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Final Report on the Project "Gasifier based Energy Generation System at Cocodrilo, Cuba"

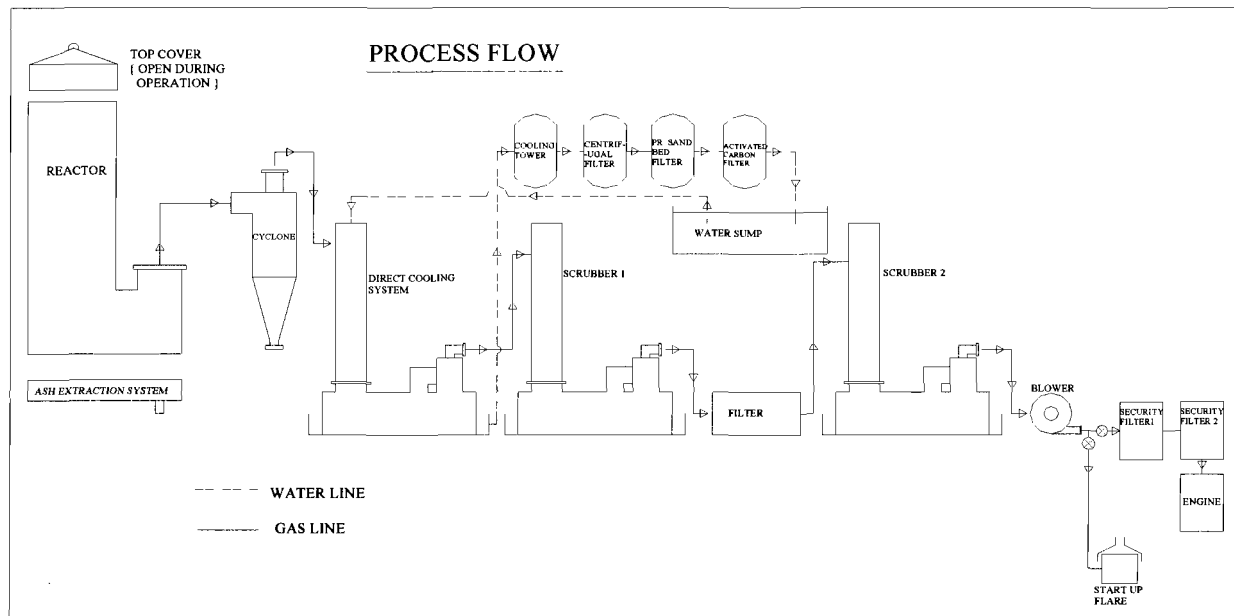
UNIDO Project No.:GP/CUB/05/001

UNIDO Contract No.: 16001226

The project was undertaken to set up a 70 kg/hr gasifier with a suitable dual fuel engine for Power generation at Cocodrilo on Island of Juventad, Cuba.

I. Process Description of IISc open top down draft gasification system

The overall schematic of the gasifier system is shown in Fig. This is basically an open top downdraft system, where both gas and feed stock move downward as the reaction proceeds. The air required for gasification is partly drawn from the top, and the remaining from the air nozzles surrounding the combustion zone and central air nozzle directed to the reactor core. The required suction for this process is obtained from the engine (or the blower depending on the mode of operation). Bio-residue after drying and pyrolysing in the upper zone of the reactor undergoes volatile combustion becoming char by the time it reaches the oxidation zone. In the oxidation zone the volatiles undergo oxidation with the release of CO_2 and H_2O . These product gases undergo reduction, in the presence of hot bed of charcoal, and yield a combustible gas mixture. The hot gas exiting at the reactor bottom passes through cooling and cleaning system consisting of water sprays, Scrubbers and fabric filters depending upon the requirements. Further the gas flows through the primary blower and then branches into two streams, one stream leads to the pilot burner and another to the engine. Water used for cooling the gas can be used either as a single pass or re-circulated by using a water treatment plant



II. Gasifier and Engine Systems – Technical Specifications

| Sub system. | Items | Qty. |
|--|--|-------|
| Reactor with ash extraction unit | <ul style="list-style-type: none"> • Ceramic lined reactor with top cover • Ash extraction system fitted to the reactor bottom • Instrumentation for pressure measurement at reactor exit. | 1 No. |
| Structural | <ul style="list-style-type: none"> • Suitable support structure to facilitate gasifier operation with epoxy coat of paint. | 1 No. |
| Gas cooling scrubbing & filtering system | <ul style="list-style-type: none"> • Suitable cooling and cleaning system to maintain the temperature and quality of the gas • Water dump to collect wash water under the cooler • Suitable water pumps • Water plumbing from/to water sump • Fabric filter | 1 set |
| Water cooling and treatment system | A suitable cooling tower with flocculation tanks and recirculation pump | 1 set |
| Blower | Mild steel blower with high quality epoxy paint and with shaft seal arrangement | 1 No. |
| Pilot burner | Stainless steel swirl burner along with flame arrestor | 1 No. |
| Plumbing | Corrosion resistant gas and water piping with necessary valves and fittings | 1 set |
| Engine Generator | A suitable Diesel Engine Generator mounted on anti vibration mounting (AVM) with producer gas adaptation to generate 220/110V at 60 HZ along with 12 V battery, diesel tank and control panel | 1set |
| Biomass loading system | A winch based manual biomass loading system | 1 No |
| Miscellaneous | <ul style="list-style-type: none"> • One oxygen measuring system for safety • Water manometers at various locations | 1 set |
| Spares | <ul style="list-style-type: none"> • Essential gasifier and engine spares for one year maintenance | 1 set |
| Tools | <ul style="list-style-type: none"> • Essential tools for gasifier and engine maintenance | 1 set |
| O & M manual | <ul style="list-style-type: none"> • Comprehensive operation and maintenance manual for gasifier and engine published in English | 1No |

