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DEMONSTRATION OF A GASIFIER FOR THE CONVERSION OF AGRICULTURAL WASTE TO FUEL FOR IRRIGATION PUMPING

SI/ETH/88/802/11-51 and 11-52

PEOPLE'S DEMOCRATIC REPUBLIC OF ETHIOPIA

Technical Report*

Installation, Commissioning and Monitoring of a 15 HP Gasifier System for Irrigation Pumping

Prepared for the Government of the People's Democratic Republic of Ethiopia
by the Unitd Nations Industrial Development Organization
acting as executing agency for the United Nations Development Programme

Based on the work of Messrs. H. Stiles and W. van Essen
Experts in Biomass Gasification

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United Nations Industrial Development Organization
Vienna

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ABSTRACT

INSTALLATION, COMMISSIONING AND MONITORING OF A 15 HP GASIFIER SYSTEM FOR IRRIGATION PUMPING.

SI/ETH/88/802

ETHIOPIA

Between 15th October and 15th November, 1988, a team consisting of two biomass gasification experts from the Biomass Technology Group of the University of Twente in the Netherlands, visited the People's Democratic Republic of Ethiopia to carry out the above mission.

Their specific Terms-of-Reference were as follows;

- to install and start-up the unit,
- to provide basic operator training,
- to furnish the local counterparts with an operators manual,
- to undertake a monitoring study on the performance of the unit,
- to write-up and present all findings in the approved manner.

The unit concerned was a small wood-charcoal gasifier purchased by UNIDO in early 1986 and never commissioned. The original project envisaged that the gasifier would spend most of its working life using carbonised maize cobs instead of wood charcoal.

The consultants conclusions were;

- the unit has a number of design and constructional faults which make it unsuitable, in its present configuration, for extended operation in a developing country,
- even if these faults were to be corrected, the unit would still be unsuitable for gasifying carbonised maize cobs, such an application requiring major alterations to the gasifier,
- the local circumstances (local production of charcoal prohibited, recent severe increases in the price of charcoal) now favoured the direct gasification of uncarbonised maize cobs.

Consultants are of the opinion that a number of possible options, i.e.:

- correction of the most serious faults of the unit and relocation to a wood charcoal manufacturing area, or
- ordering of a replacement unit, in keeping with the changed local situation,

under current Ethiopian circumstances are impractical, and therefore recommend that the project be put on hold untill more favourable conditions for introduction of biomass gasification in Ethiopia occur.

INTRODUCTION

In late 1985, under project UC/ETH/82/164 (Biofuels Demonstration Programme), a consultant (Ir. H.E.M. Stassen) visited the Peoples' Democratic Republic of Ethiopia on behalf of the United Nations Industrial Development Organization in order to examine the potential for the introduction of gasification technology within the context of extant pump irrigation schemes.

UNIDO issued a call for tenders (ref. 1 and Appendix I) after having received a draft version of the main body of Ir. Stassen's report (ref. 2), which was favourable to the introduction of a gasifier at the Golibee pump irrigation site. The tender document requested the supply of "one composite gasifier-engine-pump system, trailer mounted. Net output 15 HP at engine shaft while running on low-BTU gas".

As the result of this call for tenders, some eight offers were received, and, in early 1986, UNIDO contracted to purchase a small gasifier-engine-pump system from the gasifier manufacturer BECE of Almelo in The Netherlands. This installation was duly delivered to the Ethiopian National Energy Corporation (part of the Ministry of Mines and Energy) in mid-1986. The unit was subsequently transported by ENEC to the site recommended by Ir. Stassen; a small pump irrigation scheme at Golibee, some 2 km from the North-West shore of Lake Ziway in central Ethiopia.

Due to administrative, organisational and budgettary problems, commissioning of the unit was delayed untill October 1988. At this time UNIDO, contracted two BTG gasification experts that arrived in Addis Abeba on 15th October 1988, having travelled out via Vienna for briefing.

Their principal Terms-of-Reference were as follows:

- to install and start-up the unit,
- to provide basic operator training,
- to furnish the local counterparts with an operators manual,
- to undertake a monitoring study on the performance of the unit, with all findings to be duly written-up and presented in the approved manner (this document).

Field work finished on the 11th November, with the two experts returning to the Netherlands via Vienna early the following week.

I. OBJECTIVES

The objectives of the work were:

1) to install and commission the gasification unit and to give sufficient training that it could be satisfactorily run by local operators,
2) to provide a manual which could be translated into the local language (Amharic) for reference purposes and further training,
3) to evaluate the unit in terms of its concept, design, construction and actual performance, such an analysis permitting the identification of areas which would require attention should a decision be made to construct or purchase further, additional units.

In addition, the requirements of the unit specification (Appendix I) were to be checked. (However, the unit having been purchased some two and a half years previous, there seemed to be little hope of recovering money from the supplier in the event of the identification of faulty goods.)

The following parameters were monitored:

- fuel consumption,
- gas heating value,
- gas tar content,
- gas dust content,
- specific system fuel consumption.

II. GASIFICATION EQUIPMENT

A schematic diagram of the plant is presented in Figure 1 (overleaf).

A. Gasifier

The gasifier is a standard design fixed bed, down draught charcoal gasifier, having one central air inlet and a simple fuel bunker section with a loading hatch at the top. The gasifier shell is protected from the extreme heat of the oxidation and reduction zones by a refractory lining and the central air inlet terminates with a length of kanthal or aluminium oxide pipe. Ash removal is by means of a manually operated rotating grid and an ash port in the base of the gasifier.

