QUALIFYING, TESTING AND PERFORMANCE EVALUATION OF BIOMASS GASIFIERS AND GASIFIER-ENGINE SYSTEMS (DUAL-FUEL ENGINES)

TEST PROCEDURES, METHODOLOGY AND PROTOCOLS

TEST PROCEDURE NO. I

APRIL 2000

।। सत्यमेव जयते ।।

GOVERNMENT OF INDIA
MINISTRY OF NON-CONVENTIONAL ENERGY SOURCES
NEW DELHI 110 003

Prepared Under

GASIFIER ACTION RESEARCH PROJECT
(NO. 203-01-04/97-BM)

Department Of Mechanical Engineering
Indian Institute Of Technology, Bombay
Mumbai–400 076

From Secretary's Desk

Biomass is a primary source of energy having undebateable potential of supplementing the energy needs of the country in a foreseeable future. It is a versatile resource that can be utilised as an alternate source of energy for variety of applications: power generation, thermal applications and also as feed stock for different industries. Gasification is an important intermediate step towards utilisation of Biomass in most applications. Gasification technology and gasifier systems assume immense importance in this context. Gasifier systems are Biomass specific as well as application specific. Quality assurance and standardisation of such systems is an important but difficult task.

Biomass gasification technology has gone through phenomenal development in the past decade and a half and, is almost on the threshold of commercialisation. MNES is committed to promote and support this technology and make a measurable impact on the energy needs of the country. MNES is keen that the gasification systems produced in India conform to world class standards and are efficient and reliable. User acceptance and sustainability are mutually dependant facets of any technology. Success brings success. For a successful program it is essential that the products and systems are user friendly, efficient, reliable and give long trouble free service. In this context the importance of testing and performance evaluation of gasifier based systems is undebateable.

Formulation of test procedures, methodology and protocols of gasifier based systems for different end use applications calls for expertise and extensive experience. It is really a difficult task, which has been accomplished by the group of scientists associated with GARPs and other MNES programs. Documents as these, are probably the first of their kind in the world, in the area of biomass gasification technology. MNES takes pride in launching these documents, which reflect not only hard work, enormous amount of experience but also quality consciousness and commitment of the gasification community. The team involved in preparation of the documents needs to be complemented. It is hoped that presence of the Test Procedures, Methodology and Protocols shall catalyse every effort towards advancement of the technology and help in successful implementation of Biomass Gasification program.

Place:

Date :

N. N. Mookherjee
Secretary,
Ministry of Non-conventional Energy Sources

FOREWORD

Ever-increasing consumption rates of fossils fuels and rapid depletion of the known reserves are a matter of serious concern, the world over. Conservation of conventional fuels through utilisation of renewable energy sources is an effective approach towards alleviating these constraints. Domestic and abundant availability and non-depletable nature are essential attributes of a resource for it to qualify as a renewable source of energy. Biomass stands out as a promising resource in this context, more so for tropical countries, having plentiful sunshine and rains. The main areas where biomass can play an important role are shaft power applications through I.C. Engines and Gas Turbines, thermal applications like boilers, furnaces, kilns etc. and production of chemicals and fuels. In most applications, conversion to a gaseous or liquid form is the essential intermediate step towards utilisation of biomass. In this context, thermochemical gasification of biomass emerges as an important aspect of biomass utilisation.

Keeping in view the promise of biomass for supplementing the energy needs, particularly in rural areas, the Ministry of Non-conventional Energy Sources has formulated a broad-based program in the area of Biomass Gasification Technology and Utilisation. The components of the Program include basic and applied research and design and development of biomass conversion and utilisation devices and systems. Field demonstration of the technology annexed with action research directed towards resolving the problems in field applications, in turn leading to iterative technology improvements, are other unique features of the Program. Quality assurance through testing and performance evaluation of the gasifier systems has also been an important element of the Program.

Recognising the importance of testing and performance evaluation, "Test Facilities for Performance Evaluation of Gasifiers and Gasifier-Engine Systems" were established at the Department of Mechanical Engineering, IIT Bombay in 1985, under a project sponsored by the Department of Non-conventional Energy Sources (DNES), now the Ministry of Non-conventional Energy sources (MNES). The objectives of the project were Type Testing, Approval and Certification of the gasifier systems for various end-use applications. Development of Test Procedures and Methodology as well as formulation of acceptable performance levels were the other objectives of the project. The first draft of procedures and methodology was prepared by Prof.(Mrs.)P. P. Parikh, the Principal Investigator of the Project. At that time, when the first procedures were laid down, the main focus of the Program was development of biomass gasifier systems and utilisation of producer-gas in dual-fuel operation of existing diesel engines, with power capacity range not exceeding 100 kW. Thermal applications were few and were severely constrained by the reservations about toxic effects of CO. The project then, therefore, did not deal with testing procedures of thermal systems. Procedures and standards for Spark Ignition Producer Gas Engines (SIPGE) were also not covered.

