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DEMONSTRATION PROGRAMME ON USE OF INDIGENOUS BIOMASS RESOURCES FOR MEETING ENERGY NEEDS

RP/RAF/85/627

ETHIOPIA

Technical Report *

Mission 4 to 22 November 1985

Prepared for the Government of Ethiopia
by the United Nations Industrial Development Organization
acting as executing agency for United Nations Development Programme

Based on the work of Mr. J. de Waart
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United Nations Industrial Development Organization
Vienna

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EXPLANATORY NOTES

ARDU	= Arsi Rural Development Unit
ENEC	= Ethiopian National Energy Committee
ILCA	= International Livestock Centre for Africa
SIDFA	= Senior Industrial Development Field Adviser
GTZ	= German Gesellschaft für Technische Zusammenarbeit
JPO	= Junior Professional Officer
UNDP	= United Nations Development Programme
UNIDO	= United Nations Industrial Development Organization

ABSTRACT

Title project: Evaluation of current state of biogas technology development in Ethiopia.

Number : RP/RAF/85/627/11-01/32.1.1

Objective : Evaluation and process control of existing digesters and suggestions for improvement. Recommendations for large industrial scale digesters. Use of home-made burners. Installation of control laboratory.

Mission : 5-20 November 1985

Main conclusions and recommendations:

- Temperature in Ethiopia (14-20 °C) is 10 °C too low for optimal biogas production. Therefore existing digesters needs transparent shelter.
- Replacement of the metal dome of the Indian type digester by a plastic gasholder will decrease the cost of construction (Jwala).
- Transport facilities of the ENEC are insufficient to control the present 70 biogas digesters in the country at least four times a year.
- Apart from ENEC (15 digesters) there are other disciplines dealing with biogas digesters namely: ARDU (12 digesters); ILCA (5 digesters); private holders (14 digesters); Farmers Association, Ministry of Agriculture (9 digesters); GTZ (14 digesters); Rental House Organization (1 digester); Polytechnic Institute (1 digester) and Family Life Education Project (1 digester).
- Several home-made biogas-burners are being used in practise.
- In Ethiopia digesters are seldom fitted with traps for condensed water while traps for hydrogen sulphide (H_2S) gas are always lacking.
- Construction of Chinese type digesters is hazardous because of gas-leaks in the concrete cover: difficult to make air-tight.
- Control of digesters should be supported by a well-equipped laboratory.
- Outlying places need their own biogas centre and laboratory.
- Increase of knowledge by the users about the biogas production and treatment of digesters is necessary.
- Industrial scale high-rate digesters are recommended for: slaughterhouse, poultry farms, distillery, sewage treatment plants and water hyacinths in lakes.
- Extension of small scale digesters financed by the Government is only justified if inspection can take place at least four times a year.
- Biogas workshops in Ethiopia for all digester-users should be held once a year.

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INTRODUCTION

Although the duration of the mission in Ethiopia was planned for one month it could be completed for the greater part in 15 days. Another three days were spent in Vienna in briefing and debriefing, two days in travelling and two in preparing the equipment.

The job description with number RP/RAF/85/627/11-01/32.1.1 comprised six duties that had to be accomplished in cooperation with the Ethiopian National Energy Committee (ENEC):

1. Reviews of the relevant report of the previous UNIDO expert.
2. Evaluation of the efforts made in Ethiopia to introduce biogas technology including determination of efficiency of digesters by means of suitable monitoring equipment purchased and imported by the expert.
3. Suggestion of designs of biogasplants suitable for use in Ethiopia. Assessment of the suitability of small-scale Indian and Chinese techniques to be used in Ethiopia. Paying attention to the level of competence required for operating personnel.
4. Evaluation of designs of suitable domestic burners, lamps etc. for use with biogas. Assessment of the potential for their local manufacture.
5. Investigation of the possible utilization of agro-industrial, food-processing and slaughterhouse wastes for biogas-generation and recommendation of appropriate equipment.
6. Preparation of a final report setting out findings of the mission and recommendations to the Government for further action.

The report of July 1984 (UC/ETH/82/164) by Mr. U. Loll, consultant in biogas technology, states that in none of the plants present the effective gas quantity or quality has ever been measured. Therefore, the United Nations Industrial Development Organization (UNIDO) requested the expert to purchase, pack and import into Ethiopia suitable monitoring equipment for the determination of the efficiency of the digesters. The activity started the end of September 1985 by ordering the necessary instruments. Unfortunately, it took two days before the instruments he brought with him as unaccompanied luggage could be cleared by the customs in Ethiopia. Moreover, the four extra gas volume meters sent as air-freight were not available at all during the mission from 5-20 November.

Apart from monitoring equipment according task no 2, a drying-oven, a balance, a pH-meter, a camping gas burner and some small equipment for the installation of a permanent laboratory were taken to Ethiopia. This small laboratory can be used as a centre for evaluation of samples and determination of the suitability of organic waste for biogas processing. Furthermore plastic and rubber tubes for the gasvolume meters as well as two different models of condensed water traps were also imported.

Because time was limited only 25 digesters in 4 regions could be visited. Moreover the digesters located at Harer and Kobe were difficult to reach because for the very long distance and restrict transport facilities. These 25 digesters comprise almost all the different types used in Ethiopia. A good impression could be obtained of the competence of the users. At the request of the backstopping officer of UNIDO pictures of most of the visited digesters were taken (9 photo's are enclosed). A self-made clay biogas burner made by a potter near Awasa was taken to Vienna as an example of potential local manufacturing.

If agro-industrial waste is suitable for biogas production it can in many cases also be used as cattle feeding. It is not suitable to be fed to cattle if it contains too much lignine and natural cellulose (i.e. straw). In that case it is not biodegradable in a digester within the usual retention time either. Farmers use "soft" vegetable waste (leaves) directly as feed. A fruit- and vegetable canning industry was not visited because of lack of time.

In principle the amount of organic waste from the slaughterhouse, poultry farms, sewage treatment plant and food-processing plants is too large to be used in a low-rate, non-stirring, non-heated Indian or Chinese type digester. For this reason a big high-rate fully controlled digester is required. The high cost of such a digester is justified because of the following aspects:

- efficiency of the process, i.e. maximal biogasproduction with high methane content per kg organic matter in a relative short time,
- regular energy and fertilizer production of constant high quality, i.e. few corrosive substances in the gas (H_2S) and few pathogens.

Besides, industries have always a surplus of hot water and steam that can be used to heat the digester, while skilled labour (technicians) acquainted with this kind of machines is always available.

During debriefing in Vienna the main experiences and impressions of the mission have been reported to the back-stopping officer.

The result of the short mission, illustrated in the annex, is described in the following report.

RECOMMENDATIONS

1. To improve the efficiency of the existing Indian type biogas units because of the low average temperature (14-20 °C), a simple shelter of poles and transparent plastic can be fitted above the digester and gas dome so that the inside temperature in the day time remains high and at night drops only slightly.
2. To lower the cost of construction of a digester the Jwala type is recommended. This consists of a conventional masonry pit with a red mud plastic or semitransparent polyethylene sheet spread over the top opening of the digester to form the gasholder. The sheet is hooked to the bottom of a water seal and secured to a geodesic dome.
3. To stimulate and guarantee efficient use of digesters in the country it is absolutely necessary that by means of Governmental control, for instance ENEC, the users are visited and given practical directions at least four times a year.
4. The consequences of more frequent controls of digesters are the extension of the vehicle fleet of ENEC, appointment of a senior civil engineer and two more junior civil engineers as well as completion of the training of the three technicians already present.
5. Improvement of the utilization of the biogas units can be realized by regular and proper instruction of users concerning: (i) the necessity of cleaning the digesters repeatedly of scum, straw, sand and other undegradable material, (ii) increase and control of the gas pressure by putting boulders on the dome and connecting a safety pressure gauge at the gas pipe respectively, (iii) right amount and dry weight of digester input, (iv) proper flow of air in gas burners, (v) better use of condensed water traps and construction and use of hyrogen sulphide (H_2S) traps in gas outlet pipes, (vi) maintaining high temperature in the digester by constructing transparent shelter above and around it.
6. Backstopping of digester control by at least four small laboratories in different regions preferably in remote areas.

7. Control laboratories should be provided with running water supply and drainage, gas and electricity connection and should have facilities to carry out: 24-hour gas measurement, determination of: pH, gas pressure, gas composition (CH_4+CO_2), dry weight and ash content.
8. Stimulation by the Government of the production of local manufacturing for instance from clay of biogas burners and lamps according to the example of the Chinese devise as described in Study Tour and Seminar, Addis Ababa 17 August, 1983.
9. Decrease of the construction of Chinese type digesters because of the risk of leakage in the roof and inefficiency i.e. impossibility of stirring and breaking the scum layer.
10. Annual organisation of biogas workshop in Ethiopia with representatives of ENEC, ARDU, ILCA, IAR, Colleges, Farm Associations, private owners, where experiences and practical problems are discussed.
11. Biogas production from big amounts of regularly produced biodegradable organic waste, for instance in slaughterhouses, poultry farms, distilleries, sewage treatment plants and lakes with waterhyacinths, should preferably be carried out by the efficiently working high-rate digesters.
12. High-rate digesters produce a big quantity of biogas (maximal amount of gas per kg organic matter) and high quality biogas (maximal CH_4 content and minimal H_2S content) and give optimal reduction of pathogens and maximal mineralisation of the organic input.
13. Presence of a drainage system (Asmera) or a large number of big septic tanks (Addis) make it possible to treat the sewage slurry aerobically and to realize biogas production from the sludge thus obtained.
14. Because private owners give more care to their digesters it will be recommendable to oblige farmers to share in the cost of the digesters provided by the Government.

REPORT

The activities of the mission will be reported according to the sequence of the main duties of the job description.

I. Review of biogas report by previous UNIDO consultant

The report by Mr. Ulrich Loll of July 1984 was also an occasion for the visit of the present biogas expert to Ethiopia as stated in paragraph 5, page 16. On page 4 of his report it is stated that the effective gas production and the gas quality of none of the plants have been controlled so far. Rightly on pages 18, 19, 22 and 28 he recommends the analytical work necessary for process control of biogas plants in appropriate laboratories. Unfortunately, the analyses to be carried out are not described and high prices for the instruments are listed. It is questionable whether instruments as P, N, K analyser and a photometer are not too advanced for a process control laboratory. It would be better to have the analytical work carried out in Ethiopia under the supervision of an UNIDO expert by the junior civil engineer and the senior chemist, who have already been trained in Europe, see table 2 I.
During a training period in China too much attention will called to the Chinese type digester the low cost of which (page 8) not justifies the construction of a hazardous unit because of the roof leakage which often occurs. In 1984 the consultant found already that the installation of demonstration plants in Colleges was not always successful, due to insufficient interest to run the plant. This was also observed by the expert in the Awasa Junior College of Agriculture in 1985.

Indeed the main centre of ENEC in Addis Ababa should consist of a technically and scientifically educated staff and possess testing and controlling laboratories, working under the supervision of the Ministry of Mines and Energy. Quite rightly the consultant states on page 24 that the availability of the required cross-country vehicles in Ehiopia is very poor and that the car fleet needs extension.

It is not clear what is meant by large-scale biogas plants on page 17 and 21. It is also difficult to form a right picture of "middle-sized units". On page 21 it is considered to distribute biogas through the gas network, in plastic bags or as compressed gas in cylinders. Even in developed countries this is hardly possible and very expensive. Distribution of gas in plastic bags will actually not be easy to perform because of the huge dimensions required.

Local manufacturing of biogas burners can be realized within one year and that of lamps will take some more time. The production of mantles is very complicated and they should be imported for the time being (page 20). What is mentioned in the first two paragraphs of page 5 concerning burners and lamps imported from India and the use of local produced simple burners could be confirmed by the expert in 1985. It is not right however that climate conditions in Ethiopia are ideal (page 10 and 15) and that biogas plants do not need insulation because of the temperature range of 14 to 20 °C. It should be considered that the optimal temperature requirement of methane bacteria is about 33 °C. Biogas production in Ethiopia without heating and insulation is therefore sub-optimal. The consequences of this relatively low temperature are a low CH_4 content of the biogas, a long retention time and incomplete fermentation of organic matter.

The erection of 1000 biogas plants per year during ten years will be a feat of strength (page 7) which cannot be performed solely by the Ethiopian Government. With the existing digesters the number of vehicles is in fact already inadequate to carry out a proper control. Construction of digesters by the Government should take place gradually and keep step with the fleet of cross-country vehicles and the number of qualified biogas engineers, technicians and chemists available. Anyhow the present 20 % share of private owners in the existing digesters is expected to be continued in case of extension. Furthermore, the plants maintained best were found in private farm houses (page 5).

Including GTZ there are in Ethiopia ten organizations of three ministries which are dealing with construction and running of biogas units. Therefore obligatory participation in an annual biogas workshop is necessary to exchange experience and knowledge. It is recommendable that UNIDO place experts and demonstration material at the workshops disposal.

The prospective high-rate digester constructors and users form a separate group which is often thrown entirely on its own resources. They have to exchange experience and knowledge with experts from abroad in workshops which will have to be held more frequently than once a year.

Continuing increase of the number of small-scale digesters will be effected by several disciplines, just as in the last 5 years.

Undoubtedly, ENEC will stimulate and control these biogas activities.