III. Auxillaries

| | | |
|-----|-----------------|--|
| i) | Biomass chipper | A suitable biomass chipper to meet the requirement |
| ii) | Wood chip drier | A suitable wood chip drier to control the biomass moisture level to the specified level. |

IV. System Specifications

| Parameter | Details |
|--|---|
| Gasifier Type | Open top, twin air entry, down draft gasifier system |
| Gasifier Capacity | 70 kg/hr |
| Dual fuel engine capacity | 55 kWe (The net available after in-house consumption will be 47 kWe) |
| Turndown ratio | 4:1 |
| Diesel Replacement | 80% |
| Tar and particulate level in gas after cooling, cleaning train at rated load | <10 ppm |
| Tar and particulate level in gas after cooling, cleaning train at 2/3 rd of Full load | <15 ppm |
| Tar and particulate level in gas after cooling, cleaning train at 1/3 rd of Full load | <25 ppm |
| Calorific value of gas generated from gasifier and its composition | Mean Cal value is 4.6 ± 0.2 MJ/Kg Composition: CO: $20 \pm 1\%$; CH ₄ : $2.0 \pm 0.5\%$, H ₂ : $20 \pm 1\%$, CO ₂ : $12 \pm 1\%$ and rest N ₂ . |
| Standard System elements | Reactor, cooling and cleaning system, DG set |
| Auxiliaries | Biomass cutter, Biomass drier |
| Feed stock | Any solid bio-residue of bulk density over 250 kg/m ³ , ash content less than 5% and moisture content less than 15%. |

| | |
|---------------------------------------|--|
| Size of feed stock, mm | 60 x 25 x 25 and a mix in lower ranges |
| Allowable moisture content in biomass | < 15% |
| Biomass to gas conversion efficiency | 80 % |
| Water requirement, m ³ /hr | 14 |
| Parasitic load, kWe | 8.0 |
| System Running | System will be designed to run 24 hours on rated load |
| Annual Plant Load Factor (APLF) | > 75% |
| Biomass requirement | 1.1 ± 0.1 kg/kWh with < 15% moisture and < 5% ash content fuel |
| Man power requirement | 2 operators per shift for gasifier and 1 operator per shift for biomass processing |

V. Plant Control

| | |
|---|---|
| Voltage Control | Through Governor of Engine |
| Safety Device | (1) Oxygen Monitor for gas (2) Pressure relief diaphragm at mixing chamber near engine |
| Gasifier and Water treatment plant operations | Through Control Panel provided for the sake |

VI. Miscellaneous Item

| | |
|---------------------------------|---|
| Platform | For approach to gasifier for observation and loading of biomass |
| Fire Extinguisher (Recommended) | 1. Sand 2. CO ₂ |

VII. Specification of Equipment

| Description | Unit | Particulars |
|-----------------|-------------|--|
| GASIFIER | 1 no | |
| Manufacturer | | |
| - type | IBG - 70 | IISc Open top down draft re-burn Biomass |

| | | Gasifier |
|---|---------------------|----------------------------|
| - weight | Kg | 3000 |
| - max. gas production | Nm ³ /hr | 175 |
| - min. gas production (in continuous operation) | Nm ³ /hr | 58 |
| - gas heating value max. load | kJ/Nm ³ | 5.0 |
| - gas heating value 60% load | kJ/Nm ³ | 4.6 |
| - max. fuel moisture content | % (d.b.) | 15 |
| - max. fuel ash content | % | 5 |
| - max. fuel size | mm x mm x mm | 60 X 30 X 30 |
| - min. fuel size | mm x mm x mm | 15 X 15 X 15 |
| - fuel size distribution requirements | | Mix in the above range |
| - min. fuel bulk density | Kg/m ³ | 250 |
| - type of ash removal system | | Screw based dry extraction |
| - auxiliary power consumption gasifier | kWh/kWh | 8 |
| - gasifier start up time | Min. | 10 |

| Description | Unit | Particulars |
|---|---------------------|---|
| GAS TREATMENT SECTION | 1 set | |
| - type (filter bag, cyclone, impingement, scrubber, others) | | Filter bag, cyclone, scrubbers and chill water scrubber |
| - weight | Kg | 1500 |
| - cleaning (automatic, manual) | | manual |
| - maintenance requirements | Man hours/kWh | 6.7 X 10 ⁻⁴ |
| | | |
| - gas tar content after complete gas treatment section: | | < 2 ppm |
| - gas dust content after complete gas treatment section: | | < 8 ppm |
| - auxiliary power consumption gas treatment section | | 7 kWh |
| - auxiliary water consumption gas treatment | Kg/kWh | Make up water amounting to 3% per day |
| - consumable requirements gas treatment section (specify) | M ³ /kWh | Nil |

| Description | Unit | Particulars |
|----------------------|------|---------------|
| DIESEL ENGINE | | |
| - manufacturer | | Isuzu A-6BG1 |
| - weight | Kg | 1590 kg (Dry) |
| - cylinder volume | Ltr | 6.5 |

