8] states that fuel may be defined as any substance which on being oxidised or burned produce heat energy in commercial quantities. Avery (1960)[5] defines fuel as a material when burned would furnish heat energy at a reasonable cost.

In the opinion of Ahrens et al (1952)[9] the most common fuels used in the home to day are the solid fuels that are wood and coal, the liquid fuels which include gasoline kerosene, furnace oil and gaseous fuel such as the natural and artificial gas. Lokanathan (1950)[10] points out that cowdung, firewood, charcoal and kerosene are considered to be the domestic fuels while soft coke, gas and electricity are commercial fuels used in our country.

a) Solid fuels

i) Wood: The use of wood as a fuel is of great antiquity. According to Ahrens et al (1952)[9] a century ago wood was the only fuel used for home heating. Soundararaj (1963)[11] says wood of Portia, Casuarina, Tamarind, Mangoes and Acacia trees are commonly used for fuel purposes in India. Gray (1946)[12] remarks that wood and coal contain carbon, hydrogen and oxygen. They differ in that the percentage of carbon in the latter is much higher than in the former. Sharma (1959)[13] remarks that hard woods make better fuels than conifers or soft woods as they give more lasting and uniform heat.

According to him, the heating value depends on the kind of wood, the percentage of moisture content and resinoous gums present.

ii) Coal: The Encyclopaedia Britanica[7] defines coal as a stratified mineral that has been formed by the action of decay, heat and pressure upon accumulation of vegetable and woody of cellulosic matter laid down in bygone ages. According to Salt and Sinclair (1957)[14] lignite and peat are immature coals which are formed in between peat and bituminous coal. Chalmers (1963)[15] estimates that coal is the main source of industrial energy.

iii) Charcoal: According to Partington (1957)[16] charcoal is obtained when wood is destructively distillated. It is black in colour and burns readily leaving little ash and emits no smoke. Charcoal is effectively used as a household fuel for cooking purposes.

Saw dust, leaves, waste paper, cowdung cakes, husk, coconut shells and other organic wastes are some of the other solid fuels used for household purpose.

b) Liquid fuels

Liquid fuels are obtained from the extracted vegetable or animal matter or petroleum. Young and Porter (1955)[17] state that petroleum is the source of many liquid fuels. These include gasoline, kerosine and the oils containing large hydro-carbon molecules which are used as fuel in furnaces, locomotives and boilers. Encyclopaedia Britanica[7] stresses that liquid fuels occupy less space and weight than the equivalent amount of solid fuels.

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e) <u>Gaseous fuels</u>

According to Mack *et al* (1956)[18] several gases are commonly employed as sources of heat, light and power including (1) coal gas (2) water gas (3) producer gas and (4) natural gas.

As stated by Partington (1957)[16] coal gas is obtained as a by product by destructive distillation of coal. Weaver and Foster (1960)[19] remark that coal gas consists chiefly of hydrogen and methane with some carbon monoxide and nitrogen.

i) <u>Producer gas:</u> Deming (1952)[20] states that by burning coal in a gas producer with a limited supply of air, producer gas is obtained which contains about 60 per cent nitrogen, 30 per cent carbon monoxide and 10 per cent Hydrogen and hydrocarbons.
Mack *et al* (1956)[18] states that producer gas is used not only as a fuel but also as a source for the nitrogen and hydrogen used in making ammonia by the Haber process.

ii) <u>Water gas:</u> Mack *et al* (1956)[18] states that water gas is essentially a mixture of carbon monoxide and hydrogen. Water gas is very poisonous and especially dangerous because it has no odour.

iii) <u>Natural gas:</u> Natural gas consists chiefly of methane. According to Partington (1957)[16] Weaver and Foster (1960)[19] natural gas occurs naturally in the vegetable decays and is pumped through the pipe line system.

iv) <u>Cattledung gas:</u> The cattledung gas is of recent discovery. Desai and Biswas (1945)[21] have pointed out that by anaerobic fermentation cattledung can be used to produce fuel as well as manure.

Apart from fuels the other sources of energy used for cooking include electricity and solar energy.

d) <u>Electricity</u>

Avery (1960)[5], points out that electricity is the cleanest and most convenient source of heat. Earle (1950)[22] points out that electrical energy is energy stored or transmitted by electrical methods. Peet and Thye (1953)[23] stress that electricity is a clean and safe source of heat energy.

B. <u>Factors Affecting the Combustion of Fuel</u>

According to Allen *et al* (1946)[24] combustion may be defined as the chemical combination of a substance with oxygen proceeding at such a rate that a high temperature is produced. Ballard *et al* (1959)[25] stress that when a substance is produced, the amount of heat liberated per unit mass is called the heat of combustion. Heats of Combustion Table given by Margenau *et al* (1953)[26] is given in Appendix I. Deming (1950)[20] stresses that the kindling temperature (the temperature at which the material will continue to burn) depends upon four factors (1) the nature of the material (2) the fineness of sub-division (3) the concentration of the oxygen and (4) the rate at which fresh oxygen is supplied.

In the case of a solid fuel the oxidation reaction occurs at the surface which is the boundary between the air and the combustible material. Gray (1946)[12] states that the combustion is proportional to the area of the surface.

C. Need for Substitution of Fuel in India

a. For a community

The percapita energy consumption according to Chittaranjan Prasad (1966)[27] in U.S.A., U.K., and U.S.S.R. is 7,999 kilogram, 4,887 kilogram and 2,853 kilogram respectively with a world average of 1,409 kilograms. In India the per capita energy consumption is only 140 kilograms which is considered to be very low.

According to the mention made by the Ministry of Community Development (1959)[28] coal, oil and hydro-electricity contribute only 20 per cent on India's total energy requirements. The rest 45.5 per cent is supplied by animal dung and wood and the remaining 34.5 per cent comes from human and animal effort. The use of dung as a fuel in India amounts to an annual loss of a valuable commodity equivalent to 600 million tons of fertilizers. As expressed by Iengar (1967)[29] at present 70 to 75 percent of the energy requirements in South India are being provided by non commerical sources of fuel, namely burning cowdung, bits and pieces of timber. This is because coal is expensive while crude oil is not readily available in sufficient quantity.

The preservation of forest wealth is considered to be essential for utilisation in industries and for the prevention of soil errosion. The National Council of Applied Economic Research (NCAER 1959)[2] estimated that 55.5 million tonnes coal equivalent of wood is burnt as fuel every year causing a heavy depletion of forest resources.

This needs to be reduced in order to check the floods of soil erosion.

Iengar (1967)[29] feels that by using cowdung gas as fuel, every year the huge amount of foreign exchange needed to import, nearly nine million tonnes of diesel petrol could be saved.

A good fuel according to Konard Krauskopf (1953)[30] should be strongly exothermic, cheap and easily storable and the products of combustion, easily disposable.

b. For a House

Rama Bai (1963)[31] points out that the ninety homemakers interviewed spent six to seven hours per day for performing household activities. Evidently the Indian women spend a lot of time in homemaking activities compared to women of U.S.A. who according to Brittan (1938)[32] spend on an average five hours per day for the same. The problems faced by the rural homemakers in cooking meals by the use of wood and charcoal as fuels were listed out by Kurian (1963)[33]. These included (a) the long time taken for cooking (b) spreading of smoke and ash in kitchen (c) difficulty in lighting the fire due to wet fire wood.

Considering these facts fuels mentioned above could be substituted by cowdung gas which if rightly used produces valuable fuel and enriched manure for a household.

D. Cow Dung Gas Plant

The Indian Agriculture Research Institute [34] defines cow dung gas plant as a cheap and simply operated plant in which dung is fermented so as to yield a sufficient quantity of combustible gas which can be utilised for cooking purposes and the residue for manure without any loss of manurial constituents.

1. Principle of its working

The principle under-lying the working of the cow dung gas plant is as follows: The process of decomposition proceeds either aerobically or anaerobically. In both types of fermentation oxidation takes place. Under anaerobic condition the oxygen of fermentable material produces incomplete oxidation, the products being oxygen, methane and hydrogen say Desai and Biswas (1945)[21].

2. Factors affecting gas production

Factors such as (a) temperature (b) inorganic salts and (c) saccharine influence gas production.

a. Temperature:

The studies conducted in the laboratory by Desai (1951)[35] showed that below 30°C, there is practically no gas production. According to him the optimum temperature lieing between 40°C and 50°C and a ph. of 7.5 to 8.0 are very favourable.

b. Inorganic Salts

The addition of inorganic salts does not materially affect gas production but the presence of sulphates definitely decreases the fermentation. The addition of groundnut cake according to Desai (1951)[36] slightly increases the gas output.

e. Effect of Saccharins

Molasses Mohuwa flowers were added to dung suspensions to the extent of 5 to 10 per cent and it was found that there was quick evolutions of combustible gas in the beginning itself and the fermentation stopped after two to three days. The gas contained only carbondioxide, Hydrogen and no methane.

According to the experiments carried out in the laboratory by Acharya (1957)[4] in order to examine some of the factors which influence the production of combustible gas and manure during the anaerobic digestion of bullock dung and other organic materials showed that -

1. A period of four weeks digestion at 30°C is necessary for obtaining the potential gas production capacity. The dung loses about 27 to 28 per cent of dry matter and yields about 1.5 cu.ft of gas per pound of fresh bullock dung added, or about 8 cu.ft of gas per pound of dung matter in the added dung. The gas is combustible and contains about 55 to 60 per cent methane, 5 to 10 per cent hydrogen, 30 to 35 per cent carbon dioxide.
2. The rapidity of gas production increases with increasing proportions of inoculum to fresh added dung. A proportion of 40:1 was found to be satisfactory for obtaining rapid gas production.