The gas outlet temperature is measured using a bimetallic thermometer and the pressure drop across the gasifier as a whole can be measured by manometer using the measuring points provided.

B. Gas conditioning system

The producer gas first passes to a cyclone, where part of the entrained dust is removed. The dust collects in a purpose made hopper which can be emptied through an ash port.

The gas is then led sequentially through a pair of finned tube heat exchangers (in series) and a cloth filter which removes the remaining dust. The cloth filters are housed in a sheet metal box and must be cleaned by shaking every 100 hours or whenever the pressure differential indicates excessive values, the dust being removed from the bottom of the filter box through hatches.

The cloth filter housing is also equipped with bursting disks. As usual with such filters, temperatures in excess of 220°C lead to rapid degradation of the filter bags whilst temperatures below 100°C can lead to water condensing out in the gas, collecting on the bags and causing excessive pressure drops by formation of a sticky, hard-to-remove layer of material. (Such condensation problems rarely occur in charcoal gasification units.)

Condensate can be removed from the gas conditioning system using interlocking pairs of valves. The drain valves are arranged such that both cannot be open simultaneously, thereby preventing an ingress of air. Drainage is only possible from a point between the two coolers and from the upper, inner floor of the cloth filter housing.

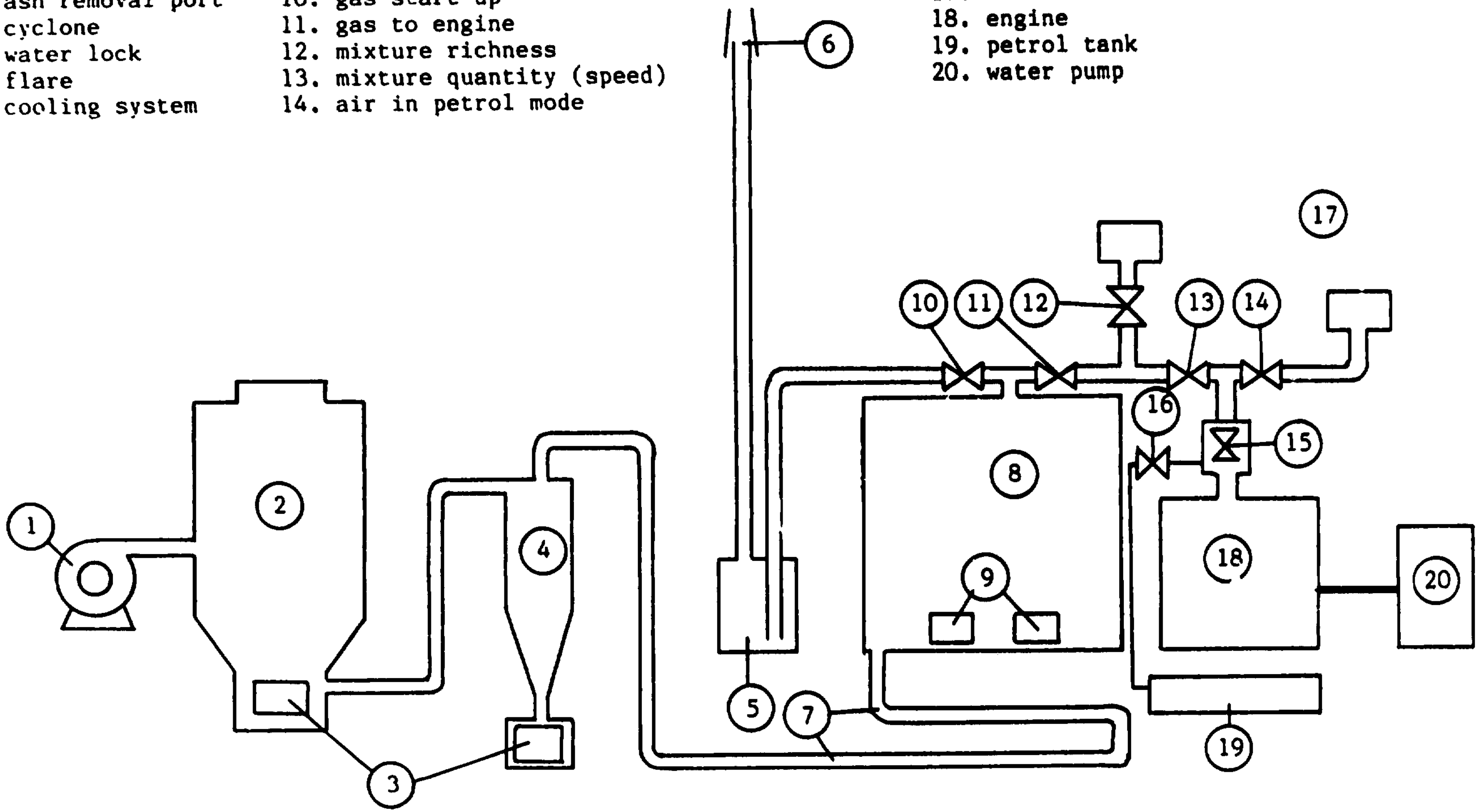
A bimetallic thermometer records the producer gas temperature after the filter housing, and provision is made for connecting a manometer across the filter housing.

C. Engine and pump

The unit is equipped with an unmodified six cylinder (2.8 ltr) Ford V6 petrol engine (as found in the Capri and Granada models) having electronic ignition.

The engine is directly coupled to a Swell centrifugal pump, type S, having 3" BSP suction and discharge orifices.