II. Determination of efficiency of the digesters visited

To perform this task instruments are needed. In The Netherlands the instruments in question were selected. Data concerning price, dealers and delivery time were telexed to UNIDO in Vienna. The telex of October : contained a list of equipment to be taken to Ethiopia by the expert. This list comprised:

(i) 1 portable methane gas analyser with charger, CO_2-filter, carrier case and telescopic probing tube

(ii) 1 wet-gasmeter; 4 more of these arrived in Addis by air-freight one week later than the expert

(iii) 1 portable pH-meter

(iv) laboratory items like:

- 1 dessicator with inlay
- 1 balance - 0,01 g
- 1 drying oven - 12 ltr
- 3 triangles with pipe clay
- 3 crucibles and 2 tongs
- 1 camping-gas burner with 5 gas tanks
- 1 stand with accessories
- 1 wash bottle
- 1 5-ltr-jerrycan

The 4 listed gobar gas burners, 2 gobar gas lamps and one automatic water remover will be dispatched directly from India to Ethiopia.

Apart from this laboratory equipment the expert took also with him to Addis 20 meter of rubber and plastic tubes, 7 rubber stoppers, 3 screw capped plastic sample bottles, silica gel container, metal connections, glas styles, petri-dish, thermometer, drawing paper and two watertraps of PVC.

After a short visit to UNDP the expert was taken to the head of ENEC, Dr. Ghebru Wolde Ghiorghis, Executive Secretary of the Ministry of Mines and Energy (Table 1).

Dr. Ghebru found the 15-day of the mission too short and preferred extension of this period. He rendered every assistance in arranging visits to as many digesters a possible. He placed at the UNIDO expert's disposal two counterparts, a Toyota cross-country car and arranged permission to drive in the week-end. Consequently, it was possible to travel on Saturdays and Sundays to reach outlying places.

In cooperation with both counterparts, Mr. Siltan Abraha (Junior Civil Engineer) and Mr. Kidane Workneh (Chief Chemist) the boxes containing instruments and material could be cleared at the customs. The counterparts, ENEC employees, had already followed a training in alternative energy application in Europe. The counterparts appeared to have special knowledge of construction and operation of small-scale biogas units. Unfortunately, these ENEC employees could visit the digesters in the country only once a year due to lack of transport. The instructions and advices they give to users of digesters is most stimulating and helpful. Even at present this is too arduous a task for one man. Extention of the group with three technicians having the same knowledge of the construction and biogas process and having the disposal of two extra cross-country vehicles is a condition to do the job properly. Each of them may control a certain area so that digesters can be visited regularly and more than once a year.
Table 2 comprises 73 biogas units which are installed in 56 places in Ethiopia. Most of the digesters are installed in the SHEWA, ARSI and WELO regions and to a lesser extent in the SIDAMO, HARERGE, ERITREA and BALE regions. In the remaining 7 regions in the wooded Western part of the country there is no scarcity of fire wood and therefore the alternative energy requirement is less great.
The expert visited 25 digesters in the SHEWA, ARSI, SIDAMO and ERITREA regions.
For backing the control of digesters a small laboratory is required. For this reason one of the rooms in the Ministry of Mines and Energy was reserved. Unfortunately, there was no running water and drainage in that room. Apart from measurements in the field analysis concerning the evaluation of organic waste and digester slurry should be carried out in a quiet place. See figures 5 and 6. Determination of dry weight, ash content and pH can reveal the suitability of organic waste for biogas production or the quality of a biogas process.

A. Region SHEWA

1. Addis Ababa

All 7 installations in Addis, being three or more years in operation of which 5 were private ones were visited. Of the 3 which are not in use, one was found on the compound of a private hospital. The manager had no time to look after the digester and often there was no water in that part of the city. The second and smallest one was not in use because the farmer, who had made the digester himself, was out of town for several months. The third one, a Chinese type, on shelving ground, situated close to the big septic tank of a residential quarter at the South side of the town, had never been used by the owners: The Rental House Organisation (see figure 7)

Farmer Taddesse Wendimeneh, living in the Eastern edge of Addis, has a well maintained Indian type digester (with a water trap) fenced by poles. He feeds the unit once in 3 days with 240 litres cow dung slurry of 8 % solids. This means a retention time of 50 days. During preparation of the feeding he takes out the pieces of straw to prevent formation of a scum layer. The gas volume meter, fixed by the expert, indicated 2,767 litres gas having a 50 % CH_4 content in 24 hours. Measuring the temperature of the effluent showed it to be 17 °C inside the pit. The gas was used daily for cooking on gobar gas burners.

Farmer Shiferaw Metaferia has a digester surrounded by a fence built close to the pit and overarched by big trees so that the influence of the wind and the radiation of warmth at night is minimal. Consequently, the temperature is kept as high as possible. As was the case with the farmer Wendimeneh here the digester was also kept in good repair. A watertrap is used as is shown in figure 2. Daily feeding amounts to 150 litres, i.e. a retention time of 27 days with a pit volume of 4,000 litres. The measured gas production was 3,939 litres in 24 hours, as a result of a higher temperature, and better feeding (optimal retention time) in comparison with the same digester used by Mr. Wendimeneh. Besides, the contents of the pit is strongly homogenized by turning the dome with the aid of balks (see figure 2) in the handles. Figure 3 shows the measurement of daily gas production with the gas volume meter and two kinds of gobar gas burners in the kitchen. A gobar gas lamp was also in use. Eventually the gas production capacity of 6 m^3/day is not reached because of a too low temperature and probably too low feeding. The low measured CH_4 content of 45-55 % is also an indication of an incomplete methane fermentation in the course of which the facultative anaerobic bacteria dominated and thus produce much carbon dioxyde. The margin of 37 % CH_4 content at which the gas mixture only just burns is fortunately not exceeded.

The third farmer Mucugeta has a 10 m^3 gas capacity/day digester which was just empty at the time the expert came along. Figure 8 shows the fermented slurry being collected in a small tanklorry. For this purpose a down grade had been made underneath the outlet pipe. The final sludge is used as fertilizer for the arable land outside the town. The gas is used for cooking.

The owners of the digesters were in all cases very pleased with the visit of ENEC and advices concerning improvements were always taken to heart.

Mr. Ephraim Bekele staff member of ILCA informed the expert about experiments with plug flow digesters in Addis and Debre Zeyit. This system using a plastic bag of 7 meter length is called the Australian type here. In Addis a polyethylene oblong bag is placed in a shallow trench. The feeding has to be watery (4 % solids) so that the contents of the bag can easily run down. Naturally the cost of such a construction is low, but the vulnerability is high so that it has to be protected against goats, rodents and birds. Every night the bag has to be guarded against heat radiation.

2. Debre Zeyit

Thanks to Mr. Bekele we could pay a visit to the Experiment Station in Debre Zeyit. On the vast ground we were first guided to a Chinese type digester which was constructed on shelving terrain near to a cottage. See figure 9. The unit was in full operation and the gas was used for cooking and lighting (5 hr/day). To the pipeline a gas meter was connected. An inner motor tube connected to the outlet gaspipe acts as control for over-pressure so that a too high gas pressure in the digester is avoided. The CH_4 content was 45 %. The final sludge streamed down the slope right to the field. This unit was the only one of the four Chinese type digesters visited which functioned quite well. Nevertheless, near Kobe there are more Chinese type units working without leakage.

Closer to the station an Indian type digester with three counter weights had been constructed (fig. 10), also on a slope. Because the counter weights are not balanced the dome leaned over. The unit was functioning and the gas was led through a pipe of 100 meter length: such a long distance is not recommendable. Meanwhile the coordinator of ILCA, Mr. Taddesse Tesemma Ambaye joined the group, which visited the small and big plug flow digesters. See figures 11 and 12. A striking feature was that especially ILCA carries out experiments with this type. The big plug flow lies in a shallow inclining ditch under a shed and has a length of 7 meters and a diameter of 1 meter. The price of the plastic bag (Bee hive vinyl products Townsville) is $ 120. The plug flow was fed with manure which had first been heated by the sun. The manure is diluted with water to 4 % solids; the retention time is 50 days. A fixed gas meter and a burner made of a 500 g big milkpowder tin are used.

As shown in figure 12, in front of the big shedded plug flow there is a small one, also in a shallow sloping ditch. A double-walled polythene bag, consisting of two 0.2 mm layers ($ 25) was lying in the burning sun. The sun raises the temperature of the liquid in the bag to 35 °C which is optimal for biogas production. The inlet and the outlet are plastic buckets without a bottom. Fed with diluted manure with a retention time of 50 days.

We met Dr. T.R. Preston, a British consultant in tropical animal production at ILCA. His opinion about digesters was as follows: Chinese types are irreliable because of leakage; Indian types are cumbersome in use; plug flows are recommendable in spite of their being unfit for use during the sunless cloudy summer months. He also recommended the use of home-made burners and lamps made from clay and milkpowder tins. He had never heard of the Jwala digester but expected it to be suitable for use in Ethiopia.

3. Nazret

The small city of Nazret is situated 100 km South West of Addis where 7 private owners run their Indian type digesters. Three of them were visited. At house number 237 (table 2) the unit was in full operation, fed with the manure of 3 cows. Gas, with a 45 % CH_4 content, was used for cooking on self-made burners with adjustable air-supply. See figure 17. The dome of the self-made digester is guided by a shaft moving in a fixed cuff.

At housenumber 502 is a 5-year old digester constructed next to the cow-house and fed once in 3 days. Gas with a methane content of 50 % is used for cooking. The burner is made of reinforced concrete and scrap. The pit had never been cleaned. Two big boulders were placed on the dome to obtain the right gas pressure.

The third private-owner, housenumber 429, had neglected the digester. The burner was broken and there was no gaspipe line connection between the dome and the burner. He was intended to use it again in the near future.

B. REGION ARSI

1. Asela

Near Asela there are 13 digesters: 12 of the Indian type and 1 of the Chinese type. The Chinese type is not in use due to the cattle having been removed from that area. In 5 hamlets 6 digesters were visited by the expert and his counterparts. First a visit was paid to Mrs. Atsede, regional chief home science of ARDU-Asela. She provided a guide to take the group to the widely dispersed digesters.

1.1 Amigna Ademere

Close to a feed-lot, an Indian type digester is being constructed by ARDU, and not yet finished. Nevertheless it has already been used for 15 months. Feeding: 2 times a week; the water is brought from a great distance in jerrycans. Gas is used for cooking on a self-made ARDU burner (see figure 17).

1.2 Bika

Two ARDU digesters have been constructed here. One of which is not in use because of lack of water. The user waits for a new water pipline being laid. ARDU burner present.

The second digester was in operation and the wife of the owner was using the gas for cooking so that measurements could not be carried out.

1.3 Sharibié

Indian type ARDU digester, in use for cooking. The burner was a tin with small holes according to the ARDU design.

1.4 Amigna Debeso

Digester was in use. Feeding once in two weeks. It is not certain whether this figure is right. In many cases the farmers or their wives in this area could not inform us about frequency and amount of feeding. The burner was not working very well and produced a fluctuating flame, probably becuse of lack of the right air-gas mixture.

1.5 Huruta Hetassa

Remote place, difficult to reach by car because of impassable terrain. Digester was not built in the proper way: distance between dome and pitwall too large. Only used for 5 months during the last 2.5 years. Neglected. Shortage of water in this area. Sandbags on dome were torn so that sand slid into the pit. Loose sand was not removed from the cover of the gasholder. Shrubs and grass are beginning to overgrow the digester.

C. REGION SIDAMO

1. Awasa

1.1 Private-owner

Hotel manager and farmer Mr. Kidane Weldekristos has several cows the manure of which is fermented in a small Indian type digester. He constructed the 2 m^3 gas capacity digester himself. He uses the gas to fry the big typically Ethiopian cakes and for lighting with gobar gas lamp. See figure 13. The measured amount of gas with 55 % CH_4 was 142 litres per hour. The shaft for guiding the dome was provided with a pin so that the dome was blocked. The result of this provision is that the gas pressure rises considerably. Another consequence of the blocked dome is removal of the pit content along the outside of the dome by the increased gas pressure. Furthermore the entrance of the inlet pipe in the pit was stopped up with sand coming along with the manure during feeding. This is a good example of the necessity to clean the pit once a year which had not been done. At the request of ENEC's adviser he also removed the pin from the shaft and will adjust the gas pressure henceforth with big stones on the gasholder.
Two years ago Mr. Weldekristos built a Chinese type digester. However, it kept leaking and he replaced it by an Indian type. Before long he will construct another Indian type digester of twice the size of the present one.

1.2 Awasa Junior College

On the compounds of the Home Science Department of Awasa Junior College of Agriculture of the Addis Ababa University there are three digesters.
Mr. Kassaye, assistant Dean of the College, gave us permission to inspect the digesters. Unfortunately, the reponsible person Mrs. Wudnesh Haily, had left one year ago for a two-year training course in Germany. Her successor was not sufficiently motivated for biogas. Consequently, the digesters do not get the attention they need. As figure 14 shows, the Chinese type digester was difficult to find because it was overgrown by bushes. It had not been used for years! The other two digesters of the Indian type have not been in operation for a long time either. Figure 15 shows one of them with a fixed protected gas meter and a gobar gas lamp on a post, which is not working, although it is in good repair.

When returning to the assistant Dean the counterparts expressed their surprise about the digesters not being used. The explanation for this disappointing situation was that most staff members and students had been employed in fighting against the drought in the Northern part of the country for a long time. Training in the College and care for the digesters had therefore to be postponed.

On inquiry Mrs. Wudnesh Hailu appeared to be present because of her temporary return from Germany. The group paid a visit to her and had a discussion about the biogas activity in the College. She regretted to be abroad for such a long time and told that she intends to return to Awasa after her training in Giessen, Germany. She hopes then to be involved again in the biogas program of the Awasa College. She appeared to be one of the members of the biogas workshop organized by UNIDO and UNESCO in February 1982 in Arusha, Tanzania.