3. A combination of the requirements under 1 and 2 above would indicate that for efficient and rapid gas production, the fermentation chamber should be 30 to 60 times the volume of bullock dung added daily.
4. During the process of digestion, the rate of gas production was somewhat higher, when the supernatant pressure above the fermenting liquid was lower than that of the atmosphere, say by about one to two inches of water head.
5. The bullock dung used for the experiments was found to contain sufficient nutrient material for rapid anaerobic digestion and satisfactory gas production, further additions of nutrients like nitrogen phosphoric acid potash or the minor elements did not increase the rate or total quantity of gas produced.
6. During the process of anaerobic digestion for four weeks at 30°C, about 15 per cent of the total nitrogen in bullock dung was found to be converted into ammoniacal form. Due to the alkaline reaction of the medium the above fraction was lost by volatilisation when digested slurry was dried. The proportion of ammoniacal nitrogen formed increased with the period of digestion.
7. Digested slurry contained about 1.8 to 1.9 per cent nitrogen on the dry basis and nitrified to a greater extent than farm yard manure, on equivalent nitrogen basis.

e. <u>Various uses of Cowdung Gas Plant</u>

The various uses of cowdung gas plant as listed out by Patel (1964)[36] are the following (a) gives good calorific value, (b) cheap as a fuel (c) high nitrogen content of the manure and (d) other benefits such as the promoting of hygenic and sanitary condition in the cooking area and around the home.

a. <u>Good calorific value of the gas</u>

Patel (1964)[36] states that the gas has a calorific value of 550 BTU (British Thermal Units) per cubic foot. Patel and Narasimhan (1966)[37] opine that the gas thus generated by the gas plant contains 55 per cent methane and 45 per cent carbon dioxide approximately.

b. <u>Cheapness of fuel</u>

Wandrekar (1964)[38] has calculated the net savings in the cost of fuel by using cowdung for cooking purposes. The cost of the production of the gas according to Patel (1964)[36] is about Rs 3.00 per 1,000 cubic foot in the gobar gas plant.

The Appendix II shows the price and effective price of the various fuels.

The Directorate of Extension (1961)[39] have estimated the instal ling expenditure of the gas plant to be Rs 350/-.

c. <u>Nitrogen content</u>

Harikurat Singh (1958)[40] has pointed out that the plant takes only the gas out of cowdungs but returns the same that could be utilised for manurial crops.

The Indian Agricultural Research Institute[34] points out that the cowdung after the removal of heat constituents in the form of gas actually is a manure of high nitrogen content. The cowdung in the form of manure obtained from Gobar gas plant contains 1.5 per cent nitrogen while the farm yard manure contains only 1 per cent nitrogen in its dry matter says Patel (1964)[36].

4. Other benefits

Indian Agricultural Research Institute[34] reports that the blue flame of gas is hot and smokeless, helps cooking. Apart from the above good quality of cowdung gas, it helps to maintain the sanitary aspects relating to complete stoppage and spread of pathogenic organisms from dried and fresh dung around the village says Harkirat Singh (1958)[40]. According to Chittaranjan Prasad (1966)[27] the gas can be utilised to generate mechanical and electrical energy by using it in an internal combustion engine which can be utilised for running pumps for irrigation purposes chaff cutting machines and for and providing light in the villages.

B. Studies Conducted on Cow Dung gas Plants

The experiments conducted by Tej Narain and Ramamurthy (1964)[41] at a Gram Sevika Training Centre at Rajendranagar show that 13 cubic feet of gas per hour is required for cooking food for six persons. The study revealed that to satisfy the gas requirements for cooking for a family of six a gas holder with a diameter of five feet, a height of four feet, located at a distance of about 33 feet, supplied with about 15 lbs of cowdung per day was necessary. According to the studies conducted by Acharya (1957)[4] the dung loses about 27 to 28 per cent of dry matter and yields about 105 cubic feet of gas per lb. of fresh bullock dung added or about 8 cu. ft of gas per lb of dry matter in the added dung. He again stresses that dilution of dung with water (1:1 or 1:1½) to 2 levels of 7 to 9 per cent solids was found to increase the rate of gas production. The rapidity of gas production increases with increasing proportion of inoculum to fresh added dung.

The study conducted by Kamalaveni (1962)[42] reveals that the following characteristics of cattle dung gas while using over fire wood.

a) A saving of 28 per cent of time for cooking three meals for a family of three was noted.

b) There was a saving of 63 per cent of time taken for scrubbing the utensils while washing them after they were used for cooking.

c) The foods cooked using cattle dung gas were acceptable to the same extent as those cooked with firewood as the fuel.

III EXPERIMENTAL PROCEDURE

The experimental procedure for the study comprises of the following steps:

A. Developing the Plan for Construction of the Gas Plant

B. Constructing the Cowdung Gas Plant

C. Evaluation of the constructed Gas Plant.

A. <u>Developing the Plan for Construction of the Gas Plant</u>

The development of a plan for construction of a gas plant included the following steps.

1. Observation of the different gas plants installed at Coimbatore city and collecting needed information from the homemakers.

2. Selection of the design for the construction of the gas plant.

1. Observation of the different gas plants in Coimbatore city and interviewing the homemakers.

Goode and Hatt (1952)[43] remark that observation is both a primitive and modern technique. It is the simple art of looking and listening. There are two types of observation - controlled and uncontrolled. In controlled observation the observer will become a temporary insider and share the feelings of the groups of individuals. The F.A.O. (1957)[44] reports that non participant observation consists of looking, for specific social situations but not taking part in them. Goode and Scates (1954)[45] state that in interview the investigator gathers data directly through face to face contacts unlike the questionnaire. The tool useful for conducting interviews are-check lists and interview schedules. Burchinal and Hawkes (1957)[46] assert that interview method is likely to be more correct than the information obtained by means of other techniques. Therefore observation coupled with interview schedule was formed in order to observe some of the gas plants in Coimbatore.

The schedule calls for information regarding the installation and operation of the cowdung gas plant in their respective homes, number of family members present in the home, number of cows maintained, benefits and problems faced while cooking with the cowdung gas. The schedule is given in Appendix III, The homemakers were interviewed and their responses were collected (Table I).

TABLE I

RESULTS OF THE OBSERVATION MADE IN THREE GAS PLANTS IN COIMBATORE CITY

Particulars	Gas plant No.1	Gas plant No. II	Gas plant No.III
Number of members in the family	10	10	100
Number of years old	13	7	2
Distance in feet from cowshed to gas plant	9	15	30
Distance in feet from gas plant to the house	20	100	120
Weight of cowdung in pounds used per day for gas plant	300	400	3200
Whether urine is utilised for mixing the dung	Yes	No	Yes
Proportion of mixing dung with water or urine	1:1	2:3	2:3
Problem faced during installation	No problem. Gas supply being high, a second gas drum was erected.	Collection of water in the tubes. So every six months tubes, are disconnected.	No problem
Advantages	1. No soot formation 2. No smoke 3. Short time needed for cooking 4. Readily ignited 5. Easy cleaning of vessels	1. No soot formation. 2. Time is saved 3. Cowdung after use in gas plant could be utilised as rich manure.	
Disadvantages	None	None	

The observations of gas plant at Coimbatore city show that the distance between cowshed and the gas plant can vary from nine feet to thirty feet. From the observations it has been calculated that nearly thirty [pounds] grams of cowdung is needed in order to obtain the necessary fuel to cook a meal for one person. So this type of observation gives a clear idea about the details of the gas plant, distances from the plants to the homes and the proportions of mixing the cowdung with water or urine.

2. Selection of the Design for the Construction of the Gas Plant

Designs collected from four different sources were studied, three locally operated at Coimbatore and one supplied by Khadi Village Industries Commission. The Khadi Village Industries Commission plan is given in Appendix IV.

B. Constructing the Cowdung Gas Plant

The construction of the cowdung gas plant involved the following steps:

1. Selection of a site
2. Estimation of the cost
3. Selection and procurement of building materials
4. Engaging labourers
5. Construction of the cowdung gas plant.

1. Selection of a site

A site with an area of three hundred square feet and a length of twenty feet and fifteen feet width was selected within Sri Avinashilingam Home Science College Campus.

Distance between cowshed and the house where the gas plant was to be installed, was the important point which decided the selection.

2. Estimated Cost of the Cowdung Gas Plant

The total estimated cost excluding the land value was Rs 2400/- The estimated cost for the various particulars regarding the cowdung gas plant are given below.

	Rs nP
Building materials for constructing the gas well	770. 00
Labour charges	440. 00
Gas drum	900. 00
Materials needed such as G.I pipes and other pipes	290. 00
	2400. 00

3. Selection and Procurement of Building Materials

Building materials such as brick, stones, mud, cement and concrete for constructing the gas plant were selected with great care.

a. Brick

For good masonry construction Yurtak (1960)[47] views bricks of fine quality, of uniform size, properly moulded, and burnt would be essential. Deshpande (1959)[48] has pointed out that quality bricks must be well burnt, they should be free from cracks when struck, firm, regular in shape, and uniform in size. For these reasons country made ground moulded, bricks were selected for constructing the gas well and mixing tank.

b. Stone

According to Vartak (1960)[47] stone of homogeneous quality without veins is the best material for construction. The Madras Detailed standard Specification (1960)[49] suggests that the stone used for foundation and wall should be sound and free from cracks and decay. Care needs to be exercised in using proper sizes of stones and correct interlocking in the width of walls. Therefore stone of homogeneous quality was selected for foundation.

c. Mud

Prem (1960)[50] states mud is the most commonly used material all over the country for building construction. Mud was included for the gas well, since it was one of the common locally available building materials.

d. Cement

The Experts Committee (1957)[51] view that the use of cement in building constructions should be curtailed as far as possible. For the purpose of durability cement should be used where the floors or walls come in contact with water. In the gas plant the space in between the gas well was plastered with cement to facilitate the circulation of water.

e. Concrete

Concrete floors are smooth, neat and lasting. They can be constructed easily by following a few elementary rules says Concrete Association of India (1956)[52].

For finishing the bottom of the gas well concrete was used in the construction.

4. Engaging the labourers for construction

A maistry who was already working in Sri Avinashilingam Trust Institutions was entrusted with the construction of the gas plant under the supervision of the investigator. He engaged the required men and women and other workers. Also a supervisor was engaged to supervise the whole construction.