1. start up fan
2. gasifier
3. ash removal port
4. cyclone
5. water lock
6. flare
7. cooling system
8. filter
9. dust removal ports
10. gas start up
11. gas to engine
12. mixture richness
13. mixture quantity (speed)
14. air in petrol mode
15. butterfly valve carburettor
16. petrol
17. air filter
18. engine
19. petrol tank
20. water pump



Schematic diagram of gasification system at Golibee.

D. Start-up equipment

Start-up is effected using a 12V fan powered from the engine battery. Waste gases during start-up (and after shut-down) can be vented through a water lock and flare system. The flare is lit using a glow plug incorporated in the flare mouth.

The start-up system is unusual in that the air is blown through the gasifier, rather than sucked.

E. Base frame

The whole unit is mounted on a base frame made of welded, box section steel tube, having a single axle in the centre and raisable stabilisers front and rear. Provision for towing is a large 'eye bolt' type ring firmly secured to an extension of the frame.

III. MEASURING EQUIPMENT

A. Fuel moisture content

Fuel samples were taken from the sacks of charcoal to be used on the day in question. The pieces of charcoal were individually wrapped in aluminium foil and then placed together in a plastic bag. This bag was itself then wrapped in aluminium foil and placed with the other samples in a further plastic bag in a Samsonite suitcase. Given the fairly constant, low relative humidity at Golibee (approx. 30%), changes in the moisture content during storage can be discounted. It is, however, impossible to categorically discount the possibility of drying during the return trip to the Netherlands.

At the University of Twente, samples of charcoal of around 100 g were dried to constant weight at 105°C in an oven, the weight loss being determined by use of an analytical balance.

B. Fuel consumption

Plant fuel consumption was determined using a spring balance (25kg x 0.25kg).

C. Gas analysis

Gas samples were analysed using an Orsat apparatus to yield a dry gas composition in terms of hydrogen, oxygen, nitrogen, methane, carbon monoxide and carbon dioxide. The dry gas heating value was calculated on the basis of the analysis results.

Given the nature of the fuel (charcoal) and the low relative humidity, the moisture content of the gas was assumed to be negligible.

D. Gas flow

The gas production rate of the system under different conditions was measured using a venturi in the gas line to the engine.

E. Water flow

The water pumping rate of the system under different conditions was measured using a venturi in the water discharge pipe from the pump.

F. Gas dust content

The gas dust content under different conditions after the filter section was measured by use of a THT ('Technische Hogeschool Twente' being the old name for the University of Twente) discontinuous, isokinetic sampling and measuring system.

G. Gas tar content

The gas tar content under different conditions after the filter section was measured using a THT discontinuous, isokinetic sampling and measuring system.

H. Pressure drops

Pressure drops across the gasifier and the cloth filters were measured using the manometer attachment points that form part of the system's equipment.

J. Temperatures

The temperatures at the exits from the gasifier and the filter housing were determined using the thermometers which comprise part of the unit's instrumentation.

K. Water head

The delivery head for the pump was determined using a pressure gauge located on the water outlet line after the venturi mentioned under Section IV.F. The head was altered using a gate valve located after the pressure gauge.

IV. MEASURING PROCEDURES

During the course of the testing, the following runs were performed;

- one three hour test run pumping to the first water outlet (6.6m head) using wood charcoal,
- one three hour test run pumping to the second water outlet (9.75m head) using wood charcoal,
- one test run using carbonised maize cobs.

During the test runs fuel consumption, pressure drops, temperatures, gas heating values, engine gas consumption rates and useful pump power output were continuously measured. Gas samples were taken regularly for analysis by the Orsat method.

The low levels of tar and dust in the gas meant that measurable quantities could only be collected by using extended sampling periods. Hence the dust and tar contents of the gas were only available as averaged values taken over complete runs.

V. RESULTS

Detailed daily log sheets are given in Appendix II.

A. Fuel moisture content

The moisture content of wood and cob charcoal as used during commissioning is given in Table 1.

Table 1: Fuel Moisture content (from random sampling)

Fuel type	mean moisture content % (dry basis)
Wood charcoal (pit)	3.6
Cob charcoal (drum)	2.3

B. Gas heating value

Analysis of the product gas by the Orsat method yielded the heating values summarised below in Table 2.

Table 2: Gas Heating Value.

Head type (m)	average gas heating value (MJ/Nm^3)	minimum gas heating value (MJ/Nm^3)	maximum gas heating value (MJ/Nm^3)
6.6	5.25	5.17	5.34
9.75	4.67	4.66	4.68

These values are most acceptable.

C. Gas composition

The results of the Orsat analyses are presented in Table 3.

Table 3: Gas Composition (Vol. %).

Date	Time	H_2	N_2	CH_4	CO	CO_2	O_2	LHV MJ/Nm^3
7/11	14:46	5.2	57.9	2.9	28.4	4.3	1.3	5.17
	16:10	6.3	56.2	2.1	31.0	3.4	1.0	5.34
8/11	11:31	4.2	61.9	2.1	27.5	2.4	1.9	4.66
	13:15	5.3	60.0	1.5	28.3	2.5	1.5	4.68

The oxygen content in the gas is fairly constant and would seem to indicate that there are a number of small air leaks somewhere in the system. Such leaks are not uncommon and present no cause for alarm.

The gas of a given day is of good consistent quality and the presence of methane helps the calorific value a great deal. The level of methane is higher than would normally be expected from charcoal and it is probably being formed through the evolution and pyrolysis of volatiles still present in the charcoal. (An experiment using an open fire showed that the charcoal burned initially with a steady yellow/orange flame, indicating a significant volatile content.)