D. REGION ERITREA

Expert and counterparts travelled to Asmera by plane for a visit to the teamleader of the Natural Resource Development and Conservation Department of the Regional Agricultural Office: Mr. Tekleab Woldu. He would be pleased to extend the number of digestrs in his region if the Government should grant sufficient financial support. The sewerage in the city having 300.000 inhabitants ends in an area where precipitation can take place. From there a stream of dirty water flows as a river out of the town. During a discussion with Mr. Woldu it became clear that this drainage system can be used for the production of biogas: aeration tanks will furnish the sludge after precipitation in appropriate big tanks. Seef figure 18. From there the sludge is collected and fermented for the production of biogas and pathogen-free fertilizer.

In the 11 day-courses about wildlife and forestry for young peasants the instruction conerning construction and running of biogas digesters is incorporated. On an average this training is attended by 1100 peasants yearly. The interest in biogas production is great and several farmers in the neighbourhood of Asmere start building digesters themselves.

Mr. Yemane Teklehaimanot is the Regional expert of the Community Forest and Soil Conservation and as such responsible for the biogas units in the region. During the above mentioned course he teaches biogas production. In the village Shiketti the Peasant Association will carry out a plan for the building of Chinese type digesters.

On the compound of a piggery a visit was paid to a 2.5 m^3 gas capacity Chinese type digester, fed with pig manure. The gas is used for cooking and lighting. The waterseal on the cover showed regularly escaping gas bubbles revealing a leak in the roof of the digester. There was no watertrap in the gas pipe. We could not carry out measurements because the door of the kitchen was locked and the man with the key was absent.

On another compound there was an Indian type digester of 6 m^3 gas capacity. See figure 1. The unit was kept in excellent repair and was fed twice a week with cow manure. The gas is used for lighting and cooking with the aid of gobar gas burners and lamps. Measurement values for gas production and CH_4 content were: 237 litres gas per hour and 50 % CH_4 respectively. The temperature of the slurry beside the dome was 19 °C. To improve the gas pressure big stones had been placed on the roof of the gasholder.

III. ASSESSMENT OF SUITABLE DESIGN OF BIOGAS PLANT AND OF COMPETENCE OF USERS

A. INDIAN, CHINESE AND "AUSTRALIAN" TECHNIQUES

1. Indian type

Although the climate in the greater part of Ethiopia is too cold for an optimal unconditoned production, there are 50 Indian type and 20 Chinese type digesters.

Digesters which are not heated and not insulated are functioning suboptimally in the cold part of Ethiopia. In the hot South East and a strip of lowland in the West and in the East heating and insulation is not necessary. From measurements carried out by the expert concerning gas amount and CH_4 content it follows that the biogas process in Indian and Chinese types in Ethiopia indeed runs moderate. The main cause is the low temperature of the sludge in the pit: in several pits temperatures of 14 to 19 °C were measured, that means 10-20 °C too low.

The temperature of the Indian type digester can be raised in a cheap way by means of the sun. In Korea a method is applied in which a shelter of transparent plastic is built around the pit and gasholder: height 1.60 m, diameter 3 m. It has been proved that a vinyl sheet cover ensures a temperature of the digester which is twice as high as effected by isolation of the pit with rice hulls. Besides, the thus formed greenhouse can be used for the cultivation of tropical crops. In the sunless summermonths the temperature is relatively high and because of the clouds, radiation is minimal during the night. One may expect that in the 3 summer months biogasproduction will be less than in the rest of the year.

Finally the Indian type with shelter will be a suitable digester for use in Ethiopia, although it will be not the cheapest one because of the expensive dome. In practise it will be purchased by well-to-do farmers and private owners in general.

2. Chinese type

The construction costs of this digester of stone cement and concrete are much lower than of the Indian type. Against this favourable aspect there are important disadvantages. The air-tight construction of the roof of the pit is very difficult. Even if one succeeds it may happen that a small crack is formed when the gas pressure becomes to high if gas consumption is not regular. Naturally, the use of inner motor tubes and other safety pressure control apparatuses minimizes the chance of leakage, but these aids are seldom applied. Another drawback is the minimal effect of the shelter because the digester is underground. Optimal fermentation in a Chinese type digester in Ethiopia is therefore hardly possible. Break of the scrum layer and homogenation of the pit contents is possible with the Indian type, but almost impossible with the Chinese type. To carry out these important actions the cover has to be removed so that all the gas escapes. After that it is a hard job to fix the cover air-tight again.
None of the digesters visited had an H_2S trap. This means that metal pipelines, gasburners and lamps will corrode very fast. The H_2S trap consists of a small container of metal or PVC filled with iron scrap or wood shavings impregnated with $FeCL_3$.
The watertraps, do not discharge automatically, are as shown in figure 19, number 3. The self discharging watertraps as shown in figure 19 numbers 1, 2, 5, 6 and 8 are hardly in use in Ethiopia. Examples, made of PVC (numbers 4 and 7) have been taken to ENEC.

For technical reasons it is doubtful if the Chinese type is suitable for the Ethiopian climate, apart from the hazardous construction with respect to gas leakage.

3. Plug flow type

With this type especially ILCA is experimenting. They test plastic and vinyl rubber bags lying in a shelving shallow trench. An advantage of this system is the cheap and simple construction. Besides, the sun is allowed to raise the temperature of the slurry in the bag upto 35 °C. The process can therefore proceed optimally. In sunless periods of the year the bag can easely be emptied, rolled up and stored. Disadvantages are the foreign currency needed to import the plastic as well as the vulnerability of the bag. Furtermore much water is required because of dilution of the feeding to 4 % solids which allows the stream to flow in the bag.
Since water is scarce in the country most of the year it is doubtful wether the plug flow can become popular. The actual cost of the big plastic bag as used by ILCA in Debre Zeyit appeared to be $ 120,- which is reasonable in comparison with an Indian type of Birr 5000,-, although the capacity is much smaller.

The reliability in operations has still to be tested in the plastic plug flow so that we have to wait for the result before a judgment can be given.

4. Jwala type

Figures 20, 21 and 22 show the Jwala digester and the construction of the dome. In general it is small and has a daily gas capacity of approximately 2.3 m^3. It generates gas pressures up to 21 cm of water. This type was developed by the Murugappa Chettiar Research Centre in India (MCRC). It is said to be the least expensive digester and can be manufactured locally by practically unskilled labour. It consists of a conventional digester pit made of brickwork. The water seal is built on the wall of the digester: 45.7 cm width and 35 cm depth. A synthetic sheet above the pit serves as a gasholder. The sheet is fixed to a geodesic dome and tied to stays in the water seal (see figures 21 and 22). The geodesic dome can be made of 35 long and 30 short struts. Determination of the lenght:
- longstrut : radius of the dome x 0,6180
- short strut : radius of the dome x 0,5465.

The diameter of the dome is taken as the diametrical distance of the inner edges of the outer water trough wall. Struts can be made of teak, PVC pipes or casuarina poles and connected with an aluminium plate, nuts and bolts.

The Jwala digester has the following advantages:

(i) it is less expensive than the Chinese or the Indian type

(ii) it can be made locally

(iii) it can be constructed by men with average skill

(iv) the balloon material can be taken to any remote place

(v) the gasholder can easily be removed for cleaning purpose and replaced

(vi) the low density polyethylene or red mud plastic sheet for gasholder solves many problems encountered in other designs.

It seemed worthwhile to test the practicability of Jwala digesters in Ethiopia. It may be the solution of energy production for the small farmers in remote areas.

B. LEVEL OF COMPETENCE FOR OPERATING PERSONNEL

During the trip of the expert along 25 digesters it was striking that private owners are superior in knowledge and care in maintening and running their digesters. They also carry out experiments with the digesters and burners to improve feeding, homogenation, gas pressure and utilization of gas. Contrary to them the farmers in the remote hamlets hardly know how to treat the digester to produce gas optimally. One of the reasons may be the low frequency of the visits of Ethiopian experts (ENEC, ARDU et al.) to advise them. The feeding rate is rather variable for many users. A positive point was that straw was removed from the dung in the feeding-pit to avoid formation of a scum layer. Also the farmers try to raise the gas pressure by placing stones or sandbags on the dome, or fixing the dome with chains or pins. Most of them are aware of the necessity to remove condensed water to keep the gaspipe free. The pits are never cleaned, probably because of the short time (1-5 years) the digesters have been in use. As soon as possible all users have to be told to clean the pits. In Awasa a private owner discovered, thanks to our visit, that the inlet was blocked by sand as a result of wich the retention time at the same feeding was decreasing so that fermentation was incomplete.

The expert has the impression that all aspects of the biogas process are not understood quite well and it will be recommendable to enlarge the knowledge about the backgrounds. Especially the influence on the biogas production of the following parameters and actions should be emphasized: temperature, retention time, feeding concentration, homogenation and cleaning (scum en precipitate).

The utilization of the gas is not optimal. Removal of condensed water is often primitive or lacking. Removal of H_2S is not known. Farmers are not always aware of the possibility to adjust the right air-gas mixture, which is often even missing in self-made burners. Several aspects can still be improved in the treatment of the digesters as well as in the utilization of the gas. Biogas experts of ENEC, ARDU et al have to perform an important task. Particularly in remote areas the users need regular visits by Ethiopian experts. Better notion of the process will result in greater interest and consequent optimal treatment resulting in maximal production of biogas.

Finally it can be concluded that the level of competence required for operating personnel is not perfect. In the country it has to be improved considerably by frequent instruction, advice and supervision.

IV. EVALUATION DOMESTIC APPLIANCES FOR USE WITH BIOGAS ASSESSMENT OF POTENTIAL FOR LOCAL MANUFACTURE

Apart from gobar gas burners, home-made types are found in different places. See figure 17. They are made of reinforced concrete, scrap iron or 500 g milkpowder tins. They appeared to function sufficiently although in some the possibility of adjustment the right air-gas mixture was lacking. A gobar gas burner brought along by the expert was given to potters to copy it in clay. Figure 16 shows the negotiations in the hamlet leku 27 km South of Awasa. With succes the potter made two burners of clay one of which was presented to the UNIDO backstopping officer in Vienna. Taking in consideration the diligence and motivation with which home-made burners were produced it can be concluded that biogas burners can be locally manufactured. As to lamps, only gobar gas lamps were seen by the expert. However, it may be expected that lamps can be imitated in metal as well as in clay. Instructive designs of home-made lamps have been published in a book available from the SIDFA, Mr. Vencatachellum of UNDP.

The tittle of the book is:

Economic and Social Council Economic Commission for Africa
Study Tour and Seminar to People's Republic of China
21 August - 12 September 1983
Briefing programme on Biomass Conversion
. Addis Ababa 17-19 August 1983
Informations on biomass conversion.
. The Biogas Technology

Drawings of earthen biogas lamps with so called "rootstock of lotus" are shown in this book. Chinese experts invited to Ethiopia could instruct local artificers how to make the lamps. Manufacturing mantles will be very difficult so that they have to be imported for the time being. Production of lamp glasses will not be a problem because there are glass works.

It can be concluded that besides mantles the potential for manufacturing domestic appliances for use with biogas is available.

V. INVESTIGATION OF UTILIZATION OF BIG AMOUNTS OF ORGANIC WASTE FOR BIOGAS GENERATION AND APPROPRIATE EQUIPMENT

Several big heaps of organic wastes are found in Ethiopia. In principle they are fit for biogas production because of their well known biodegradability and the regular production throughhout the year.

A. KALITI SEWAGE TREATMENT PLANT

In the municipality of Akiki, 10 km from the centre of Addis there is a sewage treatment plant, see figure 4. The contents of the septic tanks of the city are transported by tank lorries and dumped in five V-shaped deep troughs. When the trough is full the contents is dug up and aerated. After subsequent precipitation of the slurry the supernatant is drained and the slurry is used as fertilizer. The meaning of this treatment is to reduce the bad-smell and to prevent pests as well as to produce harmless fertilizer. In the past 2 years the plant has been transferred from a private entrepreneur to the municipality. Soon after, these activities slowed down and finally came to a complete standstill. However, it will be possible that the plant will come into operation in due time if the authorities are interested. Anyhow the supply of sludge is ensured. At the moment it is dropped in the field next to the plant, which is not very hygienic. After aeration the sludge can be anaerobically digested to biogas in a high-rate digester. The generated electricity can then be used for the plant and the sludge, free of smell and pathogens, as fertilizer for the surrounding farmers.

B. SLAUGHTERHOUSE

In Addis Ababa a visit was paid to the General Manager of the City Council Abattoir Mr. Teklu Welde Giorgis. He informed us about the plan to move the slaughterhouse outside the city in a few years. It will be also extended. The General Manager was very interested in the utilization of the slaughterhouse waste for generation of biogas and looked forward to receiving the report. At the moment the waste is dumped in a nearby river which means a heavy pollution and bad-smell. This annoyance may not last too long. The head of the planning and research department of the slaughterhouse Mr. Tekie Haile Selassie provides a conducted tour to give the expert a good impression of the available waste from:

151,642	cows	at 30 kg / cow	i.e.	4,549,260	kg manure
68,213	sheeps	at 3 kg / sheep	i.e.	204,639	kg manure
8,710	goats	at 3 kg / goat	i.e.	26,130	kg manure
3,806	pigs	at 3 kg / pig	i.e.	11,418	kg manure
Total 232,371	animals / year			4,791,447	kg manure / year

Assume the dry matter of the manure to be 20 %, the daily available amount of waste is approximately 39 tons of 6 % dry matter. From 39 tons manure 721.5 m^3 biogas per day i.e. 4,292,925 kcal/day = 178,872 kcal/hour can be produced. Because of a loss of 75 % energy by transfer of gas into electricity this amount of kcal corresponds to 52 kWh throughout the year. For the daily digestion of 39 ton manure two digesters of 600 m^3 are necessary plus a 285 m^3 slurry storage tank and a 100 m^3 gas bag. Figures 23 and 24 show two high-rate digesters of 150 and 350 m^3. Figures 25 and 26 present a scheme and a flow-sheet of a high-rate digester with explanation.