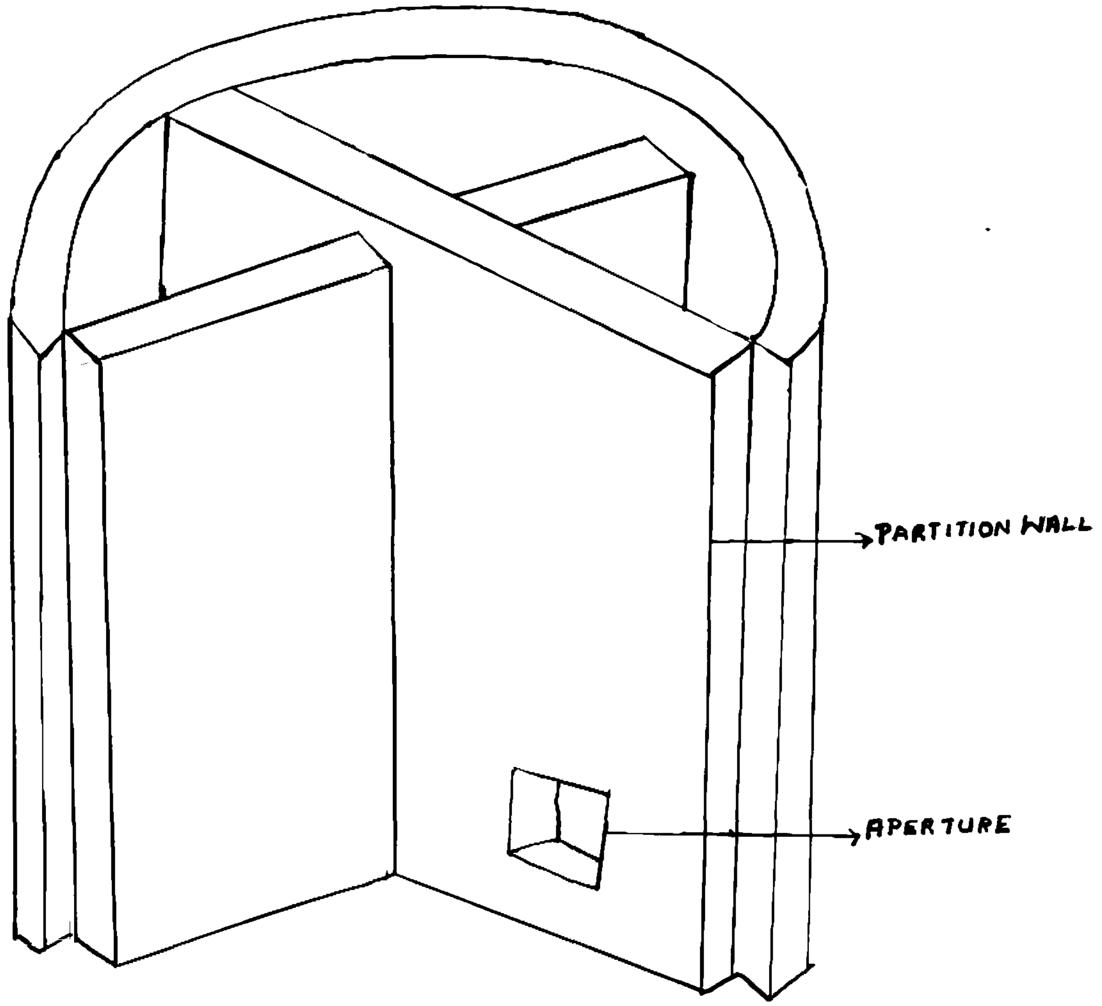

FIGURE 2.

CROSS SECTION OF THE GAS WELL.

5. Construction of the Cowdung Gas Plant

Patel has outlined the essential points to be considered in constructing a gas plant (Appendix V).

The construction of the cowdung gas plant in the selected site included the preparation of the ground such as cleaning the area, uprooting the trees, removing the thorns in the site and marking the the boundaries. The gas plant consisted of the following sections. (1) inner well, (2) outlets (3) outer wall (4) mixing tank (5) gas drum and (6) pipes.

For the inner well a cylinderical pit Figure 1 (a) of nine feet diameter with a depth of nine feet was dug. The bottom (b) was lined with concrete in cement and mortar, to a depth of one foot. A brick circular wall (c) was built on this concrete circular base and the inner surface was plastered with cement.

From the base an inlet for letting in the cowdung mixture (d) and an outlet for letting out the slurry (e) were provided. These opened out at a distance of six feet and seven feet from the gas well respectively on either side.

The area within this construction was divided into four sections as shown in Figure 2 which gives the cross section of the cylinderical pit. The dividing walls were of 4½" thickness each. One of the separating walls as shown in figure 2 was extended to 1½ feet above another wall. One square foot apertures, numbering two, were made on the higher walls.

From the ground level this cylinderical cement construction was raised to four feet. Surrounding this inner cylinderical cement wall, another outer wall (f) was, constructed with a diameter of ten feet. In between the space was filled with water.

A mixing tank (g) was constructed three feet away from the gas well by using brick and mud and it was plastered with cement. It consisted of two tanks. The length width and height of the big tank were 3'10", 3'10" and 1'3½" respectively and the wall had a thickness of 10".

The length, width and height of the smaller tank was 3'1", 2'1" and 1'1" respectively. The thickness of the wall was ten inches.

The gas drum (h) with a diameter of 8'9" with a height of 4' was specially designed for the purpose of collecting the gas produced. The gas drum was made of seven iron sheets of 16 galvanised type, fixed together, with the help of iron nails.

Operating the Cowdung Gas Plant

The cowdung from eight cows was collected every morning and evening and the sticks and other small bits of hay were removed. The dung was weighed and taken to the mixing tank, which consisted of two tanks, 'A' the bigger and one 'B' the smaller one. (Figure 3). The cowdung was mixed in the bigger tank, the proportion of mixing it with water being 2:3. The interval view of the mixing tank is shown in Figure 4. The outlet of the bigger tank was closed while mixing the cowdung with water in order to prevent the mixture from escaping. When the mixing was complete the outlet was opened to enable the mixture to pass through. The construction of the tank 'B' was such that when the outlet of the bigger tank was opened the mixture would pass on directly to the gas well. In the centre of the tank there was an opening of 6" in diameter through which the mixture passed on to the inner well.

The construction of the inner sections A,B,C,D was such that the cowdung mixed with water could pass through from one section to another in order to facilitate fermentation. To section 'A' the inlet was fixed. The cowdung mixture rose to full depth in it and then flowed into the next section B. From this it passed to section C through the opening at the bottom. On rising to the full depth, it passed to the next section, D. From section D the slurry came out through the outlet and facilitated fermentation.

The gas drum (Figure 5) placed in an inverted position in between the inner and outer gas wells helped to collect the gas evolved from the cowdung.

In order to prevent the gas drum from rising further three iron rods were fixed pointing towards the centre as shown in (Figure 5). These were used to keep the drum in position.

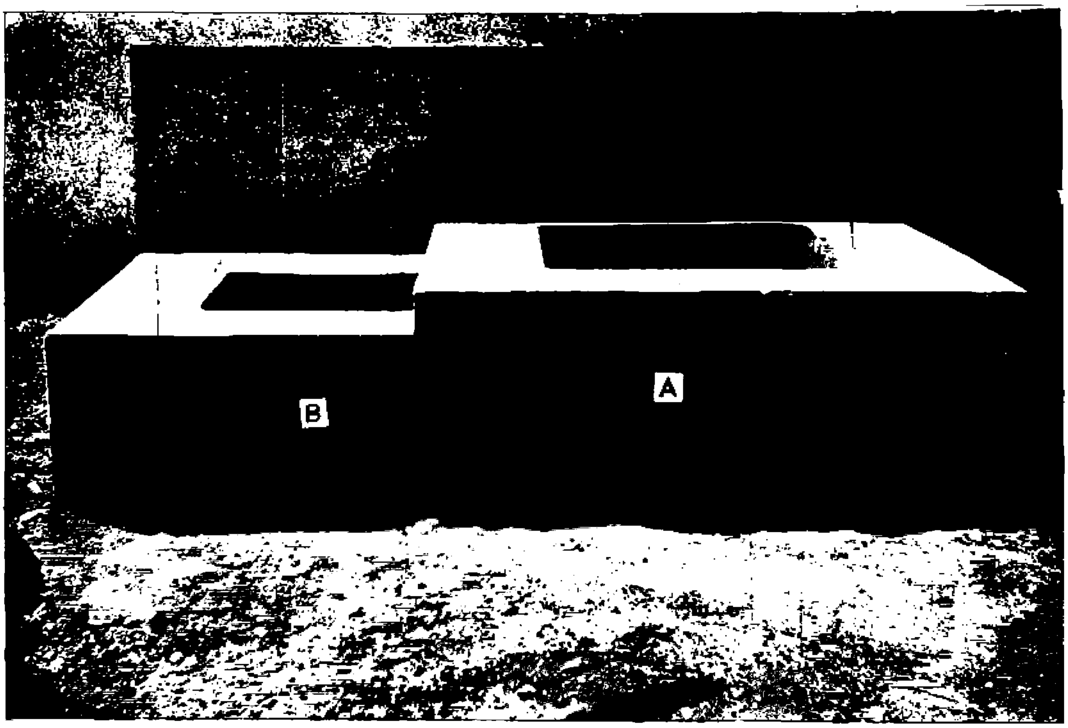

FIGURE 3

MIXING TANK.