D. Gas dust content

In all cases, the amount of dust collected in the isokinetic sampler was less than the error of the measuring techniques used. This means that the gas dust content was, in all cases, below 10 mg/Nm^3. This is most acceptable, the normal limit being 50 mg/Nm^3.

E. Gas tar content

In all cases the amount of tar collected in the isokinetic sampler was less than the error of the measuring techniques used. This means that the gas tar content was, in all cases, below 10 mg/Nm^3. This is most acceptable, the normal limit being 150 mg/Nm^3.

F. Fuel consumption and system efficiency

The bunker section was completely filled with charcoal prior to a test run. At the end of the run, it was refilled in an identical manner, the weight of charcoal required being taken as the amount of charcoal used during the run.

The fuel consumption figures and gasifier efficiencies determined during the commissioning period are given below in Table 4.

Table 4: Fuel Consumption and Gasifier Efficiency

Date	7/11		8/11
Run time (hrs)	3:05		3:00
Water pumped (m^3)	67.6		26.8
kg charcoal consumed	19.5		17.0
M.C. %		3.6	
kg (dry) ed	18.8		16.4
Load (m) (inc. suc. head)	8.4		11.65
kg(dry)/m^3 water	0.278		0.612
Corrected for gas sampling	0.289		0.634
Overall efficiency	0.0099		0.0062

(calorific value of pit charcoal assumed to be 30 MJ/kg)

These fuel consumption figures are very high, as can be seen from the extremely low overall efficiencies.

There are two main factors which lead to this poor performance:

i) the engine is being run at 2,250 rpm and ii) it is directly coupled to a pump which is supposed to run at 3,000 rpm. The former point means that a lot of the chemical energy in the gas is developed in the cylinders as heat rather than power.
ii) the second point is illustrated by Appendix III, which shows the pump characteristics at 2,250 rpm and those at 3,000 rpm. The loss of head and pumping capacity caused by slow running is clear.

One solution to both these problems would be to add a 1:2 gearbox, so that the engine can run at 1,500 rpm, driving the pump at 3,000 rpm.

G. Operational stability

To obtain an idea of the system's operational stability, a number of different temperatures and pressure drops were monitored semi-continuously. These are shown in the daily log sheets (Appendix II).

From these data , it is apparent that the system is reasonably stable in normal operation.

H. Engine operation

The engine exhaust gas composition was examined to determine whether its performance was acceptable. Average composition values are given in Table 5.

Table 5: Average Exhaust Gas Compositions

Compound	vol %
Carbonmonoxide (CO)	1.0
Carbondioxide (CO_2)	20
Oxygen (O_2)	0.0

These figures are most acceptable and indicate that the engine runs well on gas, with no obvious problem. This is extremely fortunate since the above measurements are for the engine running with the air valves closed (i.e. with the lowest air to gas ratio possible). The problem is that the hood leading the producer gas into the engine does not seal properly against the top face of the carburettor and so acts, by a ejector-like effect, as a source of air for whatever is passing into the carburettor.

J. Gas and water flowrates

The actual producer gas and water flowrates are presented in the daily log sheets (Appendix II). These data confirm the observation made under Section V.G that the system possesses good operational stability.

VI. COMMISSIONING SUMMARY

A. Installation and commissioning procedures

Installation and commissioning began on the day of arrival at Golibee. It quickly became apparent that the unit was going to present considerable problems, especially from the point of view of the wiring. This problem was exacerbated by the fact that the electrical drawings bore little resemblance to the actual situation (components often being missed out and components, where shown, possessing cryptic identification labels, often nowhere explained) and the problem that there was no colour coding of wires (most of them being either red or green).

It became obvious early on that there were defective electrical components (the engine was completely dead) and, as a result large sections of the ignition system were checked, rewired or replaced. Similarly for the engine which, when coaxed into life (after five days of trying) ran very unevenly. Before smoother performance was achieved, it proved necessary to change the coil, the distributor cap, the high tension leads, the spark plugs and the carburettor. The timing and valve clearances were also checked.

The pipework for the water pump was installed without any difficulty, but it was clear that the manufacturer had given the consultant the wrong dimensions for the hoses. (The manufacturer had spoken of 3" and 4" diameter instead of 3" BSP and 4" BSP. As a result, the ordered hoses were toc small.) Fortunately, in one case a suitable adaptor was fairly easily located and in the other it was possible to fabricate, on site, an adequate temporary converter.

This done, and with the engine running on petrol, it was possible to perform a pump test. The results are presented in Appendix IV and Appendix III presents the pump characteristics of the unit and the characteristics claimed by the pump manufacturer (as has already been explained, the pump was operating at 2,250 rpm instead of 3,000 rpm). The locals were very, very disappointed with the resultant water flowrates into the irrigation channels which were extremely poor when compared with their existing, diesel powered pump unit (purchased since Ir. Stassen's visit).

An attempt was then made to run the unit on producer gas. This showed that the petrol-to-gas change-over procedure was very complicated and awkward. This was a combination of the large number of valves requiring to be operated and their locations (not all could be reached from the operator's nominal position). At the end of the test, the engine was run for five minutes on petrol but was found to be running unevenly. It was concluded that, in just over three hours running on producer gas, the replacement carburettor had been spoilt by tar and dust. (This reflects a major design fault in the unit; all the producer gas passes through the carburettor, thereby contaminating the passages with tar and dust, and also incurring an unnecessary pressure drop. Instead of this, the gas should be able to enter the engine directly and the carburettor should be located close to the second air intake, out of the gas line, such that it is only in use when the engine is operating on petrol.)