Over the years Biomass Gasification Technology and Utilisation has made rapid progress in research, design and development of gasifier systems and gasifier based application packages. Areas of application have expanded and availability of

gasification equipment has increased, in terms of the capacity ranges, biomass materials and end-use applications. Gasification systems are being used for power generation as well as for thermal applications. Power generation up to 500 kW is carried out through use of I.C. Engines, wherein producer gas is used either as a partial substitute for diesel fuel or replaces diesel completely. Gasifier based thermal systems cover a wide range of applications starting from community cooking, CO_2 production, a source of thermal energy for rolling mills or even certain aluminum industries. Contribution of the four Gasifier Action Research Projects (GARPs) needs special mention in this context. GARPs at MKU, IISc., IITB and IITD spread out in different parts of the country, and exclusive in their expertise and strengths, have played an important role in development of the technology and growth of the Program. This is being continued under the dynamic leadership of Dr. C. L. Gupta, the Chairman of the Standing Review and Monitoring Committee for GARPs set up by MNES.

The development of technology and growth of manufacturing activities now warranted and examination of the existing Test Procedures and Methodology and to extend the scope to include the new elements such as SIPGE, thermal applications, turbo-charged engines, rice-husk gasifier, etc. Consequently, a Sub-Committee was constituted under Chairmanship of Shri Atul Bhalla, Addl. Gen. Manager, EIL to examine and modify the prevailing procedures and formulate additional ones for the expanded requirements. The Sub-Committee discussed various aspects of testing of different types of systems and sought views of the manufacturers through a one-on-one interaction. A revised draft of the existing Document, as well as new Documents for SIPGE and Thermal Applications have been prepared by Prof.(Mrs.)P. P. Parikh at IITB, under direction and guidance of the Sub-Committee. Documents that have thus been brought out are the result of several rounds of discussions with all stakeholders, manufacturers, PIs, experts, scientists and engineers.

Separate qualifying Testing Procedures, Methodology and Protocols are available for Dual-fuel Engine Systems, SIPGE Systems and Thermal Applications. Clarifications/suggestions on these documents may be addressed to the Ministry so that necessary modifications/updation, as necessary, could be carried out periodically.

We, in the Ministry of Non-conventional Energy Sources, would like to express our gratitude to the Sub-Committee Chairman, Shri Atul Bhalla, and members, as well as to Prof. (Mrs.) P. P. Parikh, Head GARP IITB, and her team, for their painstaking efforts in carrying out this monumental work in such a time-bound manner.

Place :

Date :

Ajit K. Gupta
Advisor & Head (Power Group)
Ministry of Non-Conventional Energy Sources

CONTENTS

INTRODUCTION

Energy security is a fast growing need, both in industrial and rural India. One means of meeting this growing need in an inexpensive and clean manner is through the increasing use of renewable biomass through the process of Biomass Gasification. This, is the conversion of solid biomass into a combustible gas mixture called Producer-gas through a partial combustion route under substoichoimetric conditions. Carbon monoxide and Hydrogen (which are toxic/lethal gases) are the two main combustible components as a result of which there is a need for care in designing and operating such systems. Conversion of biomass to a combustible gas mixture removes most of the conventional problems associated with the use of solid biomass fuels in combustion. This process can be employed from a scale of 3-5kW up to several megawatts. Hence is ideally suited for decentralised applications whether they are for shaft power, electricity or thermal energy, where most of the current applications exist. When used to generate power, the raw and hot producer gas needs to be cooled and cleaned, before used in reciprocating engines/gas turbines.

With the large variation in the physical and chemical characteristics of the wide variety of biomass available in India, it is important to understand that gasifier systems are not only application specific but are also biomass specific. There is, therefore, a need to characterise the intended fuel(s) so that the end-users can satisfactorily meet the requirements in terms of the raw material (biomass) used in the gasifier. Facilities for fuel characterisation and assistance in this regard are available through a MNES sponsored project at Biomass Gasification Laboratory, GARP, IIT Delhi.