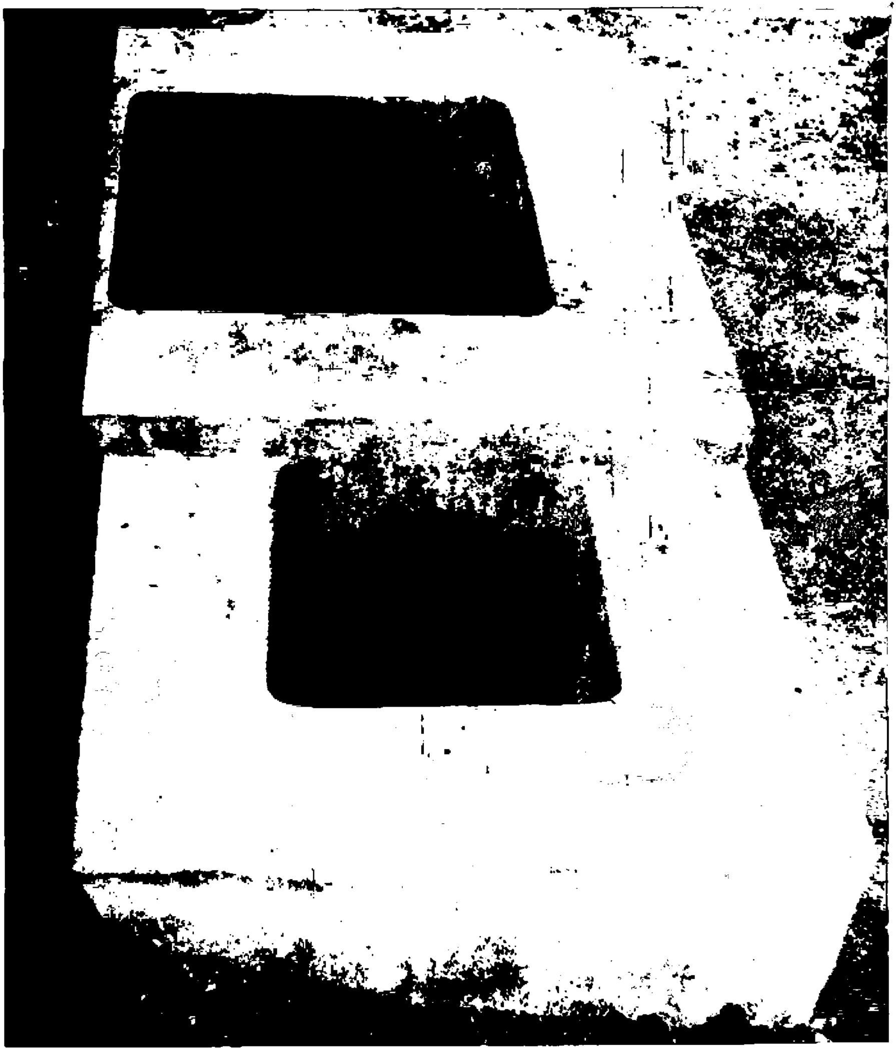

FIGURE 4

INTERNAL VIEW OF THE MIXING TANK

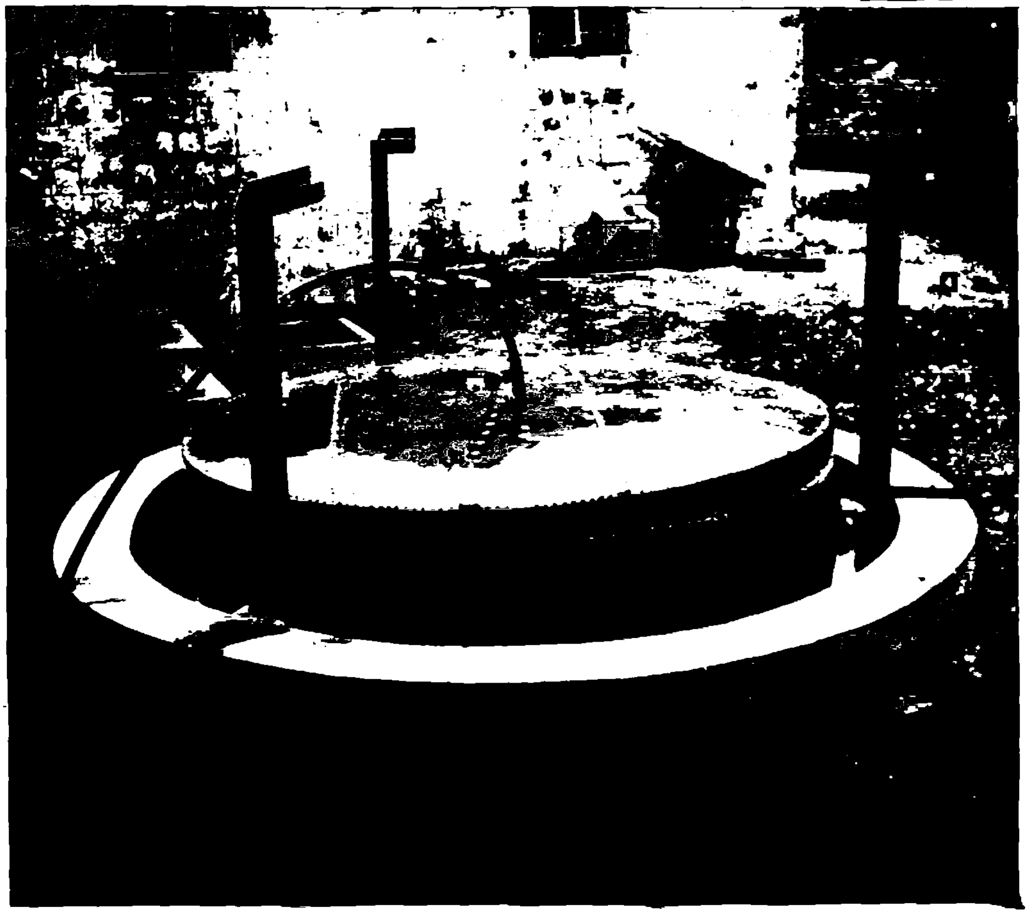

FIGURE. 5

COW DUNG GAS PLANT

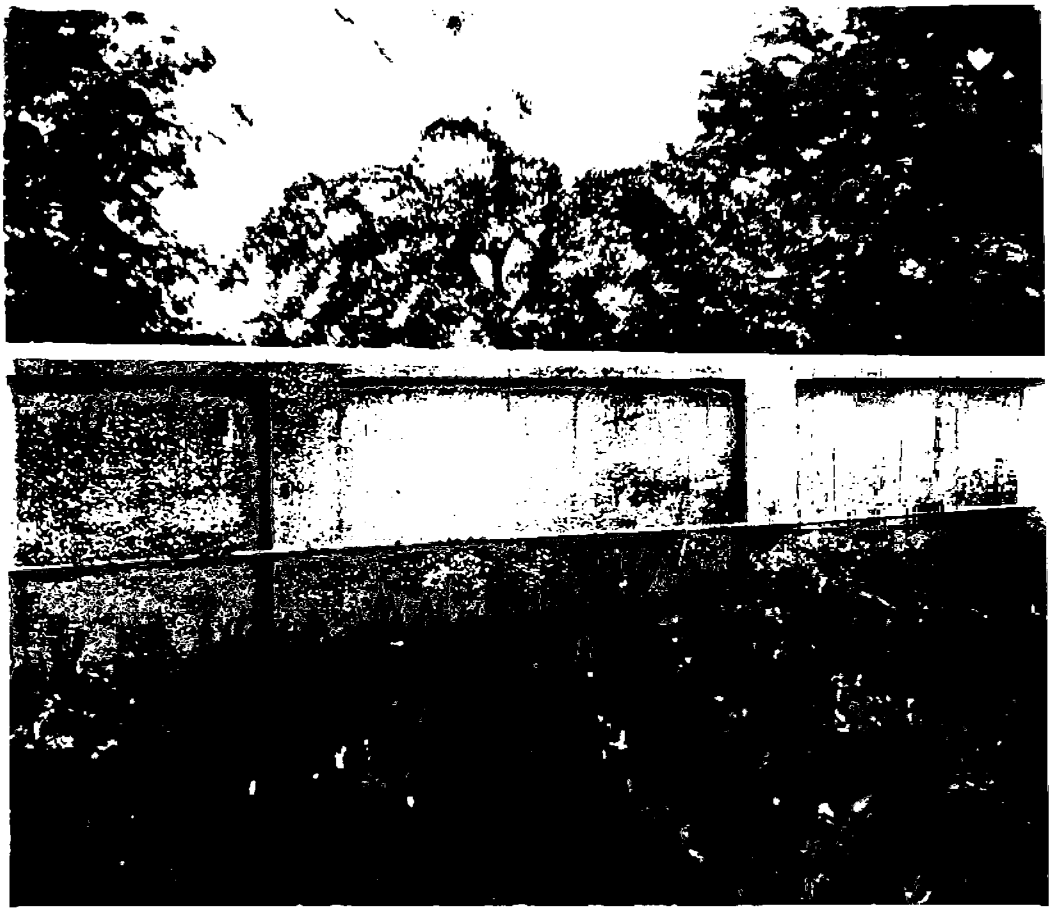

FIGURE 6

PIPE LINE

In order to take away the collected gas to the kitchen a polythene pipe with a diameter of two inches and 12' length was connected to the opening provided at the top of the gas drum. This is shown in Figure 5. The polythene pipe was connected to a galvanised iron tube of 100 feet length to take the gas to the kitchen. Figure 6 shows the pipe line system.

On the other end the galvanised iron pipe was connected to a two way pipe, each one having a separate gas regulator for regulating the flow of gas. By means of rubber tubing the two way pipes were connected to gas burners as shown in Figure 7.

The slurry after gas production was collected in the slurry pit meant for the purpose. (Figure 8).