The following day, a proper monitoring run was performed, the unit pumping to the lower water outlet (a suction head of 1.9m and a discharge head of 6.6m) and the day after, a similar test was performed but this time using a discharge head corresponding to the upper water outlet (9.75m above pump level).

The latter experiment was characterised by excessive pressure drops across the gasifier. A decision was therefore taken to empty the gasifier and determine what the problem was. It was subsequently discovered that the aluminium oxide inlet pipe had broken off in the gasifier and that excessive clinkering had taken place. The reasons behind either of these problems were not entirely clear, but the clinker formation can probably be ascribed to soil and dust ('tramp' ash) in the pit-kiln wood-charcoal.

With the air inlet replaced, a run was performed using carbonised maize cobs as gasifier fuel. This was a failure since a reduction zone failed to develop (i.e. the oxidation zone extended from the air inlet down onto the grate). It was concluded that the problem was an insufficient depth of maize cobs under the air inlet pipe. The run was aborted and the gasifier duly emptied so that it could be refilled with wood charcoal. During this process, it was discovered that the replacement aluminium oxide air inlet had also broken. Further, the attempted emptying of the gasifier clearly demonstrated that there were very significant bunker flow problems when using carbonised maize cobs.

Given this fact and the other problems with the gasifier detailed below, it was decided to cease monitoring and training activities on the grounds that the unit required significant modifications before it could be operated successfully by local labour. These alterations would be of such a nature that any training given on the existing unit would be inapplicable to the revised unit.

Further, it had become apparent that the unit was ill-suited for Golibee for the following reasons;
- wood-charcoal manufacture is not permitted in the Golibee area,
- the price of wood-charcoal is now twice what it was during Ir. Stassen's visit,
- the unit cannot run (without major rebuilding of the gasifier) using the obvious alternative fuel, carbonised maize cobs.

B. Checklist of requirements

The only applicable checklist of requirements known to the consultant is that which forms the tender specification (Appendix I). In this respect the following comments can be made;
- the gasifier is not capable of generating low-BTU gas from both wood and charcoal. It is a charcoal gasifier and totally unsuited to working with fuels having a high volatile content,
- ready access to all parts of the gas conditioning system for the purposes of internal cleaning is not available,
- the engine probably has a shaft output at Golibee (altitude 1.500m, 5,000ft) less than 15 BHP. However, from the specification, it is unclear whether this is a requirement at sea level or at the site,
- six sets of suitable operating and maintenance manuals were not supplied.

Given that the purchase occurred some two and a half years ago, it seems unlikely that any responsibility for these deficiencies will be acknowledged by the manufacturer.

The unit appeared to have suffered some transport damage but it is unclear whose responsibility this is. It is not obvious when the damage occured; it may have been whilst in the container (manufacturer's responsibility) or, more likely, whilst being unpacked in Addis Abeba and transported to Golibee. It is regrettable that strict checks were were not carried out following the unit's arrival in Ethiopia.

As previously mentioned, the unit was very problematic to work with - during the course of the installation, commissioning and monitoring, the consultants discovered a number of significant faults in the unit. These are detailed below.

1. <u>Base frame</u>

- Unsuitable for off-road use (ground clearance no more than 15 cm)
- No brakes

2. <u>Gasifier</u>

- Non-return valve fails to close properly, allowing producer gas to pass to the blower where it often detonates
- Grate surrounded by 5 cm wide, open annulus (should be occupied by a steelring).Thus the fuel bed falls into the ash pan when the grate is operated
- Most pipe joints loose in gasifier body
- Bridging problems in the bunker when using maize cobs
- Fails to run on carbonised maize cobs

3. <u>Cyclone</u>

- Needs protective mesh (cyclone surface at 300°C)

4. <u>Finned coolers</u>

- No means of access for internal cleaning
- Drain from condensate collector not at lowest point (corrosion danger)
- No pipe fall to condensate tank

5. <u>Filter housing</u>

- Lid is without hinges and must therefore be removed manually (four man job)
- Upper drain not double valved
- Upper floor has no slope to lead condensate to drain
- Lower sectiondrains to condensate collector via finned coolers (corrosion danger)
- Bag suspension frame of very weak construction ('L' profile aluminium)
- Lower floor rises to gas inlet, so condensate can never drain out

6. <u>Engine</u>

- Carburettor hood seating surface not flat and therefore fails to seal against upper face of carburettor body. (The seal is so poor that the engine can run at 1,500 rpm on petrol and 2,250 rpm on gas with both air valves fully closed!)
- Carburettor hood cannot be screwed to new carburettor since old carburettor was retapped by BECE personnel (holes in BECE fabricated hood did not line up with those in the carburettor, so the carburettor was apparently altered to fit!)
- Oilbath air filters installed vertically instead of horizontally (oil runs out)

- Unsuitable, highly complicated electronic ignition system (known to have failed once in The Netherlands, failed again in Ethiopia)
- All the producer gas passes through the carburettor. This will lead to blocking of the jets by dust and tar and an unnecessary pressure drop
- Shaft between engine and pump exposed for some 50 cm (including a universal joint)
- Petrol tank located low in base frame and afforded no protection from below
- Petrol tank located within 25 cm of gasifier
- Cyclone gas exit pipe passes within 5 cm of petrol tank
- Engine sump less than 3 mm from baseframe(engine on vibration rubbers)
- Engine too complex for a developing country (2.8 ltr Ford Capri engine)
- Acceleration pump still fitted to both carburettors. This means that the butterfly valves in the carburettor throats cannot be fully opened for gas oper.tion without pumping petrol into the engine, resulting (almost inevitably) to an overspeed failure

7. Ignition system

- Many electrical connections afforded no protection against weather, animals etc.
- Overspeed print burned out (repaired by consultants)
- Ignition switch only activates ignition system in "Run" position not in "Start" position
- Connected electronic ignition burnt out (replaced by consultants)
- No economy control when engine running on gas, since performs best with air valve fully closed (!)