| | | |
|--|-----|-----------------|
| - no. of cylinders | | 6 |
| - type | | Vertical inline |
| - rated speed | Rpm | 1800 |
| - compression ration | | NA |
| - max. power output on producer gas (state standard) | kWh | 55 |
| - efficiency at 100 % load (state standard) | % | 30 |
| - efficiency at 60% load (state standard) | % | 26 |
| - governor manufacturer | | - |
| - governor type no. | | - |

| Description | Unit | Particulars |
|------------------|------|-------------------------|
| GENERATOR | | A standard make. |
| - manufacturer | | - |
| - type nr. | | - |
| - model | | DCA-75SPI |
| - make | | - |
| - weight | kg | - |
| - kVA rating | kVA | 75 |
| - kW rating | kW | 60 |

| Description | Unit | Particulars |
|--|------|-------------------------|
| ELECTRICAL CONTROL PANEL | | A standard make. |
| - type nr | | - |
| - model | | - |
| - make | | - |
| - weight | kg | - |
| - kVA rating | kVA | 75 |
| - kW rating | kW | 60 |
| - Voltage meter | | Provided |
| - Ammeter | | Provided |
| - frequency | | Provided |
| - kWhr meter | | - |
| - Protection | | Included |
| - Change over switch if any | | - |
| - Earthing details | | Will be provided later |
| - Cables from alternator terminal to control panel bus bar | | Will be provided later |

| Description | Unit | Particulars |
|--|---------|-------------|
| OVERALL INSTALLATION | | |
| - max. power output (delivered) | kW (el) | 47 |
| - min. thermal efficiency | | 75 |
| - biomass fuel consumption for 1 hour period incl. start up: | | 70 |

| | | |
|---|---------------|-----------|
| - at 100% load | | 50 |
| - at 60% load | | |
| - biomass fuel consumption for 6 hour continuous operation: | | |
| - at 100% load | | 420 - 440 |
| - at 60% load | | 300 - 320 |
| - operation requirements | Man-hours/kWh | 0.1 |

| Description | Unit | Particulars |
|--------------------------------|------|-------------|
| MISCELLANEOUS ITEMS | | |
| - automatic plant load control | | None |
| - weight | | |

Performance Test Report on Cuba System

Member present

From Cuba

1. Dr. Alfredo Curbelo
2. Ms. Carmen Lopez

From Indian Institute of Science

1. Prof. P. J. Paul
2. Mr. HV Sridhar

Date of Test – 6/7/07

The gasifier project sponsored by UNIDO for demonstration at Cocodrilo, Cuba was trial tested at CGPL. During the visit of Cuban delegation, performance tests were conducted to qualify the system. This report provides details of the long duration performance test conducted on 6/7/07. The testing process included familiarization of the equipment in class room sessions with detailed discussion of component specifications, operation and maintenance, do and don'ts and trouble shooting.

Performance Evaluation Test

As a part of the training, the reactor was unloaded and re-loaded with fresh charcoal and biomass and gasifier was operated on 4th and 5th July for about 10 hours so that the charcoal at the nozzles is from the wood chips loaded. Before the start of gasifier, the diesel engine was run in diesel mode and fuel consumption and exhaust composition obtained at 40%, 60%, 80% and 100% of dual fuel mode power. The output power in dual fuel mode is fixed at 55 kWe at Bangalore conditions from the previous data obtained. Table 1 provides the load and other measurements taken in diesel mode.

Table 1: Specific Fuel Consumption of Diesel Engine

| Load kWe | Diesel Consumption kg/hr | SFC kg/kWh | Efficiency % |
|-------------|--------------------------------|---------------|-----------------|
| 20.93 | 6.65 | 0.32 | 27 |
| 35.14 | 9.49 | 0.27 | 32 |
| 44.66 | 12.18 | 0.27 | 31 |
| 55.31 | 14.66 | 0.27 | 31 |

The gasifier was started at 11:00 Am and allowed to operate for 1 hour in flare mode and later dual fuel operations were carried out at above loads for 1 hour at each load. Biomass was topped in the reactor before load change so that the consumption in that particular hour gives an indication of specific biomass consumption. Producer gas composition, biomass consumption, diesel replacement and exhaust composition were monitored during the test. Chart 1 shows the biomass consumption over the test duration. The biomass consumption remained steady excepting between 240 and 360 mins when the

load on the genset was high. The gas calorific value over the test duration is shown in chart 2. The gas composition remained steady and hence the calorific value remained over 4.5 MJ/kg over large part of test duration. The hot gas temperature also increased to more than 400 °C quickly and remained between 400 and 500 °C during the tests indicating stable reactor operations. Chart 3 shows the hot gas temperature with time. The diesel replacement in dual fuel mode is shown in table 2. Table 3 shows the specific biomass consumption in dual fuel mode. From the tables 3 and 4 it can be seen that nearing rated loads, the biomass consumption is less than 1 kg/kWh and diesel consumption is less than 75 ml/kWh. This value improves for long duration operations. The gasifier has met with the designed specifications and can be suitably deployed to site.

Dryer test

Dryer was tested with loading of 308 kg of biomass. The dryer was operated for 3 hours and the final dry weight of biomass is 288 kg. This suffices the system requirement.

Cutting machine testing

The cutting machine was operated and cutting rate of biomass was tested for two hours. The first hour cutting rate was 90 kg/hr and second hour cutting rate was 100 kg/hr. An average cutting rate of 95 kg/hr will be more than the demand of the gasification system.