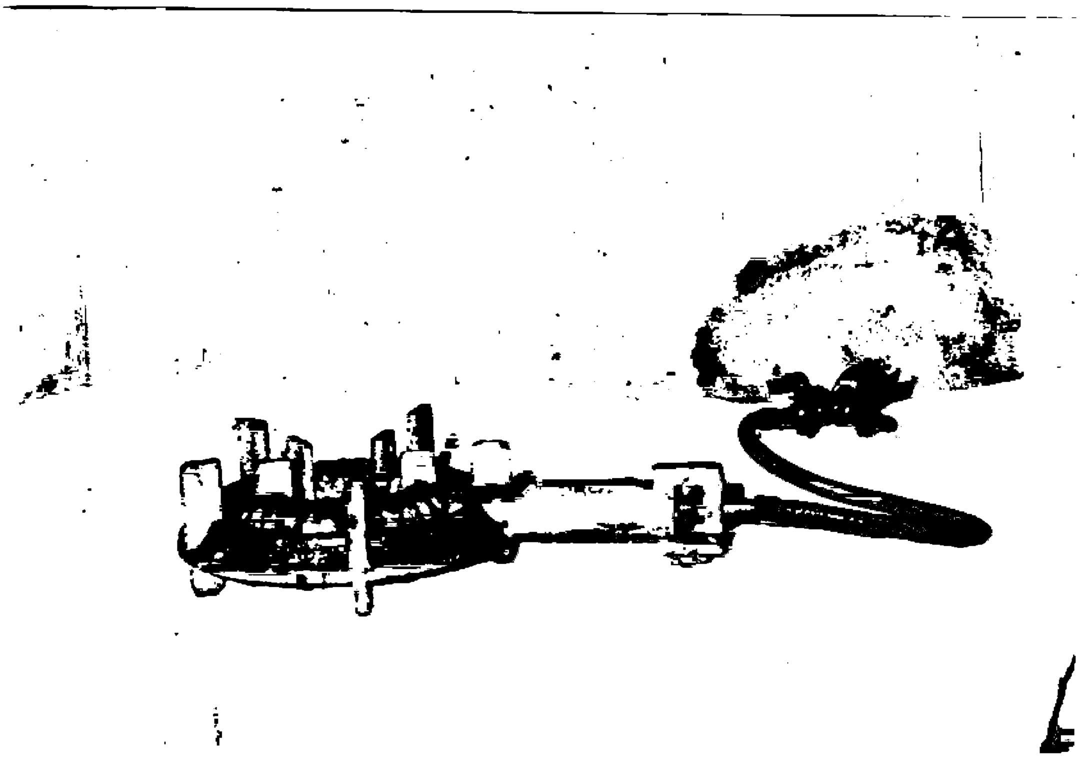

FIGURE. 7

GAS STOVE

FIGURE 8

SLURRY PIT

The slurry after gas production was collected in the slurry pit meant for the purpose. (Figure 7).

C. Evaluation of the Constructed Gas Plant

The Evaluation was done by the Investigator as stated below:

1. Comparing the two fuels - cowdung gas with kerosene.
2. Analysing the nitrogen content of the slurry and the cowdung.
3. Assessing the adequacy of gas for a household of six members.

1. Comparision of the two Fuels

The experiment expenditure in this study were based on cooking standardised food preparations using the cowdung gas fuel in comparision with the control fuel that is kerosene with the following criteria for evaluation.

1. Selection and standardisation of cooking of the food preparation.
2. Measurement of fuel consumed for cooking.

1. Selection and Standardisation of cooking of the food preparations

The equipment used in the study consisted of a gas burner, a stove, utensils for cooking, measuring, devices, balance and weights.

<u>Gas burner</u>

Two iron gas burners were connected to the G.I pipe which brought the cowdung gas to the kitchen.

The burner consisted of (1) a hollow ring with orifices for the passage of gas (2) four projections to serve as rests for the utensils and it also allowed the space for flames to heat the utensils. To compare the cow dung gas with kerosene, a janata stove with the same diameter was selected to keep the area of the flame the same in both the cases.

Utensils

For cooking dhal, rice and vegetables, two identical sets of brass utensils were also selected.

Measuring and weighing

A set of standard measuring cups graduated in grams were selected to measure water. A 1000 milli litre measuring cylinder was used for measuring kerosene. For weighing the food stuffs 500 grams capacity dietetics scale was selected. A time piece was selected for recording the time involved in all the activities of the study.

Foods

The items selected for cooking included, rice, dhal and vegetables and preliminary experiments were conducted to standardise the receipies for the above.

Lighting and maintaining the Fire

Each time the burner was lighted the gas regulator was turned to allow the fullest supply of gas and the utensil was placed on it. It was found necessary to use at three levels of heat while operating the gas burner and stove-high, medium, and low depending on the methods of cooking employed.

Apart from the above items the cooking sequence was standardised for stirring of the food, flame control and for the adjustments of lids.

2. Measurement of fuel consumed for cooking

The cowdung gas was obtained from the gas plant erected at Sri Avinashilingam Home Science College as per the given descriptions on page 26.

The rate of flow of gas was measured by simple displacement method described in Appendix VI.

By knowing the rate of flow of gas per second under high, medium and low flame, the total volume of gas consumed during the entire period of cooking was calculated. Kerosene was measured by using a measuring cylinder. From the quantity used, the cost of fuel was calculated. The cost of the cowdung gas was calculated as follows. Thousand cubic feet of gas costs about Rs 3 says Patel (1964)[36]

2. Analysing the nitrogen content of the slurry and cow dung

A sample of cowdung mixed with water and another sample of slurry were dried in the oven. After the samples got dried they were analysed for nitrogen content by using Macro kjeldhal method. The experiments were repeated thrice in order to get concordent values.

3. Adequacy of the gas for a household of six members.

The gas was utilised for cooking purposes by a family of six members, under the guidance of the investigator for a period of three days.

The time taken for cooking and the items cooked were noted down. This helped in finding out if free flow of gas was present and whether the gas available for use was sufficient enough for cooking the food for a family of six members.

IV RESULTS AND DISCUSSION

The results of the study are discussed under the following headings.

A. Cost incurred in constructing the gas plant.

B. Evaluation of the constructed gas plant.

A. Cost incurred in Constructing the Gas Plant

The cost of construction of the gas plant is discussed under the following headings.

1. Total cost of the gas plant.
2. Cost of building materials used in construction.
3. Wages for labourers for construction of the gas plant.
4. Expenditure incurred in making the gas drum
5. Number of days taken for construction of the plant.
6. Time taken for gas production.

1. Total cost of the Gas Plant

Table II presents the total cost incurred in constructing a strong durable cowdung gas plant in a city of Coimbatore.

TABLE XI

TOTAL COST INCURRED IN CONSTRUCTING THE CONDURO GAS PLANT

S.No.	Particulars	Unit	Cost per unit Rs nP	Quantity	Total Rs nP
1.	Excavation	1000cft	60. 00	1711cft	102. 66
2.	Cement concrete	100cft	125. 00	109.4cft	136. 75
3.	Brick wall with cement mortar 1:5	100cft	165. 00	440	726. 00
4.	Cement plastering	100sqft	28. 00	1291sqft	361. 48
5.	External plastering with cement	100sqft	17. 00	297.0sqft	50. 49
6.	Miscellanious war packing pipe and filling with earth etc.	-	-	-	33. 78
7.	Tin cover for the gas drum material & Labour charges	-	-	-	1000.00
8.	Transport charges for building materials	-	-	-	6. 63
		Total cost incurred			2417. 79

From the above it is clear that the total cost incurred in constructing a gas plant amounted to Rs 2417-79 and this excluded the cost of land.

2. Cost of building materials used in Construction

Table XXI shows the total cost incurred in purchasing the building materials needed for constructing a gas plant.

TABLE XXI

COST OF BUILDING MATERIALS USED FOR THE CONSTRUCTION OF THE GAS PLANT

S.No.	Building materials	Unit	Cost per unit Rs nP	Quantity purchased	Cost of quantity purchased Rs nP
1.	Granite stone	100cft	55.00	80 cft	44.00
2.	Cement	one bag	9.50	21 bags	199.50
3.	Mud	100cft	25.00	130cft	32.50
4.	Brick	1000	37.00	4500	166.50
5.	R.C.C.concrete	Number cu.ft	300.00	37.7	339.30

Total cost of building materials used in construction of gas well and mixing tank	781.80

MATERIALS NEEDED FOR FIXING UP PIPES TO THE GAS DRUM

S.No.	Materials	Unit	Cost per unit Rs P	Quantity purchased	Cost of quantity purchased Rs P
6.	1½" G.I pipe with coupling measureing 12.90 inches	one	5.08	12	60. 96
7.	1½" G.I. elbows	one	2.35	4	9. 40
8.	¾" G.I. Union	one	3.00	6	18. 00
9.	¾" Bend with coupling	one	1.50	2	3. 00
10.	¾" G.I. tube	one	1.30	2	2. 60
11.	¾" G.I. pipe coupling	one	2.95	61.50 inches	181. 42
12.	Apex stopcock	one	12.25	one	12. 25
13.	1" Nipple	one	1.25	two	2. 50
14.	1" Hose nipple brass	one	3.50	one	3. 50
15.	1" Ledger gate value	one	20.35	one	20. 35
16.	White lead	1 kg.	3.50	1 kg.	3. 50
17.	⅜" x ½" Red coiling tube	one	0.75	two	1. 50
18.	⅛" x ½" Red coiling tube	one	0.47	two	0. 94
19.	½" Plug	one	0.25	3	0. 75
20.	1" Alkathene Hosepipe	one	1.05	12	12. 60
21.	1" Hose clips	one	6.60	two	13. 20
		Sales Tax			0. 58
	Total cost involved in purchasing materials used for fixing up pipes				346. 90

MATERIALS USED FOR MAKING GAS DRUM

S.No.	Materials	Unit	Cost per unit Rs nP	Quantity purchased	Cost of quantity Rs nP
22.	G.I. sheet 16 galvanised	8'x3'	95. 00	7	665. 00
23.	Aluminium angles	1 ft	1. 00	84 ft	84. 00
24.	Riverts and washers	1 kg.	16. 50	2½ kg.	41. 25
25.	Washer pockets	1 packet	1. 75	5 packets	8. 75
26.	Lead	1 kg.	20. 00	1½ kg.	30. 00
	Transport charges				6. 63
	Sales Tax				14. 37
	Total cost for Building materials for making drum				850. 00
	Total cost of the Building Materials used for construction				1978. 79

Table XII indicates that the total cost of the building materials is Rs 1978-79 constituting 81.8 per cent of the cost of the cowdung gas plant.

2. <u>Wages for labourers for construction of the Gas Plant</u>

The two main types of labour utilised for the construction of the cowdung gas plant were skilled and semiskilled. The skilled labourer included masonry work and making of the drum where as earth work, washing, cleaning the place, bringing water, carrying building materials and similar work constituted semiskilled work.

Wage rates of the labourer were based on the type of work carried out. The mason involved in making the drum was paid Rs 5 per day and the other mason connected with building construction was a paid Rs 5.50 per day. The man majdoor grade (1) and the woman majdoor grade (2) performing unskilled work received Rs 3.25 and Rs 1.50 per day, respectively. Table VI pictures the total number of labourers engaged for the construction work.