8. Pump

- Pump runs at 2,250 rpm instead of the recommended 3.000 rpm
- Pump inlet and outlet pipes 3" and 4" BSP not 3" and 4" diameter as manufacturer stated (hoses do not fit)
- No frame member beneath pump (vibrates excessively)

9. Start-up system

- Blower situated before gasifier rather than after (i.e. pressurised rather than suction system)
- Impossible to check on state of fire during start-up (pressure system)
- Start-up is not a one man operation (too complex)

10. Flare system

- Filler port for water lock cannot be opened (glued/welded shut)
- No stay or support for flare pipe

11. Spare parts

- Spare electronic ignitions of the wrong (by-passed) type
- Replacement alternator not supplied modified for ignition system pick-up
- Incorrect air filters supplied
- Replacement engine wiring loom does not fit
- Aluminium oxide air inlets 1 3/32" diameter, kanthal only 1"
- Carburettor cannot be screwed to carburettor hood

12. General

- Piping valve system too complex
- No proper manuals supplied to consultants
- Drawings supplied do not agree with unit as completed
- Drawings, where reasonably accurate, do not reflect correct relative position of components
- Wiring diagrams incomplete
- Poor engine/pump match (engine approx.13 HP, pump approx.6 HP at 3,000 rpm, much less at 2,250 rpm)

CONCLUSIONS AND RECOMMENDATIONS

As a result of the checking and performance testing of this gasifier in Golibee, the following conclusions have been drawn;

1. The installation, has a number of design and constructional faults which make it unsuitable, in its present configuration, for extended operation in a developing country.

2. Even if these faults were to be corrected, the unit would still be unsuitable for gasifying carbonised maize cobs, such an application requiring major alterations to the gasifier,

3. During the course of the monitoring, the consultants learned that the production of wood charcoal is illegal in the Golibee area, there not being enough trees to sustain production. Where it is produced, it is made in pit kilns rather than oil drum kilns, because this reduces the labour requirement for sizing the timber. The resultant charcoal is unsuitable for gasification since it tends to be high in "tramp" ash (soil, stones etc.). It has also recently become expensive, having doubled in price since Ir. Stassen's visit.
   The only obvious alternative biomass resource in the area is maize cobs which can be carbonised (with considerable expenditure of labour) in oil drum kilns to yield a poor quality, high volatile charcoal. From an energetic and labour point of view, it would, in the opinion of the consultants, be better if these cobs could be gasified directly (i.e. uncarbonised). However, in the case of Golibee, care would have to be taken to avoid polluting the pool from which the irrigation water and the village's drinking water is taken with gasifier condensate.

Based on the above conclusions, there are a number of possible options left in order to reach the original goals of the project i.e.:

1. Pressure the manufacturer to rebuild the unit, correcting the faults.

2. Transport the unit back to Addis Abeba and rebuild it (prior to relocation), under expert supervision, in a Government workshop.

3. Purchase a replacement unit for Golibee, suitable for the gasification of uncarbonised maize cobs.

All three of options suffer from grave impracticalities i.e.:

- The gasifier manufacturer (BECE) has ceased trading and therefore it will be difficult to make a claim with respect to sloppy workmanship and engineering. In this respect it must be emphasized in the past, the gasifiers manufactured by BECE used to enjoy a sound reputation. Possibly the defects of the unit under consideration are related to difficulties the company may have been at the time of ordering and deliverance of the unit.

- In view of the current economic situation in Ethiopia which is characterized by grave shortages of materials and spare parts, the second option will call for heavy external input in funds and manpower. As it is especially this situation that also will hamper possible future dissemenation of biomass gasification technology in Ethiopia, consultants are of the opinion that that under current Ethiopian conditions such an expenditure is not warranted.

- the same arguments basically hold for the third option.

Biomass gasifiers are known to operate succesfully in a number of developing countries i.e. rice husk gasifiers in Mali, Thailand and China, wood and charcoal gasifiers in the Pacific region ,Indonesia and in Latin America. However, in all those cases a basic system for acquiring spare parts and maintenance materials is available. Unfortunitately this does not seem to be the case under present conditions in Ethiopia.

Therefore in the opinion of the consultants, at present the best option is to put the project on hold untill circumstances in Ethiopia have changed and gasification units can be technically properly backed-up with adequate repair and maintenance services.

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1. UNIDO Requisition 85/2. Issued 12th September 1985, Vienna.

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3. Letter 5/11/87 from Dr. F. van den Aarsen (BECE) to Dr. H.N. Stiles (BTG). BECE reference 87.125 FA/mw (reply to BTG letter 87359/HNS/MB).

APPENDIX I: UNIDO Call for Tenders

R. Williams/sk
12 September 1985

Additional information on Requisition 65/2
Gasifier (two items)

(1) One Composite unit gasifier-engine-pump system, trailer-mounted. Net output 15 HP at engine shaft when running on low-Btugas.

Gasifier Reactor: Capable of generating low-Btu fuel gas from wood and charcoal (lump size) suitable for use in an internal combustion engine. Batch fuel feed and char/ash removal. Manual or automatic grate activation. Fan/flare system for use during start up.

Gas cleaning: Capable of removing tar/particulate from low-Btu gas to render it suitable for use as engine fuel. Provision of ready access for cleaning if necessary. Supplied with spare filter media if used.