Water treatment jar tests

To appreciate the effectiveness of the water treatment, jar test was demonstrated. The water sample from the gasifier sump was drawn. The non-ferric alum and poly-electrolyte of required concentration was added to the water sample and allowed to settle after stirring. Within 5 minutes the sludge got settled and clear water was demonstrated.

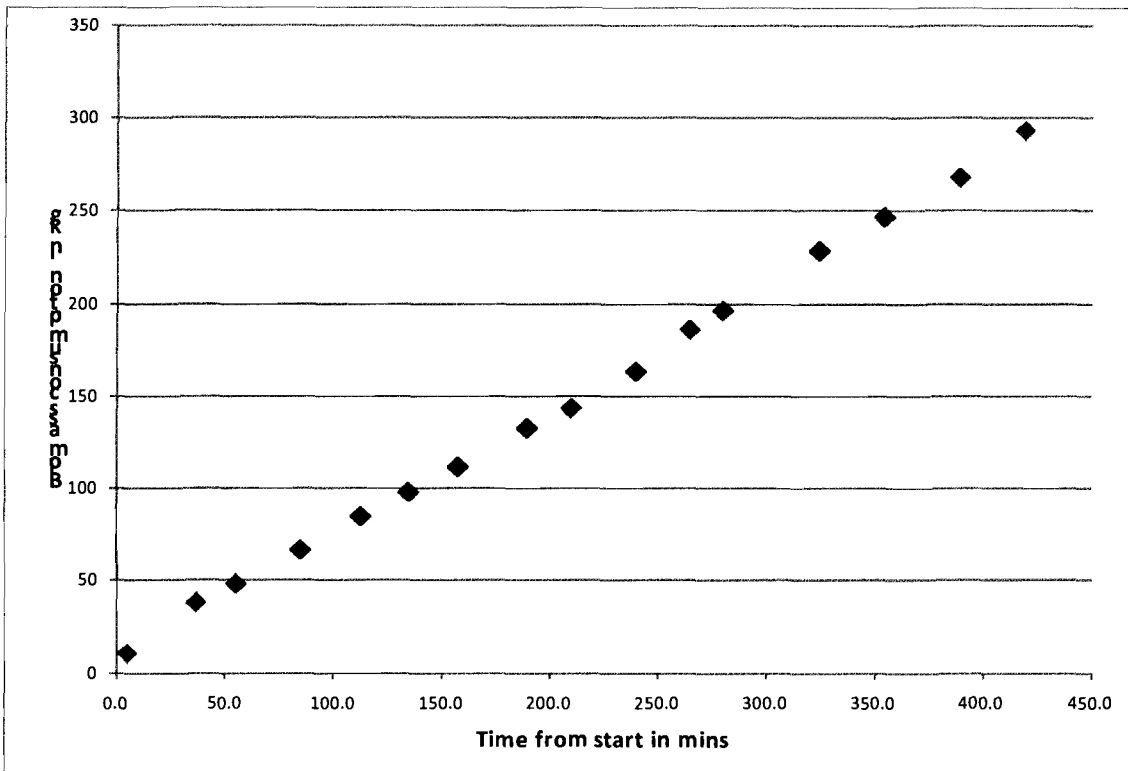


Chart 1: Cumulative Biomass consumption with time