C. NATIONAL DISTILLERY AND LIQUOR FACTORY

In this factory in Addis Ababa 120.000 litres wine per day are produced during 10 months of the year. Five fermentation tanks of 18.000 litres each produce a yeast slurry of approximately 3.5 % solids. The distillation tower adds 6000 litres of 0.3 % solids, so that the waste stream comprises 16 m^3 of 2.3 % solids per day. After concentration to 8 m^3 of 4.7 % solids this waste stream can be fermented to biogas in a 200 m^3 high-rate digester: 100 m^3 biogas i.e. 595,000 kcal per day.

D. POULTRY PRODUCTION AND FEED PROCESSING ENTERPRISE

At the Eastern edge of Addis Ababa a poultry breeding farm with 60.000 chickens is situated. The extension of the city resulted in a growing number of complaints about bad-smell. Therefore, the manager Mr. Assefa Bogale is looking for a solution of this pollution problem. Because one chicken produces 100 g manure of 36 % solids the daily amount of waste is 36 tons 6 % dry matter. Two 500 m^3 digesters will be required to ferment the 36 tons manure and make biogas and sludge free of smell and pathogens.
In Debre Zeyit there is also a chicken farm. Within a few years 350 000 chickens will threaten the environment with pollution.
The biogas process will be the obvious means to utilize this waste, to produce energy and to solve the problem of pollution.

CONCLUSIONS

1. Replacement of metal gasholders in Indian type digesters by polyethylene or red mud plastic will decrease the price considerably so that extension of the number of digesters in rural areas will be more feasible.

2. Regular control of digesters and advice to the users are important conditions to maintain and to extend the existing digesters.

3. Construction of high efficient digesters run under strict conditions concerning feeding, temperature, stirring and retention time is possible in Ethiopia thanks to the regular supply of biodegradable organic waste in big amounts, for instance from slaughterhouses, distilleries and chicken farms.

4. Local manufacturing of gasburners and lamps will be possible within one year. For the time being the mantles will have to be imported because local production takes longer.

Table 1. Discussions during the mission with the following persons:

- Mr. Kadress Vencatachellum; SIDFA-UNDP	Addis Ababa
- Mr. Wolfgang Meyer; JPO-UNDP	Addis Ababa
- Dr. Ghebru Wolde Ghiorghis; Executive Secretary ENEC, Ministry of Mines and Energy (MME)	Addis Ababa
- Mr. Siltan Abraha; Junior Civil Engineer, ENEC, MME counterpart	Addis Ababa
- Mr. Kidane Workneh, Chief Chemist ENEC, counterpart	Addis Ababa
- Mr. Tekie Haile Selassie; Head Planning and Research, Abattoir	Addis Ababa
- Mr. Teklu Welde Giorgis; General Manager, City Council Abattoirs	Addis Ababa
- Mr. Taddesse Wendimeneh;farmer, successful in biogas production	Addis Ababa
- Mr. Shiferaw Metaferia; farmer, successful in biogas production	Addis Ababa
- Mr. Kidane Weldekristos; hotelmanager, constructs biogas digester	Awasa
- Mr. Kassaye; Ass. Dean Junior College of Agriculture	Awasa
- Mrs. Wudnesh Hailu; participant biogasworkshop, Arusha 1982	Awasa
- Six farmers near Asela; biogas users	Asela
- Mrs. Atsede; Regional Chief ARDU	Asela
- Three private holders; digester contructers, biogas users	Nazret
- General Manager; National Distillery and Liquor Factory	Addis Ababa
- Mr. Assefa Bogale; Manager Poultry Production and Feed Processing Enterprise	Addis Ababa
- Mr. Ephraim Bekele; Staff member International Livestock Centre Africa (ILCA)	Addis Ababa
- Potter; clay imitation of gobar gas burner	Leku
- Mr. Taddesse Tesemma Ambaye; Coordinator ILCA	Debre Zeyit
- Dr. T.R. Preston; Consultant ILCA; biogas expert	Debre Zeyit
- Mr. Tekleab Woldu; Teamleader of Natural Resource Development and Conservation Department, Regional Agricultural Office	Asmera
- Yemane Teklehaimanot; Regional expert of Community Forest and Soil Conservation Ministry of Agriculture	Asmera

Table 2. Small-scale biogas digesters constructed in Ethiopia

No.	Location	User, address	Ownership	DIGESTER type	capacity m^3 gas/day	distance to Addis	constr. date	visited by expert
1	Addis Ababa	Farmer Wendimeneh	private	Indian	6.0	-	1983	yes
2	Addis Ababa	Farmer Metaferia	private	Indian	6.0	-	1982	yes
3	Addis Ababa	Director Hospital	private	Indian	10.0	-	1978	yes
4	Addis Ababa	Farmer Mucugeta	private	Indian	10.0	-	1978	yes
5	Addis Ababa	Farmer, House 435	private	Indian	1.5	-	1981	yes
6	Addis Ababa	none	Rental House Org.	Chinese	2.5	-	1983	yes
7.	Addis Ababa	students	ILCA	Plug flow	0.1	-	1985	yes
8	Nazret	High 2; Kebele 3	private	Indian	6.0	100 km	1978	
9	Nazret	High 3; Kebele 4	private	Indian	4.0	100 km	1980	
10	Nazret	H.3; K.4; Housenr.179	private	Indian	4.0	100 km	1978	
11	Nazret	H.2; K.19; Housenr.139	private	Indian	2.0	100 km	1979	
12	Nazret	H.2; K.10; Housenr.429	private	Indian	4.5	100 km	1980	yes
13	Nazret	H.2; K.10; Housenr.502	private	Indian	4.0	100 km	1980	yes
14	Nazret	H.3; K.04; Housenr.237	private	Indian	6.0	100 km	1980	yes
15	Wonji	Cheka Kodoke	Farm. Assoc.	Indian	6.0	130 km	1979	
16	Adame Werede	Kouche Dolota	Farm. Assoc.	Indian	6.0	80 km	1980	
17	Debre Zeyit	College of Agriculture	ENEC	Indian	6.0	45 km	1980	
18	Debre Zeyit	College of Agriculture	ENEC	Indian	6.0	45 km	1980	
19	Debre Zeyit	Coordinator Ambaye	ILCA	Indian	4.0	45 km	1980	yes
20	Debre Zeyit	Coordinator Ambaye	ILCA	Plug-flow	6.0	45 km	1983	yes

Table 2. Small-scale biogas digesters constructed in Ethiopia (continued)

No.	Location	User, address	Ownership	DIGESTER type	capacity m^3 gas/day	distance to Addis	constr. date	visited by expert
21	Debre Zeyit	Farmer	ILCA	Chinese	2.5	45 km	1982	yes
22	Adami Talu	IAR	ENEC	Indian	4.0	176 km	1984	
23	Sebeta		private	Indian	12.0	25 km	1980	
24	Holeté	IAR	ENEC	Indian	6.0	40 km	1983	
25	Melka Werer	IAR	IAR	Indian	-	-	-	
26	Debre Birham		ILCA	Chinese	2.5		1984	
27	Asmera	Nat. Resources, Cons. Dev. Dept.	ENEC	Indian	6.0	1050 km	1981	
28	Asmera	Nat. Resources, Cons. Dev. Dept.	ENEC	Chinese	2.5	1050 km	1981	
29	Mekele	-	Min. of Agri.	Indian 2x	-	850 km		
30	Alamata	Kobo	KAADP	Indian 2x	6.0	1050 km	1976	
31	Alamata	Sirbe Settl Village	KAADP	Chinese 5x	8.0	605 km	1977	
32	Alamata	Adibore, Settl Village	KAADP	Chinese 7x	8.0	605 kmg	1977	
33	Kalu Awraja	Kombolcha Harbu Settl	Min. of Agri.	Indian	6.0	380 km	1984	
34	Dejen (Yetnovo)	Integr. Family Life Education Project	UNICEF	Indian 2x	6.0	320 km	1984	
35	Bahrdor	Polytechnic Institute	Min. of Educ.	Indian	2.0	580 km	1984	
				Chinese	2.5	580 km	1984	
36	Jimma Awroja	Azelo Bero Cooperation	Min. of Agric.	Indian	4.5	-	1983	
37	Dera		ENEC	Indian 2x	6.0	130 km	1979	

Table 2. Small-scale biogas digesters constructed in Ethiopia (contiued 2)

No.	Location	User, address	Ownership	DIGESTER type	capacity m^3 gas/day	distance to Addis	constr. date	visited by expert
38	Dera		ENEC	Chinese	2.5	130 km	1979	
39	Amigna Debeso	Farmer	ARDU	Indian	6.0	140 km	1981	yes
40	Bika	Farmer	ARDU	Indian 2x	4.0	140 km	1982	yes
41	Badosa	Ademere: farmer	ARDU	Indian 2x	4.0	140 km	1982	
42	Huruta	Etosa Hetasse: farmer	ARDU	Indian 2x	4.0	140 km	1982	yes
43	Amigna	Ademere	ARDU	Indian	4.0	140 km	1983	yes
44	Sharibié		ARDU	Indian	4.0	140 km	1983	yes
45	Abo Kekersa		ARDU			140 km	1983	
46	Anko		ARDU			140 km		
47	Medeso Kileta	Koka Degaga	ARDU			140 km		
48	Hirna	Farmers Association	Min. of Agric.	Chinese	6.0	400 km	1982	
49	Alamiya	Farmers Association	Min. of Agric.	Indian 2x	6.0	560 km	1980	
50	Awasa	Junior College of Agric.	ENEC	Indian	6.0	270 km	1980	yes
51	Awasa	Junior College of Agric.	ENEC	Indian	4.0	270 km	1982	yes
52	Awasa	Junior College of Agric.	ENEC	Chinese	2.5	270 km	1983	yes
53	Awasa	Manager Weldekristos	private	Indian	2.0	270 km	1982	yes
54	Welaita Soda	WADU	ENEC	Indian	6.0	350 km	1980	
55	Welaita Soda		ENEC	Indian	6.0	350 km	1980	
56	Agarfa	Farming Training Centre	ENEC and FTC	Indian	6.0	450 km	1984	

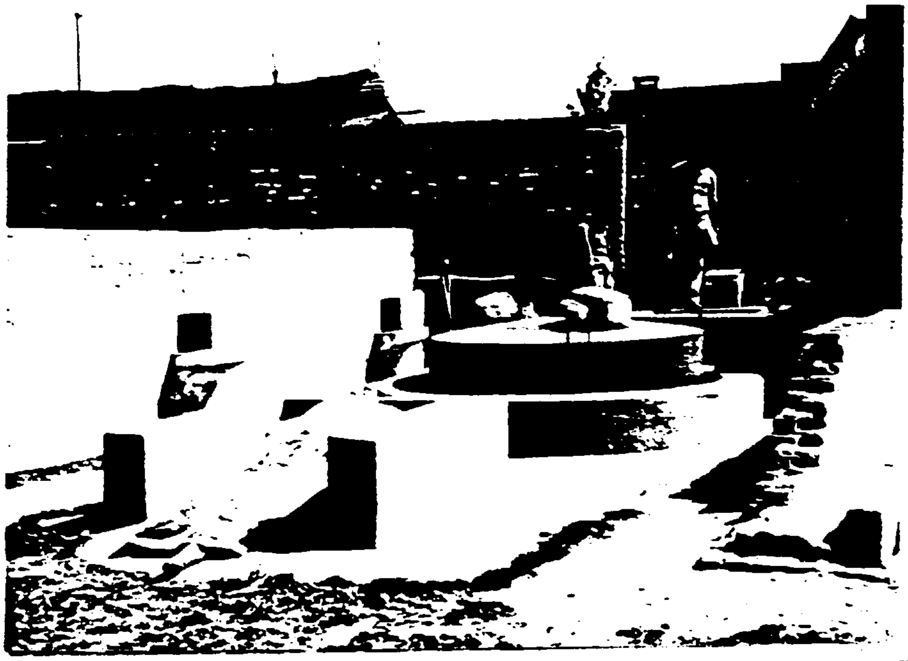


Fig. 1

Asmera, Min. Agriculture

Indian type digester in good order.

In use for lighting and cooking; gobar gas equipment.

Stones on dome for suitable gas pressure.