Engine: Spark-ignition and capable of 100% low-Btu gas operation with net output of 15 BHP minimum. Provision of low-Btu gas carburetion system incorporating appropriate speed control devices and capable of running on 100% conventional fuel in the event of interruption to low-Btu gas supply (manual changeover is acceptable).

Pump: Low-head high volume irrigation type pump.

Additional items to be supplied: Six (6) sets complete operating and maintenance instructions for complete system and sub-components where appropriate. Spare parts as necessary.

Additional Quotation information: Voluminous company advertising literature, brochures, etc., are not to be included with the quotation; however, brief details of gasifier-engine installations of similar capacity (50 HP or less) installed in the past 5 years would be of use to UNIDO in selecting the winning bid. Such details might include nature of purchaser's business, location, capacity and duty of system and length of time it has been in service.

Also to be included in the quotation:

(a) General description of the type of gasifier reactor and gas cleaning system including:

- frequency of fuel addition and ash/char removal for a given system output;
- approximate quantitative and qualitative data on solid and liquid discharges (ash/char and scrubber drain);
- nature and frequency of maintenance/cleaning operation.

(b) Nameplate data for the engine and pump/generator and derration for low-Btu gas operation.

(c) General description of method of engine conversion, speed control when running on low-Btu gas, and type of hardware employed for the conversion.

(d) Information on safety issues relating to the explosive and poisonous nature of low-Btu gas. Precautions to be taken by the user bearing in mind the system is intended for use in a developing country.

(e) Information on the operating schedule which is attainable with the gasifier equipment to be supplied (minimum requirement is 8 hours per day, 5 days per week). Realistic assessment of the frequency of maintenance for the engine and description of maintenance activities (major, minor overhaul, removal of cylinder head, etc.).

(f) Approximate dimensions and weight.

(2) One composite unit, gasifier-engine-generator system, trailer mounted, net output 50 KW when running on low-Btu.

Gasifier reactor: Capable of generating low Btu fuel gas from wood and charcoal (lump size) suitable for use in an internal combustion engine. Batch fuel and char/ash removal. Manual or automatic grate activation. Fan/flare system for use during start up.

Gas cleaning: Capable of removing tar/particulate from low-Btu gas to render it suitable for use as engine fuel. Provision of ready access for cleaning if necessary. Supplied with spare filter media if used.

Engine: Spark-ignition and capable of 100% low-Btu gas operation with net output of 50 KW minimum. Provision of low-Btu gas carburetion system incorporating appropriate speed control devices and capable of running on 100% conventional fuel in the event of interruption to low-Btu gas supply (manual changeover is acceptable).

Generator: 380/440V 50 Hertz 3ϕ (phase).

Additional items to be supplied: Six (6) sets complete operating and maintenance instructions for complete system and sub-components where appropriate. Spare parts as necessary.

Additional information: Same as at item 1.

All technical enquiries to R.O. Williams, Chemical Industries Branch, UNIDO, Vienna, Austria.

APPENDIX II: Daily Log Sheets

The symbols used in the tables forming this appendix are as follows:

Time: local time during run

T_1: Cyclone inlet temperature (^oC)

T_2: Filter house exit temperature (^oC)

P_1: Pressure drop over gasifier (cm w.g.)

P_2: Pressure drop over filters (cm w.g.)

P_3: Discharge head for pump (m w.g.)

F_1: Producer gas flowrate (Nm^3/hr)

F_2: Pumped water flowrate (m^3/hr)

In all cases, the pump suction head was 1.9m

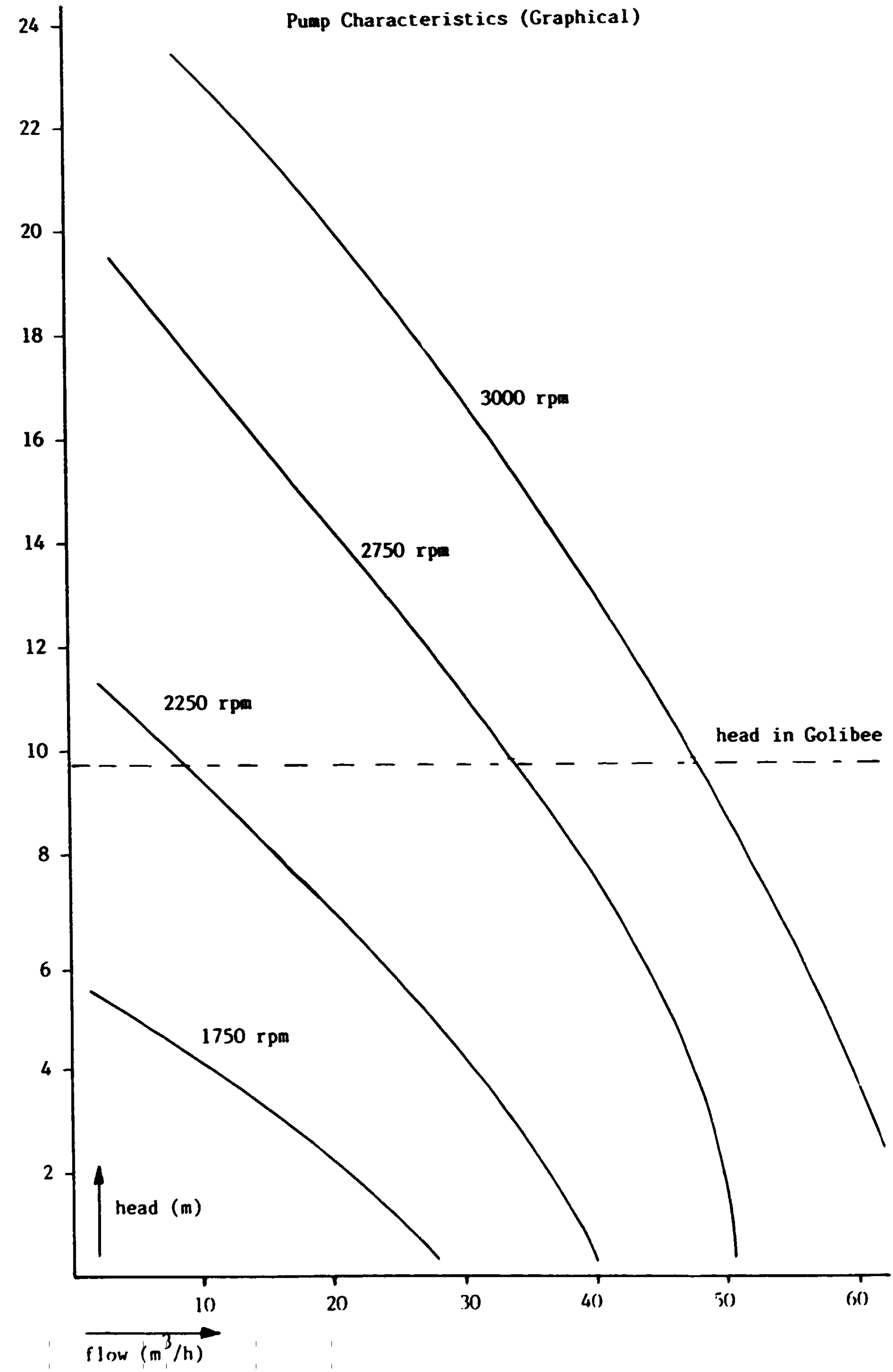
Appendix II.1: 7/11/88. Pumping to first outlet.