The long-term acceptability of the gasifier technology and the extent of penetration in the market depend on the performance of the gasifier and also on the gas cleanup systems, the end use devices and the range of fuel tolerance (both type and size). There is a need for a safe, reliable, environmentally conforming and economically viable system available to a properly trained user through a carefully screened user training program. It is in interest of the user as well as the supplier that the gasifier systems be properly tested and effectively combined to deliver expected performance. **The document herein spells out the minimum requirements for the manufacturers to follow and (mention in his documentation) the codes and standards, system specifications, operating and maintenance procedures, performance guarantees, list of items supplied and user site layout requirements for safety for the system supplied to him. This document also details the qualifying and acceptable performance levels, testing and performance evaluation procedures for biomass gasifiers and gasifier-engine (dual-fuel) systems.** The users are advised that in view of the great variety of gasifiers, gas clean-up systems and end-use devices available in market, the gasifier system being supplied to them, conform to the type tested for their particular application so as to deliver reliable and expected performance and also eligible for any financial incentives being offered by the Government of India.

QUALIFYING & ACCEPTABLE PERFORMANCE LEVELS

I	**Gasification Efficiency**		
	1) For Woody Biomass	NLT*	75% (Hot gas)
		NLT	70% (Cold gas)
	2) For Rice Husk	NLT	60%(Hot gas)
		NLT	55%(Cold gas)

II	**Tar & Particulates**	**Naturally Aspirated[a] Engines**	**Turbo-charged[b] Engines**
	1) Tar Content Of Gas	100 mg/nm^3	25 mg/nm^3
	2) Particulate Content Of Gas	50 mg/nm^3	25 mg/nm^3
	3) Total Tar and Particulate (TTP)	150 mg/nm^3	50 mg/nm^3

[a] *THT or IIT Bombay Tar Sampling Method* [b] *IISc Banglaore Tar Sampling Method*

These T & P values are as measured at the engine entry point after the cooling cleaning system.

III	**Duration Sustainable for Uninterrupted Continuous Operation**	NLT 30 hours
IV	**Capacity Realisation**	As per Manufacturer's specifications
V	**Fuel Conservation / Consumption**	
	1) % DR (Diesel Replacement)	NLT 65% at the rated load specified by the Manufacturer
	2) Allowable Specific Energy / Biomass / Fuel Consumption at Rated Load	NMT 100 gm Diesel **+** NMT** 1.0 kg of Woody Biomass **OR** NMT 1.2 kg Rice Husk **per kWh of shaft-power**
VI	**Overall Efficiency At Rated Load***	
	Woody Biomass and Electrical Applications	NLT 20%
	Rice Husk and Electrical Applications	NLT 15%
VII	**Engine Exhaust Emissions**	As per Prevailing Norms of CPCB
VIII	**Availability of the System During the Testing Schedule**	
	Down Time for any and all reasons cumulatively	NMT 5% of the total test duration

NLT - Not Less Than ** NMT - Not More Than * The values will change for other applications as per the efficiency of the corresponding final end use device*

TESTING SEQUENCE

Qualifying, Testing and Performance Evaluation of the Gasifier Dual-fuel Engine System would be carried out as follows:

I **System Introduction Test** **(Annexure-I)**

PART-A Getting the specifications / details of the system in SIT-Format and the O&M Manual and examination of these documents. *[SIT-Format to be supplied by the test center]*

PART-B **Initial Test Run (ITR)**

Part B of the schedule will be taken up only after the examination of the complete documentation provided through SIT format and the O&M Manual and ensuring that the claimed performance conforms to the **Qualifying and Acceptable Performance Levels**.

II **Starting Test** as per **Annexure-II**

III **Performance Evaluation Test [PET1 & PET2]** as per **Annexure-III**

IV **Long Duration Performance Evaluation Test [LDT]** as per **Annexure-IV**

The "Long Duration Test" **(LDT)** to be taken up only if the Gasifier-System performance (through **PET1** & **PET2**) reasonably conforms to the manufacturer specified values and are with the prescribed limits during Performance Evaluation Tests.

All the "Ready for use" biomass for the testing schedule will be provided by the manufacturer.

ANNEXURE-I

SYSTEM INTRODUCTION TEST (SIT)

SIT is to be conducted in two parts: **PART-A** and **PART-B**.

PART-A would consist of getting information about the system in the relevant format. The format is to be supplied by the Testing Agency. On receipt of a request for testing, a copy of the SIT-Format is sent to the manufacturer along with the acknowledgment of the request. The manufacturer has to fill-up the SIT-Format and furnish the required information. The manufacturer will also submit the O&M Manual of the system along with duly filled SIT-Format. **Part B** of the schedule will be taken up only if the information provided through SIT format and O&M Manual conforms to the **Qualifying and Acceptable Performance Levels and the O&M Manual Conforms to the "Minimum Requirements" as per Annexure-XIV.**

PART-A SPECIFICATIONS / DETAILS OF THE SYSTEM TO BE TESTED

*[To be supplied by the gasifier manufacturer. If the requested information is not available indicate so by writing **'NA'** (**N**ot **A**vailable), don't leave any blanks. If the information is proprietary, please mention so]*