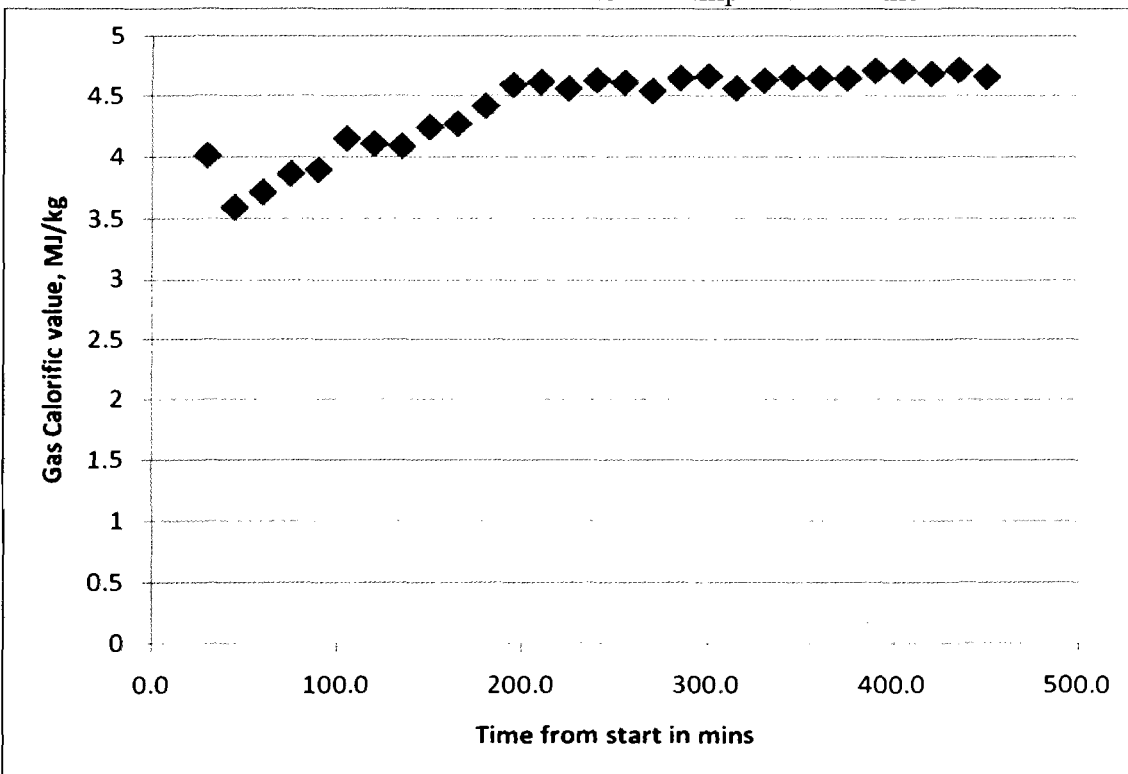


Chart 2: Gas Calorific Value with time

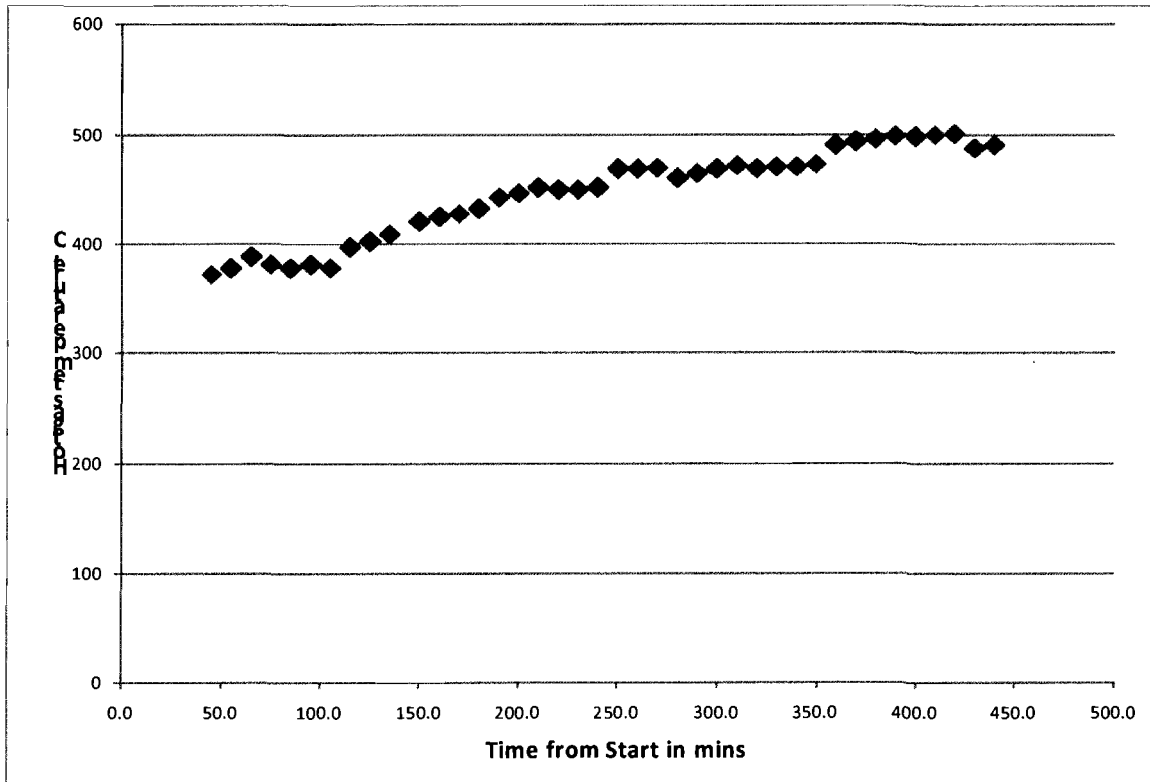


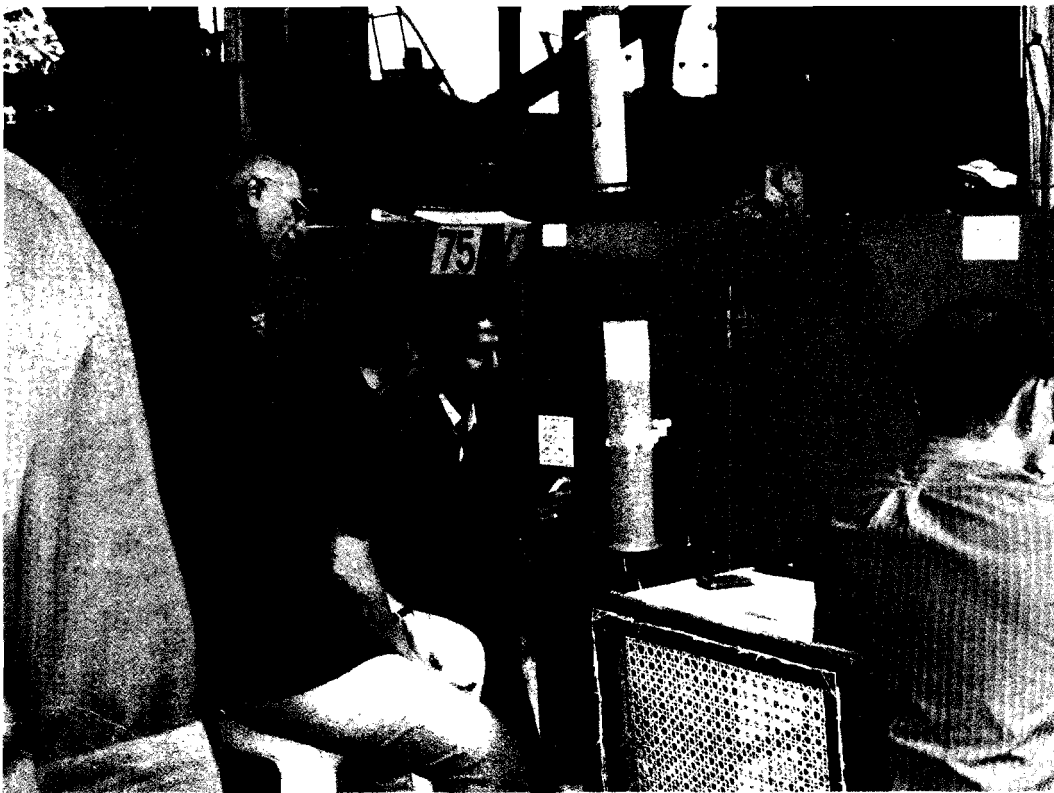
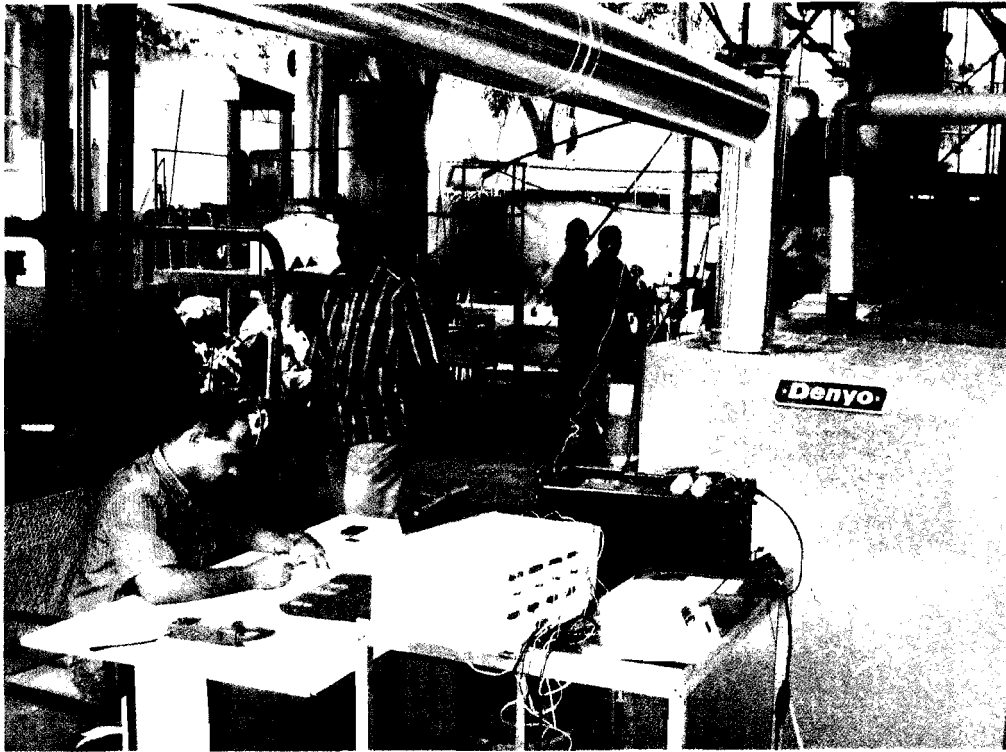
Chart 3: Hot gas temperature with time

Table 2: Diesel Replacement in Dual fuel mode

| Dual fuel mode | | | Diesel Replacement | Efficiency |
|----------------|-------|--------|--------------------|------------|
| Load | kg/hr | kg/kWh | | % |
| 25.75 | 0.85 | 0.03 | 87.22 | 15 |
| 36.15 | 1.41 | 0.04 | 85.14 | 21 |
| 44.14 | 2.16 | 0.05 | 82.27 | 20 |
| 52.38 | 3.40 | 0.06 | 76.81 | 20 |

Table 3: Specific Biomass consumption in dual fuel mode

| Load | Duration | Biomass consumption in the duration, kg/hr | Specific Biomass Consumption kg/KWh |
|------|----------|--|-------------------------------------|
| 26 | 1 | 36 | 1.38 |
| 36 | 1 | 35 | 0.97 |
| 44 | 1 | 43 | 0.98 |
| 52 | 1 | 50 | 0.96 |