TABLE IV

[illegible] COSTS OF LABOUR FOR THE CONSTRUCTION OF THE COWDUNG GAS PLANT

S.No.	Type of work	Mason		Men majdoor		Women majdoor		Company workers		Cost	
		No.	Days of work	No.	Days of work	No.	Days of work	No.	Days of work	Rs	P
1.	Site clearance	-	-	1	1	-	-	-	-	5.	25
2.	Earth Excavation	-	-	4	5	5	6	-	-	110.	00
3.	Mixing cement and concrete	1	1	4	1	3	2	-	-	27.	50
4.	Making drum	-	-	-	-	-	-	3	10	150.	00
5.	Packing pipe etc	-	-	-	-	-	-	-	-	33.	75
6.	External plastering with cement	-	-	3	2	2	3	-	-	47.	50
7.	Construction of mixing Tank and gas well	2	2	-	-	6	3	-	-	67.	00

Total cost on Labour 439 . 00

The above shows that the total labour charges paid amounted to ₨ 439.00. This constituted 18.2 per cent of the total cost of construction of the gas plant.

4. Expenditure incurred in making the gas drum

From Tables III and IV it is evident ₨ 1000 was spent on making the gas drum. This involved 41 per cent of the cost of construction. Out of ₨ 1000/- eighty five per cent of the money was spent on gas drum materials where as fifteen per cent was utilised for the labour.

5. Number of days taken for construction of the gas plant

Table V shows the number of days taken for constructing each selection of the gas plant and also the total number of days taken for the entire construction.

TABLE V

NUMBER OF DAYS TAKEN FOR CONSTRUCTION OF THE GAS PLANT

S.No.	Particulars	Number of days taken
1.	Excavation	15
2.	Constructing the inner well, and partitions	21
3.	Constructing the outer well	6
4.	Constructing the two mixing tanks	6
5.	Making gas drum	10
6.	Fixing up pipes	2
7.	Digging the slurry pit	5
8.	Total number of days taken for construction	65

It is evident from the above that the total number of days taken for the construction was 65.

6. Number of days taken for gas production

The emergence of slurry from the pit was a sign of complete circulation of dung through all the sections of the plant. This being essential for facilitating quick gas production, 1250 pounds of cowdung were added twice at intervals of 30 days. Also fermented slurry weighing 250 lbs from one of the operating gas plants was added to hasten the bacterial action. In spite of all these efforts 111 days were taken for gas production.

The gas was tested for its presence, by lighting a candle and holding it "at a distance of 6 " from the two way gas tap in the kitchen. On opening the gas tap, it took five minutes for the gas to come through the lead pipe.

Evaluation of the constructed gas plant

The gas plant was evaluated as follows:

1. Comparison of the two fuels namely cowdung gas and kerosene.
2. Analysing the slurry and cowdung for nitrogen content
3. Testing for the adequacy of the gas.

Comparision of the two fuels

The data obtained in the experiments conducted as described in page 36 were studied in relation to the two aspects of home-management, time and money.

a. Time taken for cooking:

The time taken for cooking three food items: namely rice, dhal and vegetable using kerosene and cowdung gas as fuels respectively is given in Table VI below. The details are given in

Appendix VII and VIII . For each set of rice, dhal and vegetable the average value was calculated and presented.

TABLE VI

TOTAL TIME TAKEN FOR COOKING THE THREE ITEMS USING COWDUNG GAS AND KEROSENE

Triplicates	Time taken in minutes		Average	Average in percentage
	Cowdung gas	Kerosene		
1.	23.3	27	—	—
2.	20.6	29	—	—
3.	22.6	24.6		18%
Average	22.2	26.9	4.7	—

As can be seen from Table VI the total time taken to cook the three items using cowdung gas as fuel was 18 percent less than the time taken to cook the three items using kerosene as fuel. This is because of the presence of high calorific value (550 British Thermal units per cubic foot). While applying the 't' test as shown in Appendix IX this was significant at 1 per cent level.

Time taken to cook each item

The time taken to cook rice, dhal and vegetable separately is discussed below in detail.

Time taken to cook rice

Table VII presents the time taken to cook rice using cowdung gas and kerosene.

TABLE VII

TIME TAKEN FOR COOKING RICE USING COWDUNG GAS AND KEROSENE

Triplicates	Time taken in minutes		Average time in percentage
	Cowdung gas	Kerosene	
1	27	30	—
2	23	35	—
3.	30	25	—
Average	26.6	30	11.3%

The average time saved for cooked rice by using cowdung gas is 11.3 per cent. While applying the 't' test as shown in Appendix X it was not significant at 5 per cent level.

Time taken for cooking Dhal

Table VIII indicates the time taken for cooking dhal using cowdung gas and kerosene.

TABLE VIII

TIME INVOLVED IN COOKING DHAL USING KEROSENE AND COWDUNG GAS.

Triplicates	Time taken in minutes		Average time in percentage
	Cowdung gas	Kerosene	
1	30	35	—
2	25	34	—
3	25	31	—
Average	26.7	33.3	19.9%

As indicated in the above Table 20 per cent of time was saved for cooking dhal by using cowdung gas as fuel. While applying 't' test as shown in Appendix XI this was significant at 1 per cent level.

III. <u>Time taken to cook potatoes</u>

Table IX presents the time taken to cook seventy grams of potatoes using cowdung gas and kerosene.

TABLE IX

TIME TAKEN IN COOKING POTATOES USING KEROSENE AND COWDUNG GAS

Triplicates	Time taken in minutes		Average time saved in percentage
	Cowdung gas	Kerosene	
1	13	16	—
2	14	18	—
3.	13	18	—
Average	13.3	17.3	23%

This again indicates that the use of cowdung saves 23.1 per cent of time for cooking potatoes.

On statistically analysing the data given in Table IX using the 't' test (Appendix XXI) the difference in time taken for cooking using the two fuels, was found to be significant beyond one percent level.

<u>Cost of fuels used</u>

<u>Cowdung gas consumption and cost incurred</u>:

The gas consumption for the total cooking time in terms of cubic feet was calculated on the basis described below.

30 centimeters	=	1 feet
30 x 30 x 30 centimeters	=	1 cubic feet
1000 cubic feet of gas costs	=	Rs 3
∴ x cubic feet of gas	=	$\frac{3}{1000}$ x

Table X presents the amounts of gas consumed for cooking the three items.

TABLE X

AMOUNT OF GAS CONSUMED FOR COOKING THE THREE ITEMS

Triplicates	Amount of gas used in cubic feet	Cost in paise
1	25.27	0.8
2	22.4	0.7
3	24.37	0.7
Average	24.01	·735 7.33

The above table shows that the total gas consumed for cooking the three food items on an average amounted to 24.01 cu. ft. The cost on calculation was found to be 7.3 paise for the above. The details of the gas consumption is given in Appendix XXIX.

II. Kerosene Consumption and Cost:

Table XI gives the consumption of kerosene for cooking the three items. The kerosene used for the experiment was purchased at the rate of 52 paise per litre.

TABLE XI

VOLUME OF KEROSENE CONSUMED FOR COOKING THE THREE ITEMS

Triplicates	Quantity of kerosene used in milli litres	Cost of paise
1	213	0.11
2	222.2	0.12
3	217.8	0.11
Average	217.6	11.33

Thus the figures in Table XI shows that 217.6 milli litres of kerosene were needed for cooking these three items:

<u>Total cost incurred by using cowdung gas and kerosene</u>

Table XII indicates the total cost incurred for cooking the items using cowdung gas and kerosene.

TABLE XII

COST INCURRED FOR COOKING BY USING COWDUNG GAS AND KEROSENE

Triplicates	Cost incurred				Percentage of money saved
	Cowdung gas		Kerosene		
	Rs	P	Rs	P	
1	0	6	0	11	
2	0	7	0	12	35.3%
3	0	7	0	11	
Average	7	33	11	33	

The figures in table XXI indicate that on an average an amount of 35.3 per cent was saved while cooking the three items.

Investment and Returns from the gas plant

The installation of the cowdung gas plant is recommended only to homes where dairy units are maintained. The dung obtained is free of cost and this is used for the production of gas. If cowdung gas is used as the main fuel for the household the household budget need not make any allowance for fuel. On the other hand if kerosene is used a sum of about Rs 189 would be needed for fuel annually for a family of six members. This amount could be saved if cowdung gas is used instead of kerosene. The monetary returns from the cowdung and slurry is calculated as shown in Appendix XIV. This shows the amount saved annually by selling slurry amounted to Rs 58.40. The savings realised from cow dung gas and the slurry would amount to Rs 247.40 annually. This is a substantial sum though the installation cost of the gas plant had been as high as Rs 2500. If the capital Rs 2500 had been invested in a bank on fixed deposit scheme at the rate of 7 per cent per year it would fetch Rs 175 which when compared to the total monetary returns from the same capital invested on a gas plant is found to be low.

Therefore in the long run, the cowdung gas plant would be found economical. Patel (1964)* has pointed out some of the facilities available to homemakers for installation of gas plants. These include free technical advice, and the financial assistance on capital amounts which could be returned on instalment

* Patel, J. J., GOBAR GAS SCHEME, Khadi and Village Industries Commission.

basis (Rs 250 annually in a period of ten years). This would be practicable for homemakers considering the substantial annual monetary returns from the gas plant.

4. Sanitary aspects of Cowdung gas:

Cowdung gas is produced by the treatment of cowdung, waste matter, where as kerosene has to be purchased. The digested cowdung after gas production does not attract any flies and organisms. Thus it helps in maintaining the sanitation around the dairy unit cowdung and home premises.

As a fuel cowdung gas was found to be easy, satisfactory and convenient compared to kerosene.

5. Nitrogen Content of the Slurry and Cowdung

Table XIII shows the nitrogen content of the slurry and cowdung.

TABLE XII

NITROGEN CONTENT OF THE SLURRY AND COWDUNG.