Time	T_1	T_2	P_1	P_2	P_3	F_1	F_2
12:25	start						
12:30	engine on - runs badly						
12:42	nothing happening, restart						
12:52	engine start - missing badly						
13:12	nothing happening, restart						
13:17	engine start						
13:40	hammer non-return valve. pressure drop over gasifier falls dramatically and exit temperature begins to climb						
14:05	change engine over to gas operation						
14:10	205	41	6.5	1.0	6.6	27.9	21.9
14:25	239	41	5.8	1.0	6.6	28.5	22.1
14:40	258	43	6.6	1.0	6.6	29.4	21.8
14:55	271	44	8.1	1.0	6.6	30.4	21.9
15:10	282	44	7.8	1.5	6.6	28.9	22.1
15:25	283	44	9.3	1.5	6.6	28.4	21.8
15:40	288	44	6.9	1.5	6.6	28.0	21.9
15:55	291	44	6.9	1.5	6.6	27.7	22.1
16:10	294	43	7.0	1.5	6.6	27.6	21.9
16:25	294	41	6.4	1.5	6.6	27.2	22.1
16:40	290	40	6.5	1.5	6.6	26.5	21.8
16:55	286	39	5.9	1.5	6.6	26.5	21.8
17:10	282	37	5.2	1.5	6.6	25.7	21.8
	change engine back to petrol operation						
17:15	stop engine						

Appendix II.2: 8/11/88. Pumping to second outlet.

Time	T_1	T_2	P_1	P_2	P_3	F_1	F_2
10:00	start						
10:05	engine on, note high pressure drop over gasifier						
10:30	nothing much happening, try using engine to suck air through gasifier.						
10:45	change engine over to gas operation						
11:00	261	32		2.0	9.75	28.9	9.6
11:15	280	35	115	2.0	9.75	30.8	8.8
11:30	293	41	113	2.0	9.75	29.4	8.8
11:45	309	38	121	2.0	9.75	29.7	8.8
12:00	315	40	124	2.0	9.75	30.6	8.8
12:15	295	41	79	2.0	9.75	30.0	8.8
12:30	315	41	116	2.0	9.75	31.2	8.8
12:45	320	42	115	2.0	9.75	30.2	8.8
13:00	327	42	110	2.0	9.75	30.9	8.8
13:15	328	44	111	2.0	9.75	30.8	8.8
13:30	331	44	121	2.0	9.75	32.3	8.8
13:45	325	45	95	2.0	9 75	28.8	8.8
	change engine back to petrol operation						
13:50	stop engine						

APPENDIX III: Pump Characteristics (Graphical)



Pump Characteristics (Graphical)
24
22
20
18
16
14
12
10
8
6
4
2
3000 rpm
2750 rpm
2250 rpm
1750 rpm
head in Golibee
head (m)
10
20
30
40
50
60
flow (m³/h)

APPENDIX IV: Pump characteristics (Numerical)

The two tests detailed below give some impression of how the characteristics of the pump change with speed. Owing to the presence of an overspeed failure relay, cutting in at 3,000 rpm, it was not possible to check the pump manufacturer's claims. Please note that 'Head" in the data below does not include the 1.9 m suction head for the unit.

Head (m)	Water flowrate (m^3/hr) 2,250 rpm	2,750 rpm
0	39.6	48.6
1	38.8	48.6
2	36.4	48.0
3	33.7	47.7
4	30.4	46.6
5	27.2	45.0
6	22.9	42.6
7	20.7	40.7
8	15.7	37.6
9	11.8	34.6
10	7.8	31.8
11	3.9	28.8
12	2.5	25.4
13	0.0	22.2
14		18.8
15		15.2
16		12.4
17		8.8
18		6.8
19		2.5
20		0.0