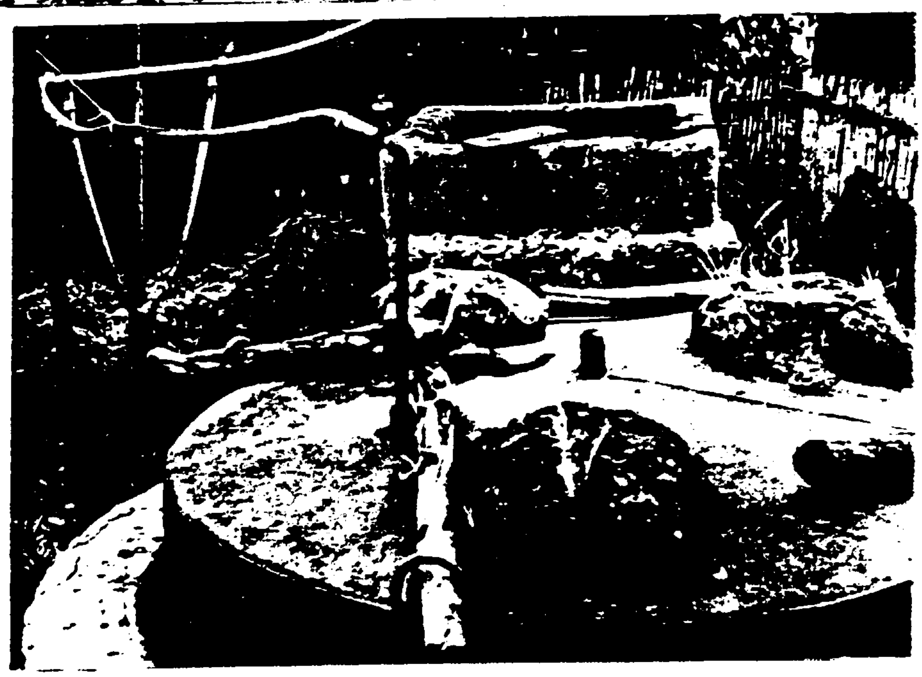


Fig. 2

Addis Ababa

Personel owner:

Mr. Metaferia.

Sand bags on dome for gas pressure. Note watertrap in gas pipe. Gas for lighting and cooking.

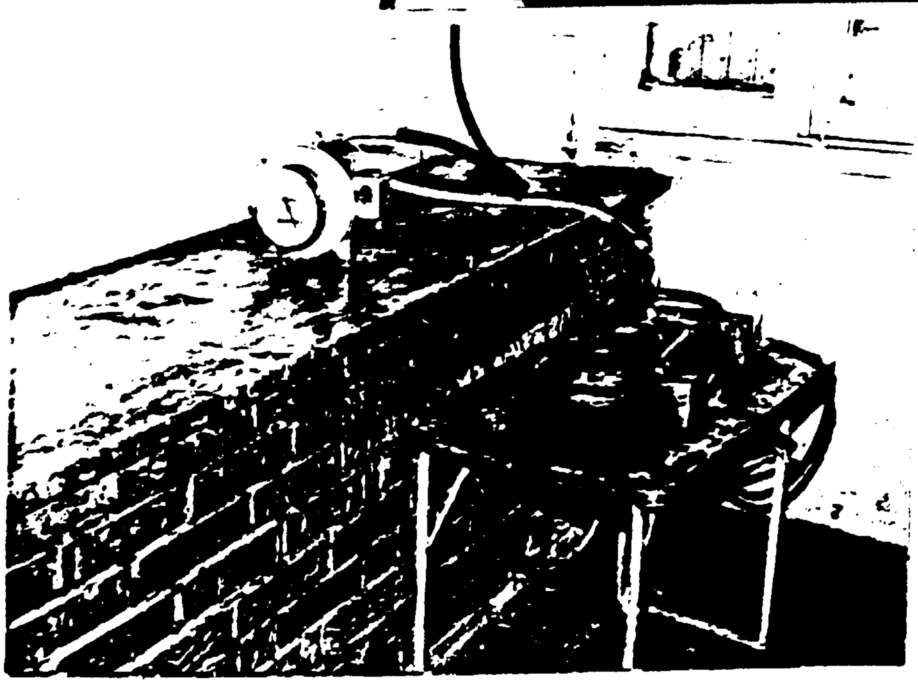


Fig. 3

24-hours measurement of biogas production: 4000 ltr/24 hours, in kitchen of farmer in fig. 2. Note the double hot plate and single gobar gas burner.

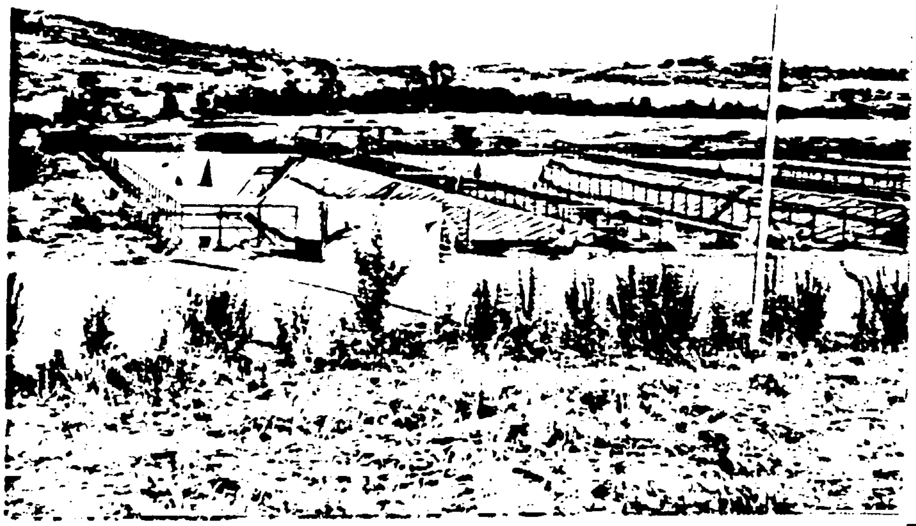


Fig. 4

Akaki near Addis Ababa.
Kaliti sewage treatment plant. Contents of septic tanks transported in tank lorries and aerated in the troughs shown.

Fig. 5

Addis Ababa

Biogas control laboratory just installed.

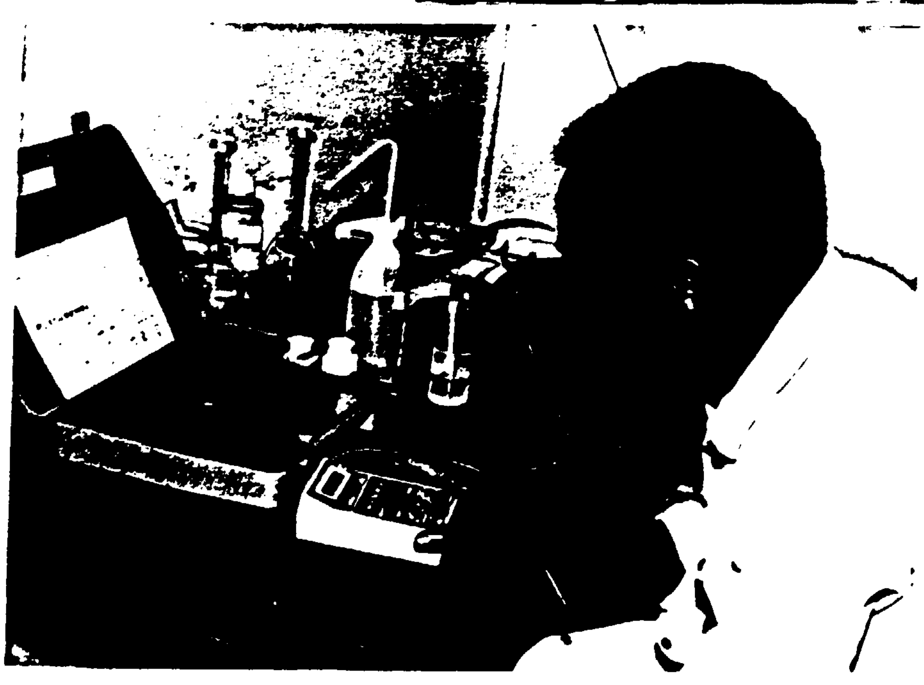


Fig. 6

Addis Ababa

Measuring pH.

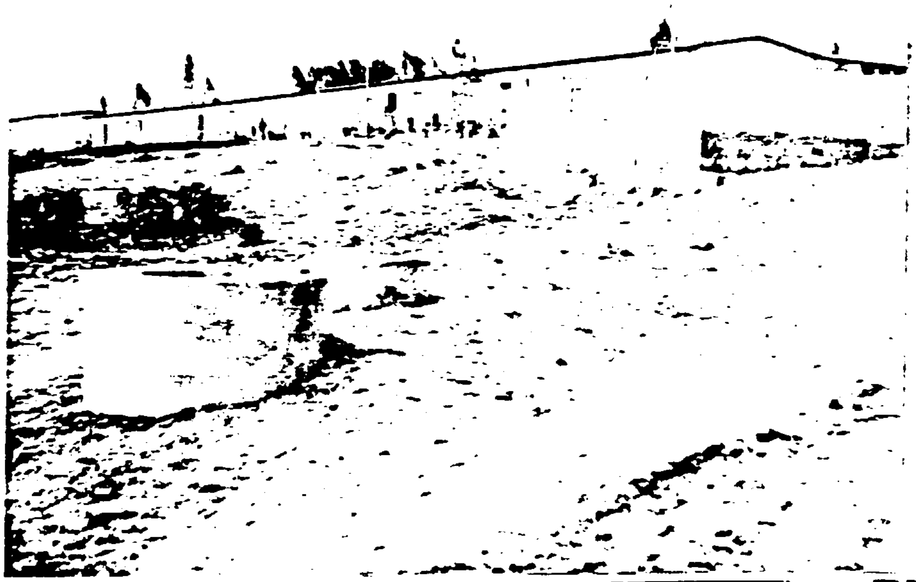


Fig. 7
Addis Ababa
Chinese type digester near septic tank of the quarter.
Never used.

Fig. 8
Addis Ababa
Final fermented sludge of Indian type digester collected in lorry.
Farmer: Mr. Mucugeta

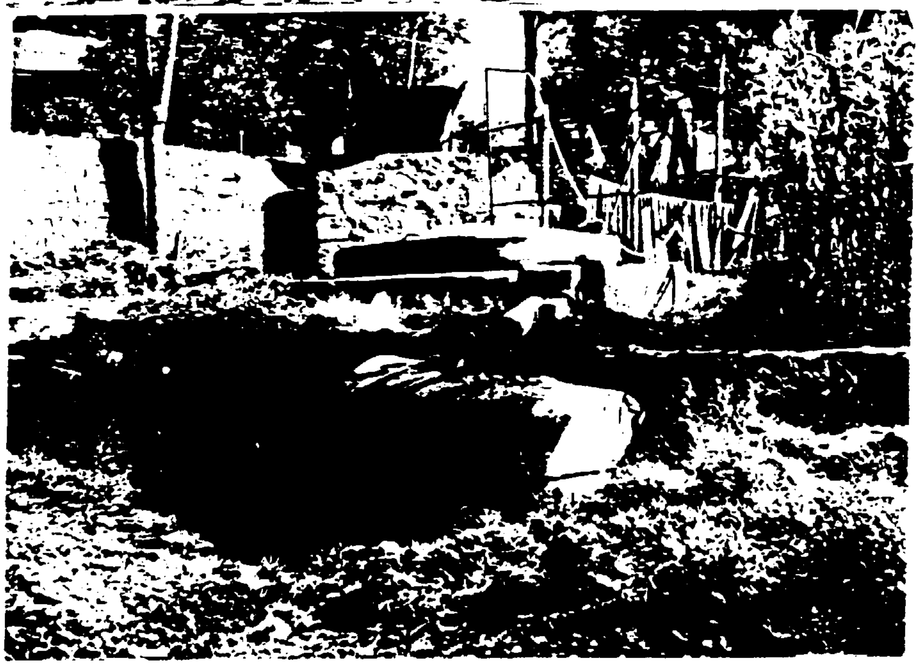


Fig. 9
Debre Zeyit
(ILCA)
Chinese type digester with inner motor tube for gas pressure control.
Gas used for lighting and cooking; gobar gas equipment.

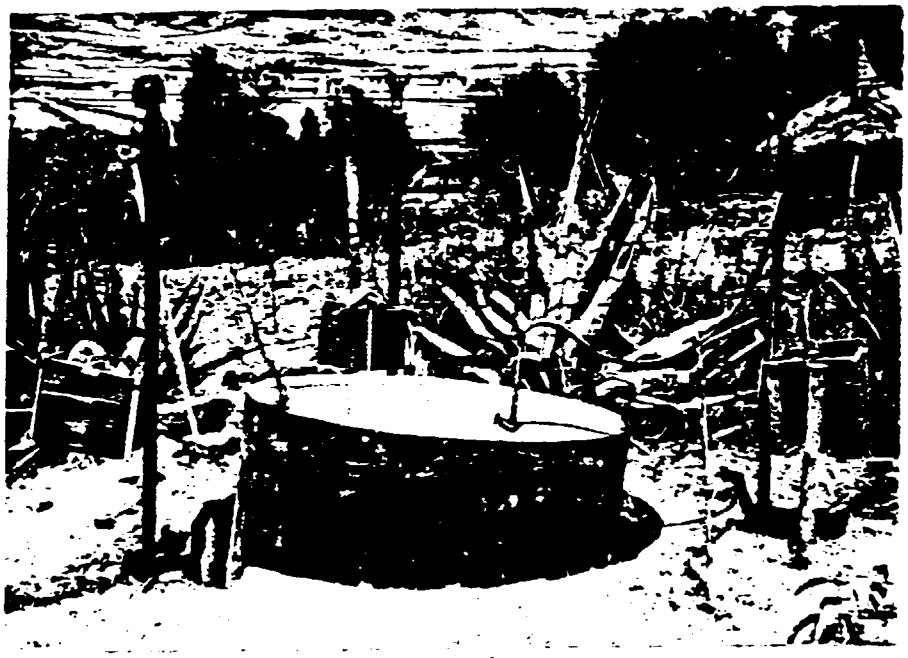


Fig. 10
Debre Zeyit
ILCA Experiment Station.
Indian type digester.
Dome with three counter weights not in balance.

Fig. 11
Debre Zeyit
(ILCA)
Bee-hive vinyl plastic bag, length 7 m, as plug-flow digester.
Retention time: 50 days.

Fig. 12
Debre Zeyit
(ILCA)
In the background: roofed-in plastic plug flow digester, length 7 m
In the foreground: small polythene plug flow diges-ter in shallow trench.