Cowdung		Cowdung after gas production	
Titre value	Nitrogen content in percentage	Titre value	Nitrogen content in percentage
13.0	2.45	15.5	3.25
13.0	2.45	15.0	3.15
13.1	2.35	15.0	3.15
	2.35		3.18

The table above show in an average cowdung contains 2.55 percent of nitrogen where as cowdung after gas production contains 3.18 percent of nitrogen. This depicts the rich manurial value of cowdung after gas production.

2. Nitrogen Content of the Slurry and Cowdung

Table XIII shows the nitrogen content of the slurry and cowdung.

TABLE XXII

NITROGEN CONTENT OF THE SLURRY AND COWDUNG

Cowdung		Cowdung after gas production	
Titre Value	Nitrogen content in percentage	Titre value	Nitrogen content in percentage
13 - 0	2.45	15.5	3.25
13 - 0	2.45	15.0	3.15
13 - 1	2.75	15.0	3.15
	2.55	—	3.18

The Table above shows that on an average cowdung contains 2.55 per-cent of nitrogen where as cowdung after gas production contains 3.18 per cent of nitrogen. This depicts the rich manurial value of cowdung after gas production.

3. Adequacy of the gas for a Households of six members:

For a family of six members used of this gas was found to be adequate. The time taken for cooking, and the cost of the fuel are given in appendices XV, XVI, XVII. The gas flow was found to be continuous and adequate. The total volume of gas used for three days was calculated and the average used per day was obtained. On an average it was found that ninety one cubic feet of gas was needed to cook the whole day menu for a family of six members. The cost of 91 cubic feet of gas used was 27 paise where as the cost of cooking the same menu with kerosene amounted to 52 paise per day.

So it was concluded that 250 pounds of cowdung collected from eight cows was adequate enough to cook the whole day menu for a family of six members.

V. SUMMARY AND CONCLUSION

This study was undertaken in order to construct a cowdung gas plant at Sri Avinashilingam Home Science College and then to Evaluate the same with the following specific purposes.

1. Evolving a suitable plan for construction of the cowdung gas plant by observing and studying the gas plants operated at Coimbatore city and the one suggested by Khadi and Village Industries Commission.

2. Constructing scientifically a cowdung gas plant and finding out the expenditure incurred and time taken for completing the construction.

3. Evaluating the constructed gas plant by (a) comparing cowdung gas with kerosene (b) estimating the nitrogen content of the cowdung and the slurry (c) assessing the adequacy of the gas for a family of six members for cooking purposes.

On the basis of the observations conducted at Coimbatore city and by studying the plan evolved by Khadi and Village Industries Commission, a suitable plan was evolved. A cowdung gas plant was constructed at Sri Avinashilingam Home Science College grounds for supplying gas for a family of six members. This helped in ascertaining the cost incurred and time taken for construction. The gas plant was evaluated as follows. Three food items, rice, dhal and vegetable were selected and cooked with two common household fuels namely kerosene and cowdung gas. The cooking procedure, equipment and receipies were standardised. The time taken for cooking the food items and expenditure incurred for the fuels consumed were calculated. The adequacy of the gas was assessed by a family of six by cooking the menu for three days. The volume of gas consumed and the time taken for cooking were noted down. The cowdung and the slurry were analysed by Macro Kjeldhal method for nitrogen content and the results were compared.

The Outcomes of the study are given below:

1. The cost of installing a cowdung gas plant for a family of six members at Coimbatore city amounted to a sum of Rs 2417.79 . The cost of building materials and labour charges amounted to Rs 1980.82 and Rs 439/- and the former comprising 82 per cent of the total cost and the latter, 18 per cent.

2. The comparative study of cowdung gas with kerosene revealed the following:

(a). A saving of 18 per cent of time was noted for cooking the three items namely rice, dhal and vegetable . A saving of 11.3 per cent, 19 per cent and 23 per cent time was noted for cooking rice, dhal and vegetable individually.

(b) When compared with Kerosene, there was a saving of 35.3 per cent of the cost in using gas for cooking the three food items.

3. The nitrogen contentof the slurry and cowdung in the dry state was found to be 2.95 per cent and 3.18 per cent respectively.

4. The flow of gas was found to be continuous and adequate. On an average 91 cubic feet of gas was needed to cook the whole day menu for a family of six members. The gas obtained from 250 lbs of cowdung per day was found to meet the requirements of cooking for a family of six members.

5. The use of the dung for gas production contributed towards the sanitary aspects of the dairy a unit and the surroundings.

6. The annual monetary returns from the cowdung gas plant amounted to Rs 247.40 (58.40 from the slurry and Rs 189.00 from the fuel).

Considering the substantial annual returns from the gas plant and the ease with which gas could be utilised for cooking, in the long run, the plant would be found an economical and beneficial one inspite of high installation costs.

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APPENDICES

APPENDIX I

HEATS OF COMBUSTION TABLE*

Substance	Cal/gm.	Btu/lb.	Btu/ft^3
Acetylene	11800	21200	1,456
Coal bituminous	5000-7000	10,000-4000	—
Coke	6,900	12,600	—
Gasoline	11,500	20,750	—
Furnace oil	10,500	19,000	—
Methane	13,000	23,550	995
Coal gas	—	—	634
Natural gas	—	—	1050
Fats animal	9500	17,000	—

* Margenau H., Watson, W.W., Montgomery C.G., PHYSICS PRINCIPLES AND APPLICATIONS. McGraw Hill Book Company, Inc 1953, p 257.

APPENDIX H

PRICE AND EFFECTIVE PRICE OF VARIOUS FUELS*

Fuel	Calorific value k.cal.per.lb.	efficiency	Price per maund	Price per lb.	Effective price 100 k.cal
Soft coke	2800	28	2.60	3.17	3.95
Charcoal	3,150	28	8.25	10.00	11.40
Wood	2,140	17.3	2.00	2.44	6.59
Cattle dung cake	967	11.0	2.00/md	2.44	22.7
Kerosene	4903	48	1.75/gal	21.90	9.35
Electricity	—	75	.10pk. wh.	—	15.40
Coal gas	119.k.cal	60	4.30/ 1000c.ft	—	6.3
Gobar gas	142.k.cal per cft	60	3.00 1000 cft	—	—

*Patel, J.J. GOBAR GAS PLANT, ITS VARIOUS USES AND IMPACT ON SOCIETY. Khadigramodyog, Vol X. No. XI, 1964. p 759.

APPENDIX III

SCHEDULE USED FOR OBSERVATION

1. Name of the Head of the family ------------

2. Address

3. Number of members in the family ----------

4. Year of starting the cowdung gas plant ----------

5. Distance from cowshed to cowdung gas plant ------ -

6. Distance between cowdung gas plant to the house -- - --

7. Weight of the cowdung used per day for gas plant --- ---

8. Whether urine is used along with the cow dung --- -- -

9. If water is used the proportion of water used for mixing the cow dung -- -------------- --

10. Problem faced during installation and operation

11. Advantages and Disadvantages of cow dung gas plant.

APPENDIX V

POINTS TO BE CONSIDERED WHILE CONSTRUCTING A COW DUNG GAS PLANT

The cowdung gas plant consists of three parts. (1) Digester in which the raw material ferments, or digests, (2) gas holder which collects stores and delivers the gas at predetermined pressure. (3) gas pipe which carries the gas to the points of use without undue loss of pressure and in required amount.

1. Digester:- Digester is built entirely under ground with brick masonry cement and concrete. The size should be adequate to negotiate the quantity of raw material available daily and to carry the digestion to proper limits without being over loaded. It should produce the quantities of gas for which it is built, when required quantities of raw materials is fed in daily.

2. Gas Holder:- The gas holder should be made up of mild steel sheets. It should be protected by right type of paint to protect it from corrosion. It must be of adequate size to provide gas when needed and to collect, all gas produced in the digester without loss. It should be so designed that it delivers the gas at right pressure. It should also function as a scum breaker for digesting the slurry where it also form the cover the degester. It should be leak proof.

3. Gas Pipe:- Ordinary Galvanised Iron pipe can be used. Diameter should be sufficient enough to allow flow of gas, in adequate quantities in specific time without loss of pressure.

It should be provided with water traps at correct places and so laid that water is collected into traps provided and not in the pipes to block the passage of gas or to reduce the pressure of gas.

4. <u>Raw materials:-</u> It is therefore necessary to have an accurate estimate of available raw materials. When estimating availability of cow dung it is necessary to actually weigh the fresh dung weight of cowdung per cow varies widely due to the following reasons the size of cattle, the quantity and quality of feeding, the considerable variation in the time of cattle are out for grazing. This varies from region to region and from place to place in the same region.

Patel J.J., 'GOBAR GAS BURNER' - Khadi Industries Commission.

APPENDIX VI

MEASURING OF CATTLEDUNG GAS

The rate of flow of gas was measured by simple displacement method. A gas jar completely filled with water and covered with a ground glass cover was inverted over a beehive shelf placed in a trough of water and the cover was carefully removed under the water. The burner was detached and gas was was led to the shelf by means of a rubber tube. Gas was collected for a known period of time in the jar by displacement of water. After turning off the gas the levels of water inside the jar and outside were equalised in order to equalise the pressure of the gas collected to atmospheric pressure and the volume of the water collected was measured by pouring it in a measuring cylinder. This was repeated twice and the average rate of flow of gas per second was found out. The atmospheric pressure and room temperature was noted by applying the gas equation $PV = RT$ where P, V and T stand for pressure, volume and temperature measured in absolute scale of the gas collected and R is a constant the volume of gas at N. T. P was calculated by appropriate manipulation of the gas regulator the rate of flow of gas under high, medium and low flame were obtained:

This was repeated on two days and average was taken. The readings are given below.