Name and Address of the Manufacturer _____

_____

_____

_____

Contact Person _____

Phone/Fax _____

Email _____

Name and Address of the Technology Provider/Associated R&D organisation/GARP

_____

_____

Number of Systems Already Supplied

Sr. No.	Capacity in Electrical Equivalent (kW)	Industrial Sites		Non-Industrial Sites	
		Electrical	Thermal	Electrical	Thermal
1.	<20				
2.	≥ 20, <100				
3.	100				
4.	>100, ≤ 200				
5.	>200, <500				
6.	500				
7.	>500				

Has this Design/Technology been Tested before YES ☐ NO ☐

If yes, please give details of capacities/models Tested_____

_____

_____

_____

_____

_____

I INFORMATION ABOUT THE GASIFIER PROPOSED TO BE TESTED

1) **Make** : _____

2) **Model** : _____

3) **Sr. No./Ref. No.** : _____

4) **Type** : a) Downdraft / Updraft / Fluid Bed / Any Other *(Please specify)* _____

: b) Air/Oxygen/Any Other *(Please specify)* _____

: c) Operational Mode *(Please ✔ the appropriate)*

i) Under pressure operation ☐

ii) Under suction operation ☐

iii) Any other (*Please specify*) _____

_____

5) **Rated Capacity** : _____kW_e (Electrical applications)
_____kW (Mechanical applications)
_____nm^3/h of gas produced

6) **Starting System**

a) Type

(Please ✔ the appropriate) : Electric Blower ☐

Hand Blower ☐

Any Other *(Please specify)*_____

b) Power requirement for the starting system _____kW_e

7) **Starting Time**

a) From torching to flaring : ____ minutes

b) From torching to supply to the engine : ____ minutes

(Please give in minutes & not as "immediate" etc.)

8) **Biomass Requirement**

a) <u>Size and quantity of charcoal required during initial filling</u> : Size Max _____(mm)
Min _____(mm)
Quantity _____kg

b) <u>Biomass Particulars</u>

i) Name of the feed stock : Subabul / Prosopis / Rice Husk / Bagasse / Any Other
(Please specify) _____

ii) Size of feed stock (Give max & min sizes) : Max_____(mm)
Min_____(mm)

iii) Acceptable Moisture content of feed stock (Range) : _____% to _____%

iv) Calorific value of feed stock (Dry basis) : _____kcal/kg

v) Biomass consumption at Rated Capacity Operation : _____kg/h

vi) Biomass consumption at Minimum Load Condition : _____kg/h

c) Turndown Ratio : _____

9) **Gas Output Rate**

a) At Rated Condition : _____ nm^3/h

b) At Minimum Load Condition : _____ nm^3/h

10) **Average Composition of Gas**

a) **At Rated Output** :

CO ____% H_2 ____% CH_4 ____%

CO_2 ____% N_2 ____%

b) **At Minimum Load** :

CO ____% H_2 ____% CH_4 ___%

CO_2 ____% N_2 ____%

11) **Calorific Value of Gas Produced**

a) At Rated Condition : _____kcal/nm^3

b) At Minimum Load : _____kcal/nm^3

12) **Gasification Efficiency at Rated Output** : _____%

(Please ✔ the appropriate)

Hot gas ☐

Cold gas ☐

13) **Gasification Efficiency at Minimum Load** : _____%

(Please ✔ the appropriate) **Hot gas** ☐
Cold gas ☐

14) **Pressure Drop Across the Gasifier at Rated Output** : _____mm of WC*

15) **Hopper Capacity** : a) _____kg of biomass
b) _____hour of operation @ Rated Condition

16) **Hopper Vibrations** *(Give details of type and mode of provision)* : _____
_____
_____

17) **Longest Duration for which the Gasifier System can be operated continuously** : _____ hours

18) a) **Type of Biomass Re-filling** *(Please ✔ the appropriate)* : Manual ☐ Mechanised ☐

b) **Time spent per Refill of Hopper [minutes]** _____

c) **Frequency of Biomass Re-filling**:

i) **per** _____ hours of continuous operation @ Rated Conditions

ii) **per** _____ hours of continuous operation @ Minimum Load Conditions

iii) **Continuous** ☐
If continuous, specify the power requirement _____ kW

19) a) **Type of Ash Disposal** : Dry ☐ Water Seal / Wet ☐

b) **Frequency of Ash Removal** :