Fig. 13

Awasa

Personal owner:
Mr. Weldekristos
Small Indian type digester home-made: note gobar gas lamp in front.

Fig. 14

Awasa

Junior College of Agriculture, Dept. Home Science and Technology. Neglected overgrown Chinese type digester. Not in use.

Fig. 15

Awasa

Junior College of Agriculture. Indian type digester in very good condition. Not in use. Note boulders on dome, gobar gas lamp and gas meter.

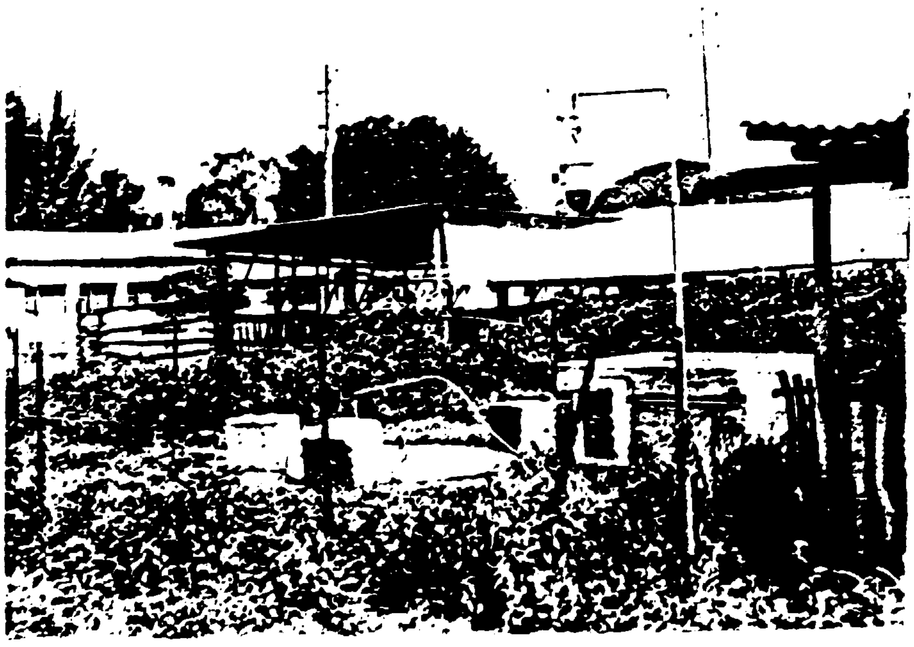


Fig. 16

Leku, 27 km south of Awasa.

Negotiations with potter about imitation of iron gobar gas burner.

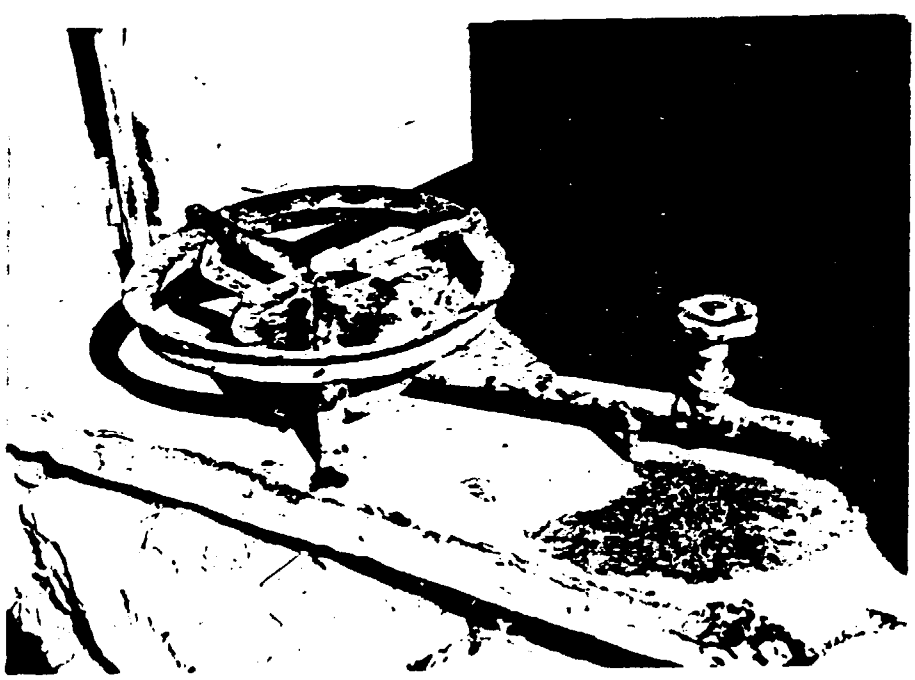


Fig. 17

Amigna-Ademere near Asela.

Gas burner made from reinforced concrete , a tin with holes and iron scrap

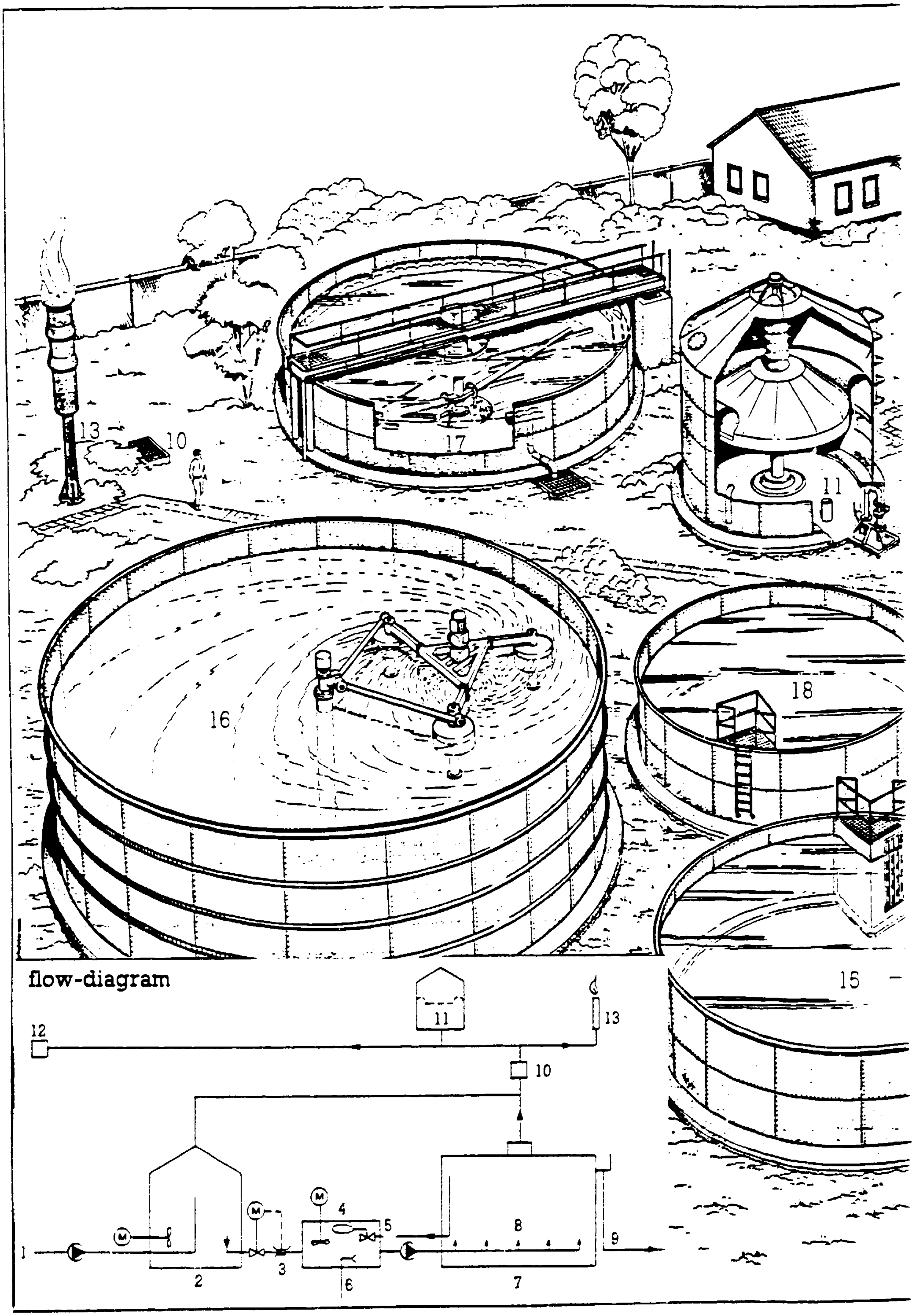
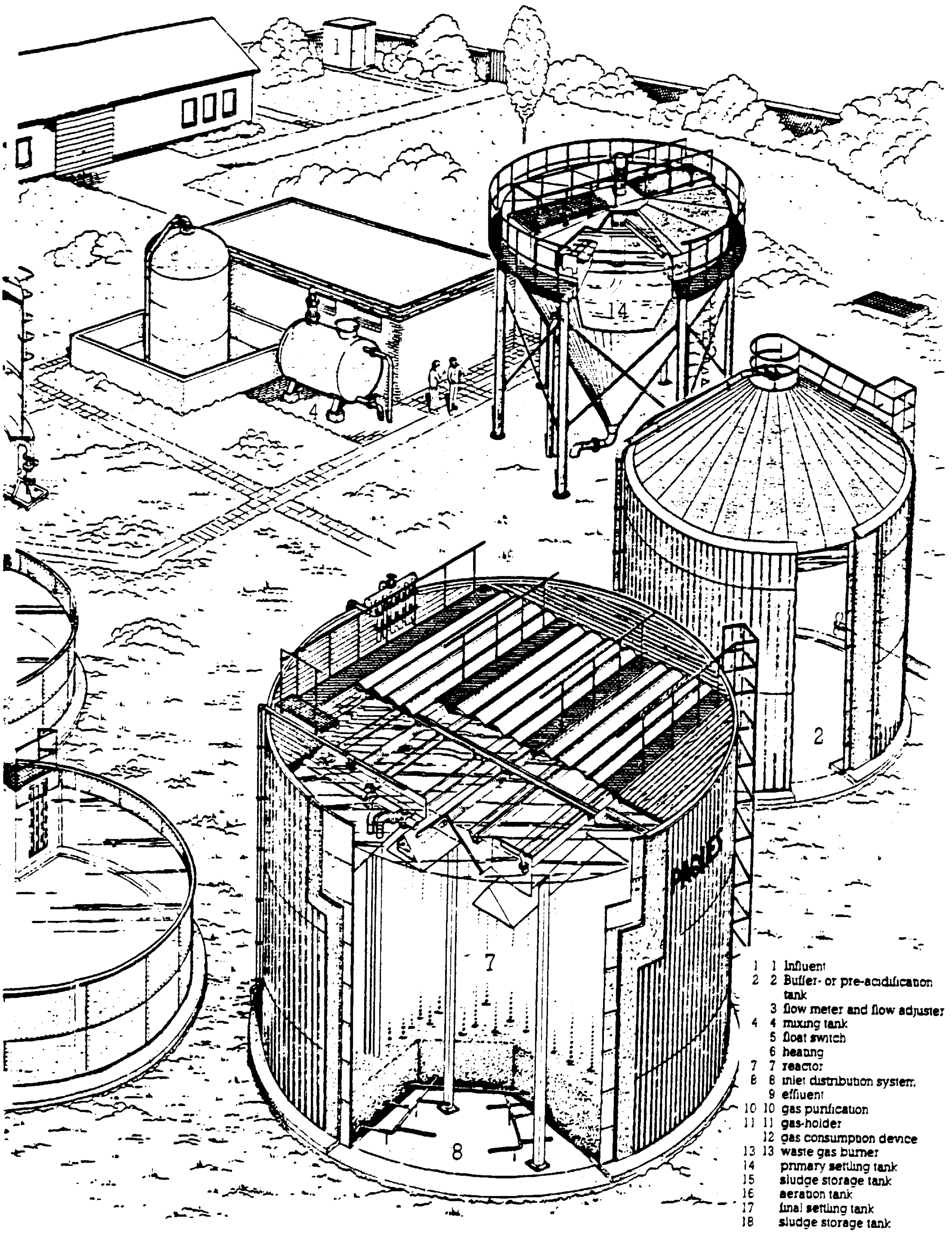


Fig. 18 Effluent treatment system


1
14
4
2
7
8
1 1 Influent
2 2 Buffer- or pre-acidification tank
3 flow meter and flow adjuster
4 4 mixing tank
5 float switch
6 heating
7 7 reactor
8 8 inlet distribution system
9 effluent
10 10 gas purification
11 11 gas-holder
12 gas consumption device
13 13 waste gas burner
14 primary settling tank
15 sludge storage tank
16 aeration tank
17 final settling tank
18 sludge storage tank