Replicates	Rate of flow of cowdung gas volume of gas per second.		
	High flame level	Medium	Low
1	181 c.c	101 c.c	83. c.c
2	178 c.c	129 c.c	81 c.c
Average	180 c.c	115 c.c	82 c.c

Kamalaveni 'A STUDY OF CATTLEDUNG GAS AS A HOUSEHOLD FUEL'
A thesis submitted to University of Madras, 1962. p

APPENDIX VII

TIME TAKEN FOR COOKING RICE, DHAL AND VEGETABLE BY USING COW DUNG GAS

Items	Sample I					Sample II					Sample III					Average in minutes
	Initial		Final		Time taken	Initial		Final		Time taken	Initial		Final		Time taken	
	Hr	Mts	hr	mts	mts	hr	mts	hr	mts	mts	hr	mts	hr	mts	mts	
Rice	2.	13	2.	40	27	3.	07	3.	30	23	5.	15	5.	45	30	26.7
Dhal	3.	35	4.	05	30	4.	15	4.	40	25	4.	45	5.	10	25	26.7
Vegetable	11.	37	11.	50	13	11.	59	12.	13	14	12.	17	12.	30	13	13.3
Total time taken in minutes	—		—		70	—		—		62	—		—		68	66.7
Average time taken in minutes	—		—		23.3	—		—		20.7	—		—		22.7	22.2

APPENDIX VIII

TIME TAKEN FOR COOKING RICE DHAL AND VEGETABLE USING KEROSENE

Items	Sample I					Sample II					Sample III					
	Initial		Final		Time taken	Initial		Final		Time taken	Initial		Final		Time taken	Average time
	hr	mts	hr	mts	mts	hr	mts	hr	mts	mts	hr	mts	hr	mts	mts	mts
Rice	10.	50	11.	20	30	11	30	12.	05	35	12.	15	12	40	25	30
Dhal	1.	30	1.	35	35	1.	45	2.	19	34	2.	25	2.	56	31	33.5
Potato	3.	10	3.	26	16	3.	30	3.	48	18	3.	50	4.	08	18	17.3
Total time taken in minutes	—		—		81	—		—		87	—		—		74	80.6
Average time taken in minutes	—		—		27	—		—		29	—		—		24.6	26.9

APPENDIX IX

't' TEST FOR THE TOTAL TIME TAKEN FOR COOKING THE THREE ITEMS USING COWDUNG GAS AND KEROSENE

Two fuels	Mean	Standard Deviation	't' value*
Cowdung gas	22.2	1.31	3.96
Kerosene	26.9	3.24	

$\bar{x}_1 = 22.2$

$\bar{x}_2 = 26.9$

$= \frac{1}{3} (22.2 - 23.3)^2 + (22.2 - 20.6)^2 + (22.6 - 22.2)^2$

$= \frac{1}{3} (1.1)^2 + (1.6)^2 + (1.4)^2$

$= \frac{1}{3} (1.21 + 2.56 + .16)$

$= 1.31.$

$= \frac{1}{3} (26.9 - 27)^2 + (29 - 26.9)^2 + (24.6 - 26.9)^2$

$= \frac{1}{3} (.1)^2 + (2.1)^2 + (2.3)^2$

$= \frac{1}{3} (.01) + (4.41) + (5.29)$

$= 3.24$

't' value is calculated by using the formula .

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{n_1 \sigma_1^2 + n_2 \sigma_2^2}{n_1 + n_2 - 2} \left(\dfrac{1}{n_1} + \dfrac{1}{n_2} \right)}}$$

Where $\bar{x}_1$ and $\bar{x}_2$ are the mean values for the two fuels cooking gas and kerosene and σ_1^2 and σ_2^2 are squares of the standard Deviation in the two values and n_1 n_2 are the number of two sets.

$$\text{'t' value} = \frac{26.9 - 22.2}{\sqrt{\dfrac{3.24 + 1.31}{2}}}$$

$$= \frac{4.7}{1.4} = 3.36$$

* Significant at 5% level.

APPENDIX X

't' TEST FOR THE TIME TAKEN FOR COOKING RICE IN COWDUNG GAS AND KEROSENE

Two types of fuels	Mean	Standard Deviation	't' value*
Cowdung	26.6	8.25	1.03
Kerosene	30	16.6	

$\bar{x}_1 = 26.6$

$\bar{x}_2 = 30$

't' value is calculated by using the formula

$$'t' = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{n_1\sigma_1^2 + n_2\sigma_2^2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

where $\bar{x}_1$ and $\bar{x}_2$ are the mean values for the two fuels cowdung gas and kerosene and σ_1^2 and σ_2^2 are squares of the standard Deviation in the two values n_1 n_2 are the number of two sets.

$$'t'\text{ value} = \frac{30 - 26.4}{\sqrt{\frac{16.6 + 8.25}{2}}} = \frac{3.4}{3.3} = 1.03$$

* Not significant

APPENDIX XI

't' TEST FOR THE TIME TAKEN FOR COOKING DHAL IN COWDUNG GAS AND KEROSENE

Two types of fuels	Mean	Standard deviation	't' value*
Cowdung gas	26.7	5.55	3.
			3.2
Kerosene	33.3	2.89	

't' value is calculated by using the formula.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{n_1\sigma_1^2 + n_2\sigma_2^2}{n_1 + n_2 - 2.}\left(\frac{1}{N_1} + \frac{1}{N_2}\right)}}$$

Where $\bar{x}_1$ and $\bar{x}_2$ are the mean value for the two fuels cowdung gas and kerosene and σ_1^2 and σ_2^2 are squares of the standard Deviation in the two values and n_1 n_2 are the number of two sets.

$$t = \frac{33.3 - 26.7}{\sqrt{\frac{5.55 - 2.89}{2}}} = \frac{6.6}{2.05} \qquad 3.2^*$$

* Significant at 1 percent level.

APPENDIX XII

't' TEST FOR THE TIME TAKEN FOR COOKING POTATOES IN COWDUNG GAS AND KEROSENE

Two types of fuels	Mean	Standard deviation	't' value*
Cowdung gas	13.3	.22	5.7
Kerosene	17.3	.89	

't' value is calculated by using the formula

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{n_1\sigma_1^2 + n_2\sigma_2^2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

where $\bar{x}_1$ and $\bar{x}_2$ are the mean value for the two fuels cowdung gas and kerosene and σ_1^2 and σ_2^2 are squares of the standard Deviation in the two values and n_1 n_2 are the number of two sets.

$$t \text{ value} = \frac{17.3 - 13.3}{\sqrt{\frac{.22 + .89}{2}}} = \frac{4}{.7} = \frac{40}{7} = 5.7$$

* Significant at 1% level.

APPENDIX XIII

CONSUMPTION OF GAS FOR COOKING THREE ITEMS

Items	Sample I gas consumption in cu.ft	Sample II gas consumption in cu.ft.	Sample III gas consumption in cu.ft	Average gas consumption in cu.ft
Rice (high flame level)	10. 9	9. 9	12. 00	10. 9
Dhal (high flame level)	12. 0	10. 0	10. 00	10. 7
Vegetable	2. 37	2. 5	2. 37	2. 41
Total amount of gas used for each sample	25. 27	22. 4	24. 37	24. 01

APPENDIX XIV

MONETARY RETURNS PER YEAR FOR COWDUNG **

The daily collection of cowdung mixed with water proportion 1:1 | 500 lb.

The original moisture in the sample = 85%

Therefore the weight of drymatter = 15%

Five hundred lbs will contain = $\frac{500 \times 15}{100}$ = 75 lbs of drymatter

∴ Nitrogen content in the dry state = $\frac{2.55 \times 75}{100}$ = 1.91

The cost was calculated by taking nitrogen of ammonium sulphate as standard*

Per pound, if it contained 1% percent nitrogen the cost 1 rupee.

Therefore the cost of the cowdung Rs 1.91

This is obtained from 250 lbs of cowdung per day.

So per year the monetary returns from cowdung = 365 x 1.91

= Rs 697.15/-

Monetary returns per year for slurry

Quantity of slurry obtained 500 lbs

The original moisture in the slurry | 87%

∴ Weight of dry matter in the slurry | 13%

∴ Weight of dry matter in 500 lbs of slurry = $\frac{500 \times 13}{100}$ = 65 lbs

Nitrogen content in the dry state = $\frac{3.18 \times 65}{100}$ = 2.07

The cost was calculated by taking nitrogen of ammonium sulphate as standard*

Per pound if it contains 1% nitrogen the cost = 1 rupee.

The cost of the slurry Rs 2.07

Therefore Per year the monetary returns fom slurry } Rs 2.07 x 365

= 755.55

The money saved by selling slurry (755.55 - 697.15)

= Rs 58.40

** 'A Note Book of Agricultural Facts and Figure'.

Government of Madras, 1961, p. 135.

* The fertiliser Association of India 'FERTILISER STATISTIC'

1962-63, p. 75.

APPENDIX XV.

COOKED ITEMS, OF THE MENU, GAS CONSUMPTION AND COST INCURRED FOR THE GAS FOR THE FIRST DAY

Cooked Items of the menu	Time taken in minutes	Gas consumption in cu.ft.	Cost incurred Rs.	Paise
Dosai	40	16	0.	5
Potato masal	30	12	0.	4
Carrot Kalumbu	45	18	0.	5
Rice	45	18	0.	5
Brinjal pariyal	32	12.8	0.	4
Milk	17	6.8	0.	2
Wheat Dosai	35	14	0.	4
Total time taken gas consumption and cost incurred for the first day	244	97.6	0.	29

APPENDIX XVI

COOKED ITEMS OF THE MENU AND GAS CONSUMPTION AND COST INCURRED FOR THE GAS FOR THE SECOND DAY

Cooked Items of the menu	Time taken in minutes	Gas consumption in cu.ft	Cost incurred Rs.	Paise
Rice	45	18	0.	5
Brinjal kolambu	45	18	0.	5
Bittergourd poriyal	20	8	0.	2
Plantain curry	30	12	0.	4
Uppuma	40	16	0.	5
Stuffed chappathi	105	42	0.	13
Total time taken gas consumption and cost incurred for the second day	285	112	0.	34

APPENDIX XVII

COOKED ITEMS OF THE MENU, GAS CONSUMPTION AND COST INCURRED FOR THE GAS FOR THE THIRD DAY

Cooked Items of the menu	Time taken in minutes	Gas consumption in cu.ft	Cost incurred Rs.	Paise
Rice	45	18	0.	5
Dhal	40	16	0.	5
Pappadam	10	4	0.	1
Water (for boiling)	10	4	0.	1
Bajji	55	22	0.	7
Milk	15	6	0.	2
Dosai	35	14	0.	4
Total time taken gas consumption and cost incurred for the third day	210	84	0.	25