i) **per** _____ hours of continuous operation @ Rated Conditions

ii) **per** _____ hours of continuous operation @ Minimum Load Conditions

iii) **Continuous** ☐
If continuous, specify the power requirement _____ kW

** Water Column*

20) **Tar & Particulate Contents of Gas**

a) Measurement Method used _____

_____

_____

b) Before the cleaner-cooler

Tar	i) At Rated Condition	_____	mg/nm^3
	ii) At Min. Load Condition	_____	mg/nm^3
Particulates	i) At Rated Condition	_____	mg/nm^3
	ii) At Min. Load Condition	_____	mg/nm^3

c) After cleaner-cooler

Tar	i) At Rated Condition	_____	mg/nm^3
	ii) At Min. Load Condition	_____	mg/nm^3
Particulates	i) At Rated Condition	_____	mg/nm^3
	ii) At Min. Load Condition	_____	mg/nm^3

21) **Manpower Requirement**

No. of persons required for operation of system _____

a) Supervisory _____

b) Skilled _____

c) Unskilled _____

22) **Description of any other procedures/precautions OR checks prescribed by the manufacturer** *(Please use extra sheet if needed)*

_____

_____

_____

_____

_____

_____

II GAS PROCESSING TRAIN *(Gas Cooling & Cleaning System)*

1) Type : Wet ☐ Dry ☐

2) Power requirement for :

a) *Water pump* _____kW
b) *Air blower (if used)* _____kW
c) *Gas booster blower (if used)* _____kW
d) *Any other (Please specify)* _____kW

_____

II (A) IF WET COOLING-CLEANING SYSTEM

1) Cooling water requirement : _____litres/h

2) Cooling water treatment and disposal : Please give details and a sketch on a separate sheet

3) Pressure drop across cooling & cleaning system (∆Pc)

a) At Rated gas flow rates : _____mm of WC
b) At the Minimum Load : _____mm of WC

4) Particulars / technical specification of filter material

a) Name : _____
b) Brand : _____
c) Pore size : _____Microns
d) Size of filter material : _____mm X mm
e) Max. temperature rating : _____C

5) Filter material washable and re-usable? Yes ☐ No ☐

6) Please describe the procedure of cleaning the filter material *(if it is re-usable)*_____

_____

_____

7) Recommended period for change of filter material in hours of operation

a) When operating @ Rated Load _____
b) When operating @ Minimum Load _____

8) Recommended “complete cleanup schedule" in terms of hours of operating duration *(Please use additional page if necessary)*

_____

_____

_____

9) Temperature of gas at the gasifier outlet @ Rated condition _____ C

10) Temperature of gas at the outlet of cooling cleaning system @ Rated condition _____ C

II (B) IF DRY COOLING-CLEANING SYSTEM

1) Type and kind *(Give a sketch on a separate page)* _____

2) Pressure drop (ΔPc) across the cooling & cleaning system
   a) At Rated gas flow rates _____mm of WC
   b) At the Minimum Load _____mm of WC

3) Particulars / technical specification of filter material
   a) Name _____
   b) Brand _____
   c) Pore size _____ Microns
   d) Size of filter material _____mm X mm
   e) Max. Temperature rating _____C

4) Filter material re-usable? Yes ☐ No ☐

5) If re-usable please describe the procedure of cleaning the filter material

_____

_____

_____

6) Recommended period for change of filter material in hours of operations
   a) When operating @ Rated Load _____
   b) When operating @ Minimum Load _____

7) Recommended “complete cleanup schedule" in terms of hours of operating duration _____

_____

_____

8) Temperature of gas at the gasifier outlet _____ C

@ Rated Condition

9) Temperature of gas at the outlet of cooling cleaning system @ Rated Condition _____ C

III GAS BLOWER

1) Specify number of Blowers supplied as integrated sub-systems of the gasifier system package _____

Please furnish the following details of each Blower:

Blower No. I

a) Location/use _____

b) Type _____

c) Material of Construction

i) Impeller _____

ii) Casing _____

iii) Shaft _____

d) Maximum Temperature Rating [C] _____

e) Capacity [nm^3/minute] _____

f) Head in mm WC _____

g) Maximum Suction Head Permissible [mm of WC] _____

h) Connected Motor Rating [kW] _____

i) Speed of Blower [rpm] _____

j) Type of Drive Direct Motor Driven ☐ Belt Driven ☐

k) Gas Seal Provided YES ☐ NO ☐

l) Whether Casing Insulated YES ☐ NO ☐

m) Any Provision for Draining Tar/Condensates YES ☐ NO ☐

n) Are the Bearing Cooled YES ☐ NO ☐

Blower No. II

a) Location/use _____

b) Type _____

c) Material of Construction

i) Impeller _____

ii) Casing _____

iv) Shaft _____

d) Maximum Temperature Rating [C] _____

e) Capacity[nm^3/minute] _____

f) Head in mm WC _____

g) Maximum Suction Head Permissible [mm of WC] _____

h) Connected Motor Rating [kW] _____

i) Speed of Blower [rpm] _____

j) Type of Drive Direct Motor Driven ☐ Belt Driven ☐

k) Gas Seal Provided YES ☐ NO ☐

l) Whether Casing Insulated YES ☐ NO ☐

m) Any Provision for Draining Tar/Condensates YES ☐ NO ☐

n) Are the Bearing Cooled YES ☐ NO ☐

IV INSTRUMENTATION & CONTROL SYSTEMS OF GASIFIER

Sr. No.	Parameter to be		Method / Instrument / System Provided
	Measured	Controlled	

V END USE APPLICATION

V (A) MODE: MECHANICAL / ELECTRICAL

V (A1) THE ENGINE

1) **Engine Make & Model No.** _____

2) **Engine Type** *(Please ✔ the appropriate)*

a) DI ☐ IDI ☐

b) Water cooled ☐ Air cooled ☐

c) NA ☐ TC ☐ TCIC ☐

3) **No. of Cylinders** _____

4) **Total Displacement** _____ litres

5) **Rating** _____ kW(Mech.)

OR

_____ kWe

@_____ RPM

6) **Compression Ratio** _____

7) **Injection System Parameters**

a) Make & Model _____

b) Timing _____ Degree Crank Angle BTDC

c) Needle setting pressure _____ kPa

8) **Lubricating Oil Particulars**

a) Grade of oil _____

b) Sump capacity _____litres

c) Recommended period for topping **per**_____ hours of operation

d) Recommended period for **change of oil** in terms of hours

i) Under diesel operation _____hours

ii) Under Dual-fuel _____hours

e) Rate of Lubricating oil consumption _____cc/h

f) Lubricating oil disposal or treatment Please give details and a sketch on a separate sheet

PLEASE PROVIDE THE ENGINE MANUFACTURER'S OPERATION AND MAINTENANCE MANUAL FOR THE ENGINE

9) **Gasifier-Engine System Performance @ Rated Load**

a) Under Diesel operation

i) Power Produced _____[kW]

ii) Diesel Consumption _____[litre/hour]

b) Under Dual-fuel operation

i) Power Produced _____[kW]

ii) Diesel Consumption _____[litre/hour]

iii) Biomass Consumption _____[kg/hour]

c) Engine & System performance

i) Diesel Replacement [%] _____

ii) Dual-fuel Engine Efficiency at Rated Conditions [%]_____

iii) Overall System Efficiency [%] _____

d) Exhaust Temperature @ Rated Load [C] _____

e) Exhaust Emissions

CO [% or mg/kWh] _____

NOx [ppm or mg/kWh] _____

Smoke [HSU/Bosch] _____

V (A2) **THE DRIVEN MACHINERY** *(Fill up the relevant parts & write 'NA' where **N**ot **A**pplicable. Please do not leave blanks.)*

1) **Mechanical Mode**

Pump

a) Make _____

b) Type _____

c) Rated Flow Rate Q [lit/min] _____

d) Head H [meters] _____

e) Power Rating [kW] _____

f) Efficiency [%] _____

g) Max Suction Head Permissible [meters] _____

2) **Electrical Mode**

Generator

a) Make _____

b) Type _____

c) Rating [kWe] _____

Voltage [V] _____

Current [Amp] _____

d) Power Factor _____

e) Efficiency @ Rated Load [%] _____

PART-B: THE INITIAL TEST RUN (ITR)

The initial test run is to be carried out in presence of the manufacturer's representative on a date fixed through prior communications. **Change of date is not permitted under normal circumstances**.

After noting the specifications, a detailed packing list for the system will be made. Missing items if any, to be noted down clearly. **System is to be installed and commissioned by the representatives of the manufacturer**.

The **Initial Test Run (ITR)** would consist of **STARTING** the gasifier system and operating it for a minimum period of 4 hours along with the engine at rated conditions. Starting of gasifier system and commencement of supply of gas to the engine shall be carried out by the manufacturer's representative present at the test site as per the procedure prescribed by the manufacturer in the O&M Manual. Measurements during **ITR** shall include gas output rate, gas cal-value and biomass consumption rate. Gas temperature at gasifier outlet will be recorded continuously (Or every 15 minutes if the testing is a field site).

Performance evaluation of the engine shall also form a part of **ITR**. For example, in case of mechanical and electrical applications, engine power capacity, diesel & wood consumption rates and engine exhaust parameters shall constitute important measurements. Percentage Diesel Replacement [% DR] shall be calculated every 30 minutes. Observations and results of **ITR** to be recorded as per **TABLE-1**.