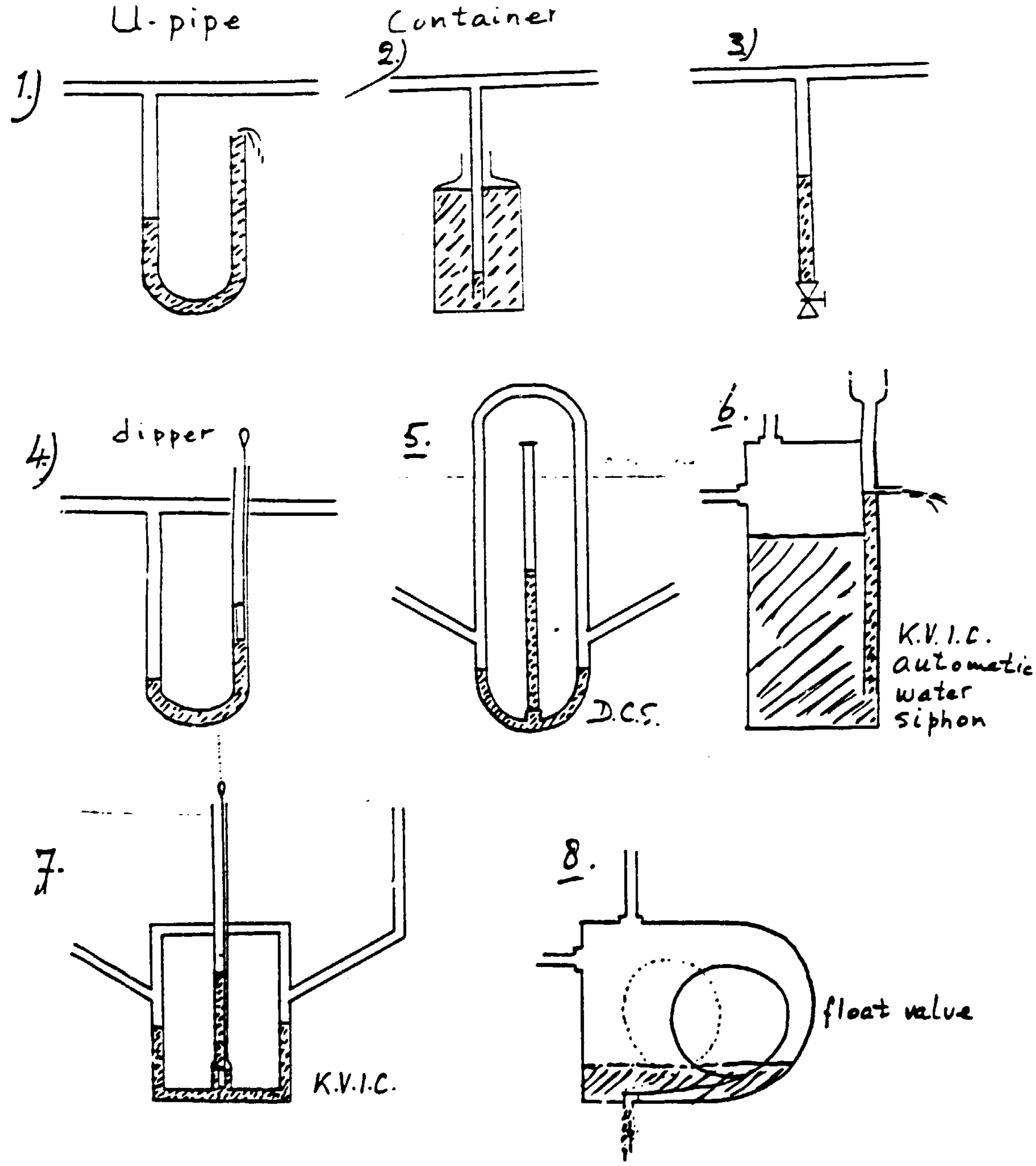


Fig. 19 Water traps for condensed water

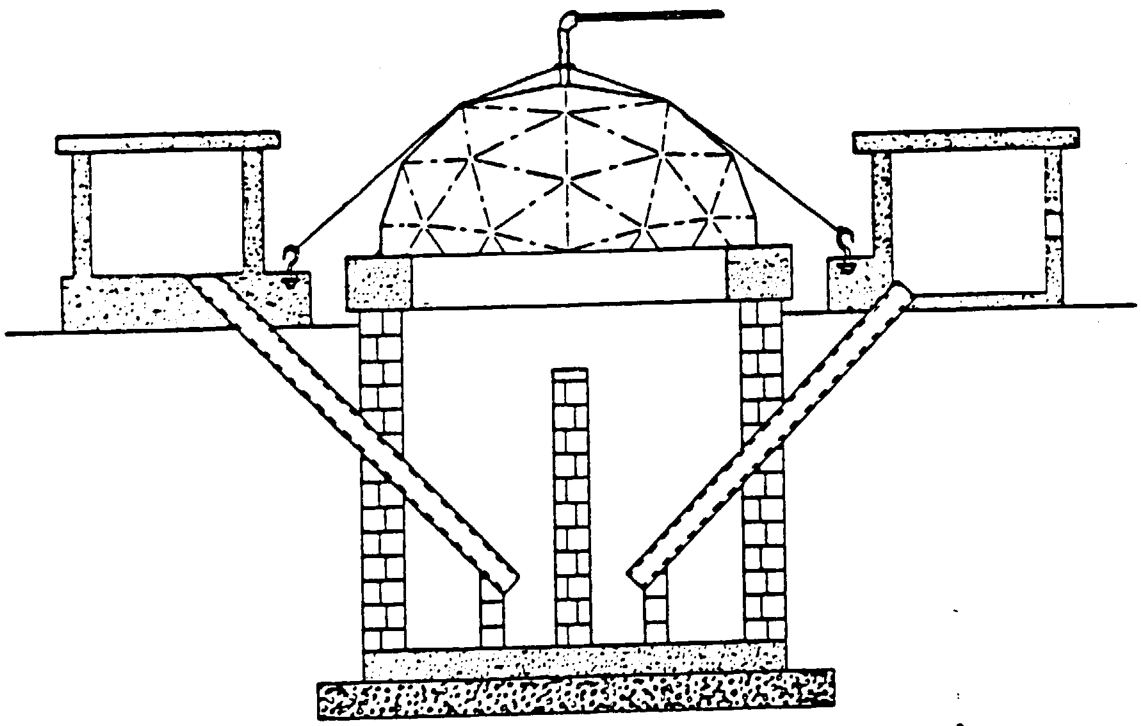
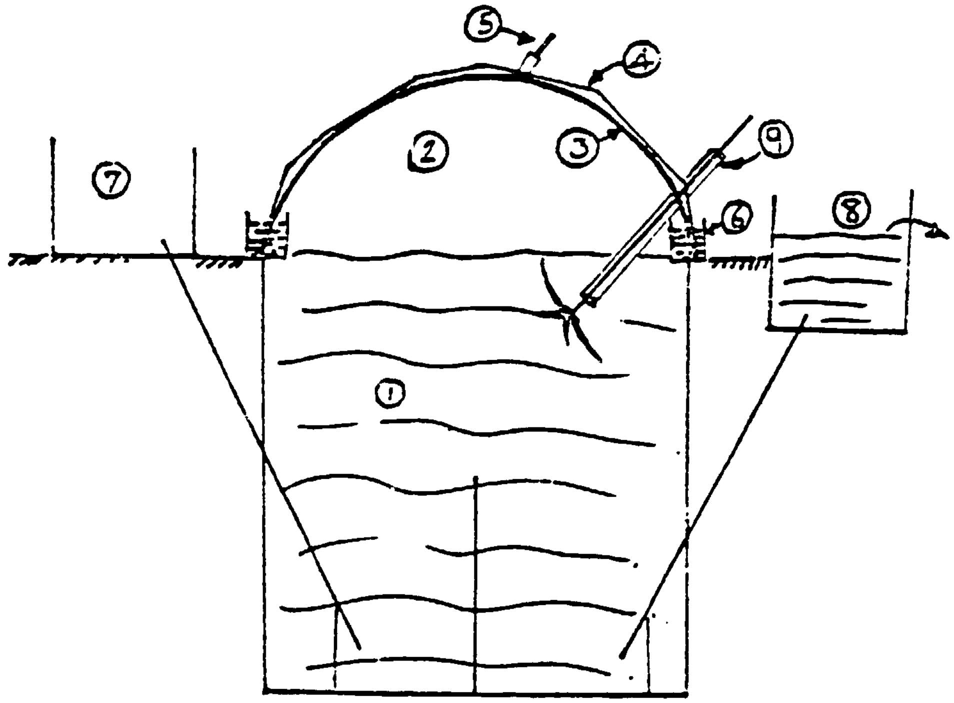
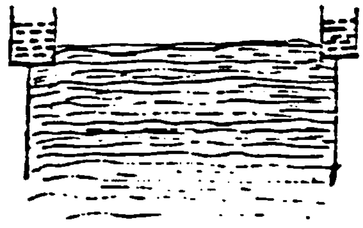


Fig. 20 Jwala digester
Source: Lichtman, 1983

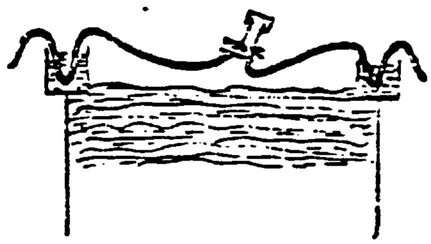


1. DIGESTER
2. GAS HOLDING SPACE
3. LDPE BALLOON
4. GEODESIC DOME
5. GAS OUTLET
6. WATER SEAL
7. SLURRY INLET
8. SLURRY OUTLET
9. STIKRER ASSEMBLY (OPTIONAL)

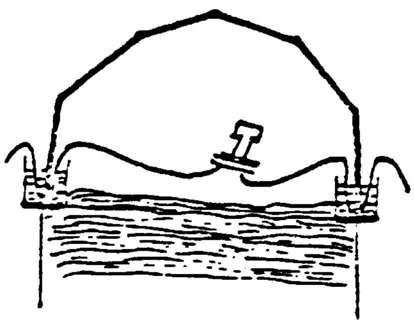
FIG-21 'JWALA' LINE DIAGRAM



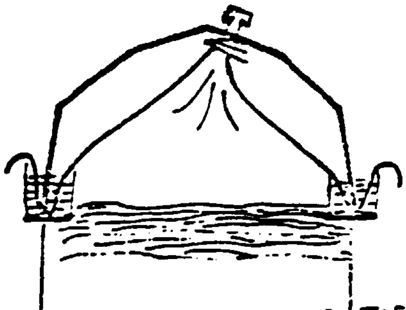
(i) FILL THE DIGESTER



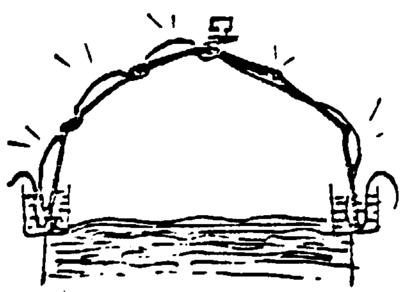
(ii) LAY THE 'LDPE' SHEET



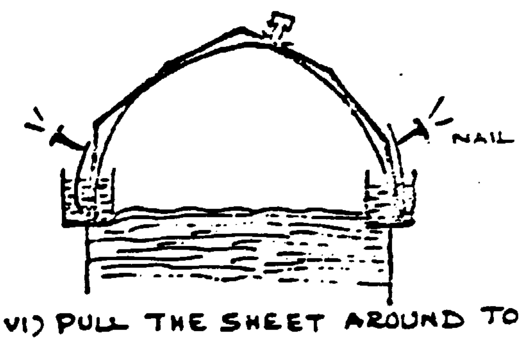
(iii) PLACE THE DOME OVER THE SHEET



(iv) PULL THE SHEET UP. TIE THE OUTLET WITH THE APEX OF THE DOME



(v) NOTE THE UNEVEN WAY IN WHICH SHEET HAS INFLATED.



(vi) PULL THE SHEET AROUND TO GET AN EVEN SPHERICAL SHAPE AND NAIL THE SHEET, PROTRUDING FROM THE BOTTOM, WITH THE DOME THEN TIE THE DOME WITH THE HOOKS PROVIDED AT THE BOTTOM OF THE WATER SEAL.

FIG 22
FIXING the GAS HOLDER.