Data Sheets of the tests

Pressure and Temperature readings of the Gasifier

| Time | Time from start in mins | Gasifier Readings | | | | | 9th July 2007 | | Hot gas Temp(°C) | Cold gas Temp(°C) |
|-------|-------------------------|---------------------------|--------------------|---------------------|------------------------|------------------|-------------------|-----|------------------|-------------------|
| | | Reactor exit pressure(P1) | Cooler-1 Inlet(P2) | Cooler-1 Outlet(P3) | Chill Cooler Inlet(P4) | Filter Inlet(P6) | Filter Outlet(P7) | | | |
| 11:45 | 45.0 | -47 | -51 | 40 | 160 | 230 | -38 | 371 | 7.2 | |
| 11:55 | 55.0 | -48 | -56 | 39 | 162 | 231 | -35 | 377 | 7.2 | |
| 12:05 | 65.0 | -45 | -51 | 38 | 160 | 235 | -35 | 388 | 6.8 | |
| 12:15 | 75.0 | -41 | -48 | 40 | 166 | 233 | -35 | 380 | 7.5 | |
| 12:25 | 85.0 | -42 | -47 | 40 | 170 | 234 | -35 | 377 | 6.5 | |
| 12:35 | 95.0 | -42 | -49 | 39 | 164 | 235 | -34 | 380 | 7.1 | |
| 12:45 | 105.0 | -43 | -48 | 40 | 164 | 234 | -35 | 377 | 6.5 | |
| 12:55 | 115.0 | -45 | -51 | 39 | 163 | 235 | -35 | 398 | 9.8 | |
| 13:05 | 125.0 | -48 | -56 | 29 | 150 | 235 | -35 | 402 | 6.5 | |
| 13:15 | 135.0 | -40 | -45 | 38 | 162 | 225 | -35 | 408 | 6 | |
| 13:30 | 150.0 | -40 | -50 | 40 | 160 | 225 | -33 | 420 | 5.8 | |
| 13:40 | 160.0 | -41 | -45 | 40 | 160 | 225 | -34 | 424 | 5.9 | |
| 13:50 | 170.0 | -41 | -44 | 41 | 160 | 228 | -34 | 427 | 6.8 | |
| 14:00 | 180.0 | -41 | -48 | 40 | 160 | 225 | -33 | 432 | 6.7 | |
| 14:10 | 190.0 | -35 | -40 | 41 | 160 | 230 | -35 | 442 | 7.3 | |
| 14:20 | 200.0 | -36 | -41 | 41 | 160 | 225 | -33 | 446 | 6.8 | |
| 14:30 | 210.0 | -39 | -44 | 38 | 150 | 215 | -33 | 451 | 7.3 | |
| 14:40 | 220.0 | -41 | -46 | 38 | 150 | 212 | -31 | 449 | 7.2 | |
| 14:50 | 230.0 | -42 | -50 | 30 | 144 | 212 | -32 | 449 | 7.2 | |
| 15:00 | 240.0 | -42 | -51 | 30 | 147 | 231 | -30 | 451 | 6.8 | |
| 15:10 | 250.0 | -41 | -48 | 30 | 146 | 230 | -34 | 458 | 7.3 | |
| 15:20 | 260.0 | -42 | -48 | 4 | 150 | 220 | -30 | 468 | 7 | |
| 15:30 | 270.0 | -40 | -44 | 44 | 160 | 245 | -34 | 469 | 7.2 | |
| 15:40 | 280.0 | -39 | -42 | 50 | 180 | 250 | -37 | 460 | 7.4 | |
| 15:50 | 290.0 | -52 | -60 | 20 | 138 | 210 | -35 | 464 | 7.5 | |
| 16:00 | 300.0 | -49 | -52 | 50 | 182 | 285 | -55 | 468 | 7.2 | |
| 16:10 | 310.0 | -56 | -60 | 38 | 170 | 245 | -55 | 471 | 7.3 | |
| 16:20 | 320.0 | -55 | -61 | 32 | 170 | 230 | -55 | 468 | 6.8 | |
| 16:30 | 330.0 | -55 | -60 | 30 | 160 | 230 | -65 | 470 | 7 | |
| 16:40 | 340.0 | -56 | -60 | 30 | 155 | 230 | -55 | 470 | 7.3 | |
| 16:50 | 350.0 | -57 | -64 | 25 | 148 | 215 | -45 | 472 | 7.1 | |
| 17:00 | 360.0 | -54 | -60 | 21 | 140 | 205 | -40 | 490 | 6.9 | |
| 17:10 | 370.0 | -58 | -61 | 20 | 140 | 203 | -35 | 493 | 7.8 | |
| 17:20 | 380.0 | -56 | -60 | 20 | 141 | 205 | -35 | 495 | 7.6 | |
| 17:30 | 390.0 | -58 | -66 | 18 | 139 | 202 | -35 | 498 | 7.5 | |
| 17:40 | 400.0 | -58 | -65 | 15 | 136 | 205 | -35 | 487 | 7.6 | |
| 17:50 | 410.0 | -60 | -68 | 12 | 130 | 209 | -35 | 499 | 7 | |
| 18:00 | 420.0 | -62 | -69 | 19 | 141 | 215 | -45 | 500 | 7.7 | |
| 18:10 | 430.0 | -68 | -71 | 18 | 140 | 215 | -45 | 487 | 6.6 | |
| 18:30 | 440.0 | -75 | -80 | 10 | 140 | 210 | -55 | 490 | 6.8 | |