The results / observations of the **ITR** will be signed by the manufacturer's representative present during the test and the Test Incharge from Testing Agency. The same will be included in final Test Report to be submitted to MNES.

ITR results will be discussed with the manufacturer's representative. Performance Evaluation Tests **(PETs)** and Long Duration Test **(LDT)** shall be taken up only if **ITR** results are satisfactory. Upon unsatisfactory **ITR** results/experience, the testing shall stand cancelled. In case of testing being conducted at a GARP/Test Center, it will be mandatory for the manufacturer to remove the system from the Test-Center within a prescribed period of time. ***NO REPAIRS OR MODIFICATIONS SHALL BE PERMITTED TO BE CARRIED OUT AT THE TESTING SITE AFTER COMMENCEMENT OF THE TEST.***

In case the testing exercise is undertaken at field site, the testing schedule shall stand cancelled and test team shall return back**.**

FOR ONCE CANCELLED TEST PROGRAM, TESTING WOULD BE RE-SCHEDULED AS PER MUTUAL CONVENIENCE.

TABLE-1 OBSERVATIONS & RESULTS OF INITIAL TEST RUN (ITR)

Name of the Test Incharge:_____ **Date:** _____ **Time of starting** [am/pm]_____

Ambient Temp [C]_____ **Relative Humidity** [%]_____

Biomass Particulars : i) Name of Biomass _____ ii) Size [mm]_____ iii) Moisture Content [%]_____

System Rating : i) Gasifier [kW or nm^3/h]_____ ii) End-Use-Application rating [kW/kWe]_____

a) **Starting Time Duration:** _____minutes _____sec

Any Other Observation _____

Avg. Values

b) **DIESEL CONSUMPTION RATE** (1) Time for X*** cc (sec) (i) (ii) (iii) (iv)

Under Diesel operation (2) kg/h (i) (ii) (iii) (iv)

@ rated load

c) **DUAL-FUEL PERFORMANCE RECORD**

Time h-min	$T_{gas(go)}$ at gasifier outlet [C]	$(\Delta P)_{gasifier}$ [mm of WC]	$(\Delta P)_{cooler}$ [mm of WC]	$T_{gas(ei)}$ at engine inlet [C]	Amount** of biomass added [kg]	Biomass Consumption Rate [kg/h]	Engine Output [kW]	Time for X*** cc of Diesel consumption [sec]	Diesel Rates [kg/hr]	% DR	Remarks
*0-00											
0-30											
1-00											
1-30											
2-00											
2-30											
3-00											
3-30											
4-00											

All observations to be recorded every 30 minutes for at least four hours

* *Starting Point = Zero time*

** *1. The hopper should be full up to top at zero time.*
2. Quantity of biomass fed to top-up the hopper, to be recorded with respective time.

*** *Diesel quantity to be 50 -500 cc depending on size of the engine*

Name & Signature_____
Lab Scientist

Name & Signature_____
Manufacturers Representative

ANNEXURE-II

STARTING TEST

This test is the commencement of the formal test procedures. Manufacturer's representative shall continue to operate the system in strict conformity to the procedure as laid down in the O&M Manual. The Testing Agency shall reserve the right of terminating the testing in case of any deviation from the operating procedures as laid down in the O&M Manual. Procedure shall be as follows:

1) Gasifier to be completely emptied, cleaned and refilled with quantities of the materials (charcoal + biomass) **as specified** in the O&M Manual. Name / type of biomass material and its size is to be selected as per specifications. **(All the biomass of the recommended, type, size, and moisture content for the "Gasifier" and the required amount of charcoal is to be supplied by the manufacturer).[TABLE-2]**
2) Start the blower (hand or electric) or the other device as specified by the manufacturer for starting/firing the gasifier.
3) Light a flaming torch and **start clocking the time** from the instant the torch is held near the firing port to the instant when gas starts flaring steadily. **Use the procedure specified by the manufacturer in the O&M Manual, in case it is different from above**.

4)* Note the time taken for achieving a steady flare.

5)* Monitor continuously (every two minutes or so) the temperature of gas at the gasifier outlet and the pressure drops $(\Delta P)_{gasifier}$ & $(\Delta P)_{cooler}$, across gasifier and cooling system. **[TABLE-3]**

6)* Continue flaring till the temperature of the gas at gasifier outlet stabilises. Range of temperature will be 180-350 C depending upon gasifier design and the flow rate during starting. Note down this time.

Gas must be sampled for its tar & particulate contents at this point. If the tar & particulates are within specified limits, then only, it is to be considered ready for feeding into the warmed up engine.