Two types of anaerobic digesters on farms in Holland

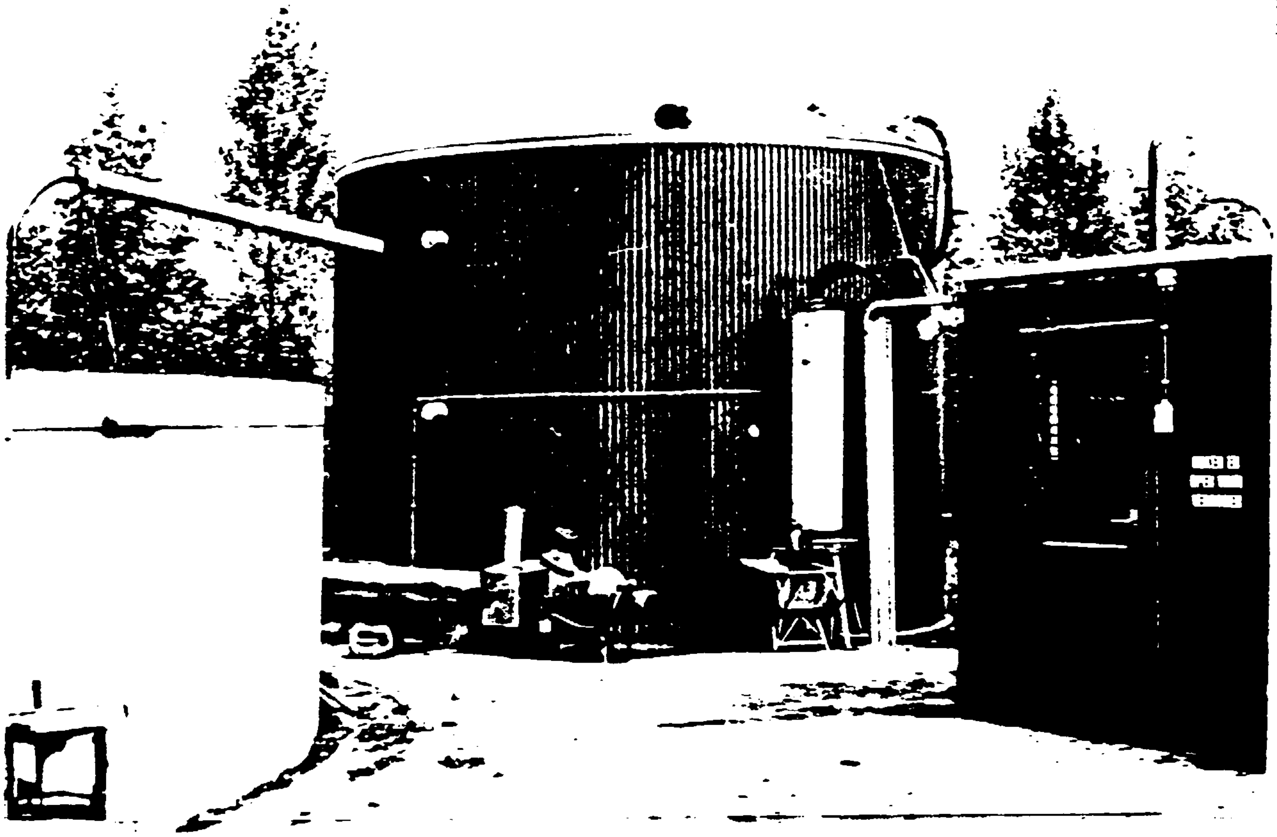
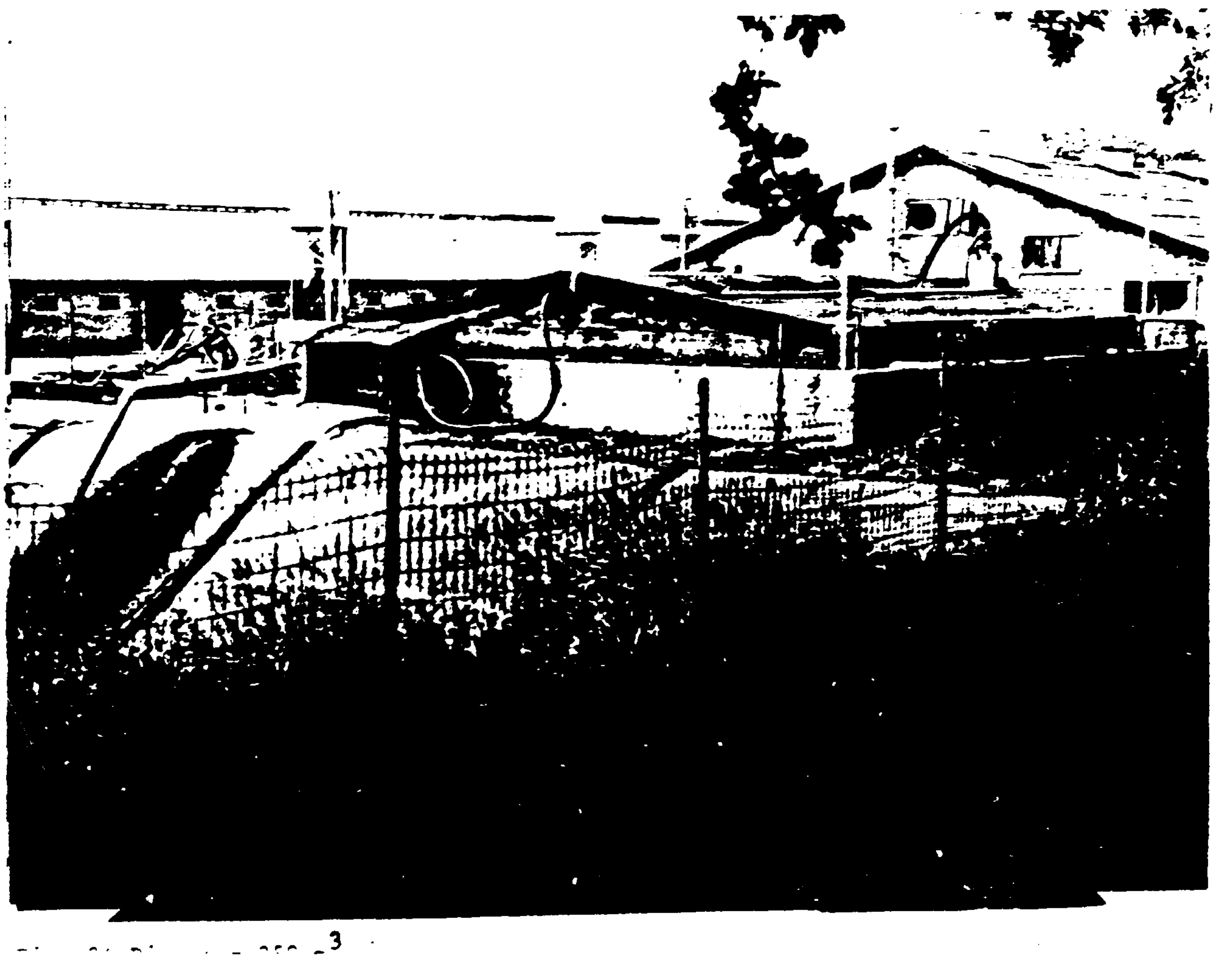


Fig. 23 Digester 150 m^3



[illegible]

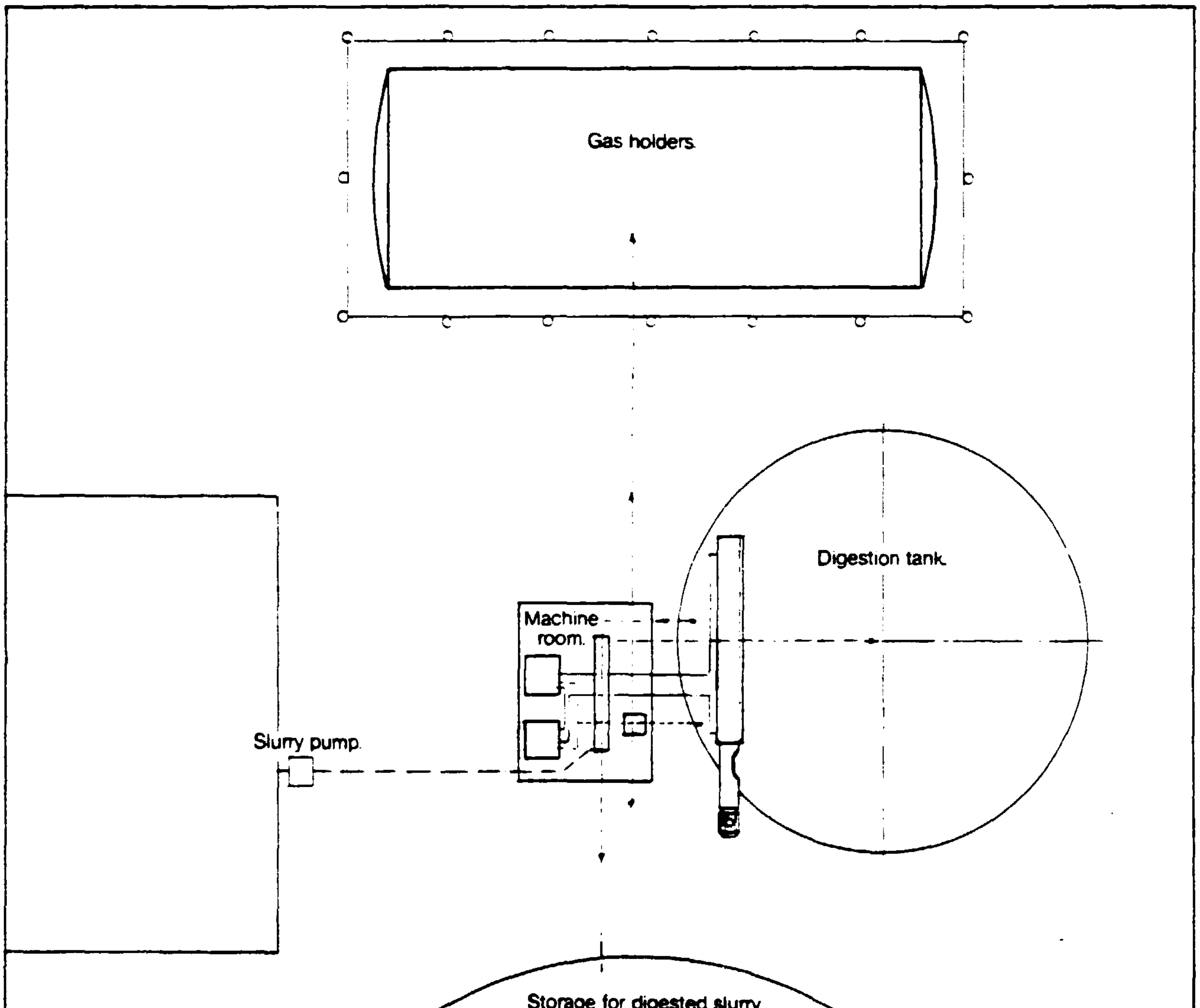
THERE WILL ALWAYS BE SLURRY

An installation lasting for years and years.
There is only one kind of Biopaq, available in several sizes. Before buying Biopaq we evaluate its cost against returns, based on your present and future needs.

Good advice is essential.
And remember, rises in the cost of energy makes Biopaq more attractive year by year.

More valuable fertiliser
During the process of digestion half of the organic material disappears. The result is that you can't smell the slurry anymore and yet it retains its original volume. The value of the slurry remains the same. For these reasons your cattle can graze on the meadows days after the digested slurry is spread.

Paques can tell you all the ins and outs of Biopaq.
A good investment now and in future!



The complete installation works on its own energy, fully automatically, without any supervision.

PAQUES

Fig. 25 Scheme of high-rate biogas unit

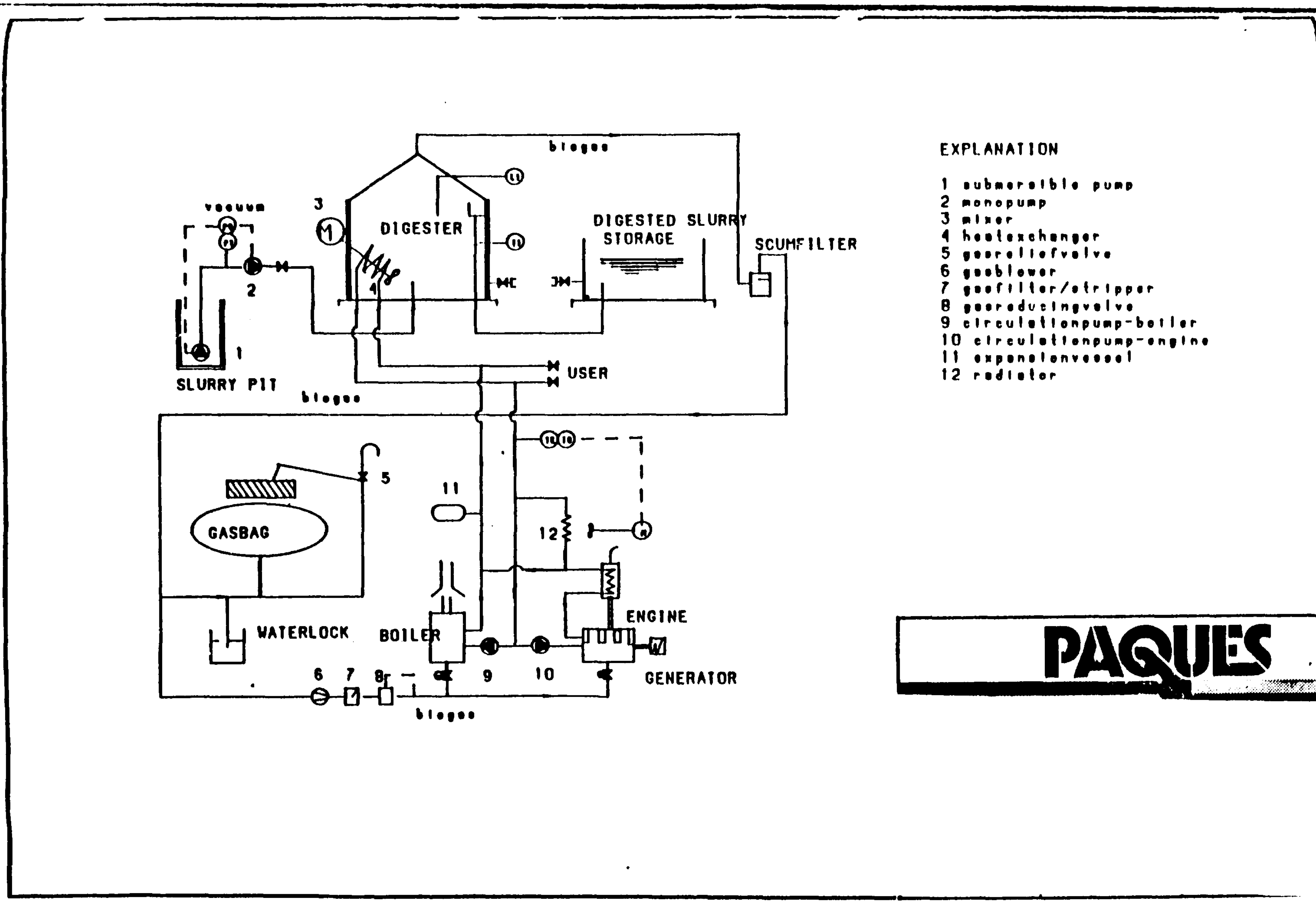


Fig. 26 Flow-sheet of high-rate digester