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Gas Composition

| Producer Gas Composition | | | | | | | |
|--------------------------|-----------------|-----------------|----------------|----------------|----------------|---------|-------------|
| CO | CO ₂ | CH ₄ | O ₂ | H ₂ | N ₂ | Mol wt | cv MJ/kg |
| Vol (%) | | | | | | | |
| 17.11 | 22.45 | 3.62 | 0.29 | 14.03 | 42.5 | 27.5214 | 4.009934 |
| 15.69 | 15.73 | 1.82 | 0.3 | 15.12 | 51.34 | 26.3792 | 3.589533 |
| 18.04 | 14.27 | 1.01 | 0.36 | 15.89 | 50.43 | 26.045 | 3.711941 |
| 17.46 | 15.26 | 1.37 | 0.38 | 16.8 | 48.73 | 25.9244 | 3.861208 |
| 18.18 | 14.63 | 1.3 | 0.3 | 16.51 | 49.08 | 25.9042 | 3.893693 |
| 19.32 | 13.69 | 1.17 | 0.31 | 17.61 | 47.9 | 25.4838 | 4.146222 |
| 19.44 | 13.53 | 1.18 | 0.3 | 17.16 | 48.39 | 25.5736 | 4.105679 |
| 19 | 13.73 | 1.21 | 0.31 | 17.34 | 48.41 | 25.5556 | 4.086599 |
| 20.66 | 12.71 | 1.08 | 0.27 | 17.25 | 48.03 | 25.4298 | 4.240458 |
| 20.7 | 12.64 | 1.07 | 0.29 | 17.43 | 47.87 | 25.3738 | 4.268123 |
| 20.35 | 13.16 | 1.4 | 0.27 | 18.06 | 46.76 | 25.2528 | 4.41353 |
| 20.83 | 13.18 | 1.61 | 0.25 | 18.43 | 45.7 | 25.1338 | 4.589656 |
| 21.18 | 13.08 | 1.61 | 0.25 | 18.31 | 45.57 | 25.149 | 4.614398 |
| 20.84 | 13.28 | 1.55 | 0.26 | 18.38 | 45.69 | 25.1704 | 4.560376 |
| 20.57 | 13.66 | 1.76 | 0.26 | 18.64 | 45.11 | 25.1384 | 4.627343 |
| 19.85 | 14.12 | 1.85 | 0.27 | 18.96 | 44.95 | 25.1184 | 4.609828 |
| 21.22 | 12.8 | 1.39 | 0.25 | 18.24 | 46.1 | 25.1488 | 4.542662 |
| 20.45 | 13.48 | 1.66 | 0.26 | 19.06 | 45.09 | 25.0124 | 4.645736 |
| 20.9 | 13.32 | 1.72 | 0.26 | 18.66 | 45.14 | 25.0836 | 4.663525 |
| 20.65 | 13.3 | 1.54 | 0.27 | 18.57 | 45.67 | 25.1258 | 4.562283 |
| 20.22 | 13.8 | 1.77 | 0.27 | 18.91 | 45.03 | 25.0898 | 4.626243 |
| 20.1 | 13.98 | 1.81 | 0.38 | 19.14 | 44.59 | 25.0584 | 4.65335 |
| 20.37 | 13.75 | 1.89 | 0.27 | 18.64 | 45.08 | 25.1376 | 4.646327 |
| 20.36 | 13.88 | 1.86 | 0.25 | 18.74 | 44.91 | 25.1352 | 4.645716 |
| 21 | 13.5 | 1.85 | 0.25 | 18.62 | 44.78 | 25.1068 | 4.707709 |
| 21.11 | 13.38 | 1.89 | 0.26 | 18.43 | 44.93 | 25.1326 | 4.70964 |
| 21.04 | 13.48 | 1.85 | 0.26 | 18.42 | 44.95 | 25.156 | 4.683873 |
| 20.91 | 13.74 | 1.96 | 0.26 | 18.5 | 44.63 | 25.1636 | 4.710375 |
| 21.17 | 13.26 | 1.77 | 0.28 | 18.27 | 45.25 | 25.1702 | 4.656121 |

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Biomass Consumption

| Biomass Consumption | | | | |
|---------------------|-------|------------|----------|---------|
| Time | | Weight(kg) | Cumm(kg) | Remarks |
| 11:05 | 5.0 | 11 | 11 | topped |
| 11:37 | 37.0 | 27 | 38 | |
| 11:55 | 55.0 | 10 | 48 | topped |
| 12:25 | 85.0 | 18 | 66 | |
| 12:53 | 113.0 | 18 | 84 | |
| 1:15 | 135.0 | 13 | 97 | topped |
| 1:38 | 158.0 | 14 | 111 | |
| 2:10 | 190.0 | 21 | 132 | topped |
| 2:30 | 210.0 | 11 | 143 | topped |
| 3:00 | 240.0 | 20 | 163 | |
| 3:25 | 265.0 | 23 | 186 | |
| 3:40 | 280.0 | 10 | 196 | topped |
| 4:25 | 325.0 | 32 | 228 | |
| 4:55 | 355.0 | 18 | 246 | topped |
| 5:30 | 390.0 | 21 | 267 | |
| 6:00 | 420.0 | 25 | 292 | topped |

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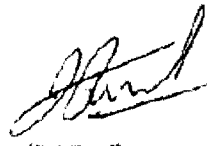
Test Summary

| Parameter | Guaranteed | Achieved |
|--------------------------------|---|---|
| Power Output | 50 kWe generation including in-house consumption | 55 kWe generation including in-house consumption |
| Gas Quality | Gas Calorific value 4.6 ± 0.2 MJ/kg | Gas Calorific value 4.6 ± 0.2 MJ/kg |
| Fuel Consumption at rated load | a) 1.1 ± 0.1 kg/kWh of biomass b) 60 – 90 ml/kWh of diesel | a) 0.96 kg/kWh of biomass b) 60 ml/kWh of diesel |
| Cutting machine | 70 kg/hr | 95 kg/hr |
| Dryer | 70 kg/hr | 70 kg/hr |

The system has met the guaranteed parameters and can be suitable deployed to site.


[Alfredo Curbelo]


[Carmen Lopez]


[P J Paul]