[The engine has to be started and run on diesel-mode for at least 15 minutes to be warmed up, before producer gas is fed into it. For this reason engine should be started simultaneous to firing of the gasifier unless, otherwise is specified by the manufacturer]

Time required for starting / flaring and achieving a steady gas outlet temperature / flare temperature is to be noted carefully. Depending upon the End-Use-Application either the former or the later will be termed as the **STARTING TIME**.

**Some gasifier systems do not have Blower and flare arrangement. Steps 2 to 6 cannot be performed in such cases. "Starting time" definition is required to be revised suitably by the testing agency.*

TABLE-2 OBSERVATIONS / RESULTS SHEET FOR THE STARTING TEST

Date _____

Amount of the "INITIAL FILL" charcoal fed [kg] _____

Weight of the "INITIAL FILL" of wood / biomass [kg] _____

Recommended Biomass Size [mm x mm] _____

Moisture content of Biomass [%] _____

Time at torching [am/pm] _____

Time at flaring [am/pm] _____

Time at steady gas outlet temperature [am/pm] _____

Starting / Flaring duration [min.] _____

Time for "READY FOR ENGINE" _____[min.]

TABLE-3 OBSERVATIONS OF STARTING TEST

Time (min) →	0	2	4	6	8	10	12	14	16	18	20
Temp. of Gas at the Gasifier outlet [C]											
$(\Delta P)_{gasifier}$ [mm H_2O]											
$(\Delta P)_{Cooler\ etc.}$ [mm H_2O]											

Note (1) '0' time corresponds to the time of torching.
(2) Continue the observations till the gas temperature stabilises.
(3) Note the instant when gas is supplied to engine.

ANY OTHER OBSERVATIONS

_____

_____

_____

_____

FINAL REMARKS*

Acceptable ☐

Not Acceptable ☐

_____

**Normal time duration from torching to flaring of a cold gasifier is 5 to 10 min. Time for "READY FOR ENGINE" is 15 to 20 min. Time for any other application would be less than this limit.*

*If the starting time is **equal to or less** than 20 min., then the remark should be "ACCEPTABLE". If more, the remark should be "NOT ACCEPTABLE" **unless otherwise specified by the manufacturer**. There should be no change in ΔP values during this period for the testing to continue*.

ANNEXURE-III

PERFORMANCE EVALUATION TESTS FOR GASIFIER-ENGINE SYSTEMS [PET1 & PET2]

Two **PETs**, each of 12 hour duration are to be conducted. **PET1** is to be conducted in continuation with the **Starting Test**. The system is then completely cooled down before **PET2**. Each of the **PET** would consist of two parts **A-1** & **A-2**, the Diesel Operation and the Dual-fuel Operation. The engine is to be started on diesel mode. The diesel mode of starting and operation need to be carried out parallelly or preceding the **Starting Test** in **PET1.**

The PET2 shall follow PET1. No cleaning other than ash removal is to be carried out between PET1 and PET2. Charcoal and biomass beds are not to be touched and the system is only to be re-fired. Ash removal and biomass topping up operation shall precede commencement of **PET2.**

Proceed as follows:

A-1 DIESEL OPERATION

1) Start the engine and put on the rated normal connected load. If it is a pump, the same will load the engine. In case of electric generator, the load has to be connected to the lines.

2) Note down the following observations, 30 minutes after starting the engine **(TABLE-4)**

    a) Load on the engine (in kW in case of electricity generation or rate of water pumping and suction & delivery heads in pumping application).

    b) Speed of engine [RPM] (to be maintained constant)

    c) Diesel consumption rate (time for consumption of 'X' cc of fuel in sec) *['X' may be 50 cc or 100 cc or even 500-1000 cc depending upon the engine size. The quantity should be so chosen to give 60 to 100 sec time duration. This much time is essential to ensure the measurement accuracy]*

    d) Exhaust temperature [C].

    e) Exhaust smoke density [HSU OR BOSCH NO./ UNITS BU].

    Repeat all the above readings after 30 minutes in the first round and again after 20 minutes. The values of the above five parameters should remain practically unchanged. If not, take a third set of observations after another 20 minutes and compare the same with the previous values. The parameters remaining unchanged indicates that the engine has stabilised and is ready for Dual-fuel operation.

Caution: Producer gas must not be supplied to a cold engine (unless so specified by the manufacturer) or else it may lead to tar condensation in the engine and related problems..

TABLE-4 PERFORMANCE TEST UNDER DIESEL OPERATION - OBSERVATIONS

Sr. No.	Time [am/pm]	Engine Load				Engine [RPM]	Time for Consumption of _____* cc of diesel [sec]	Exhaust Temp. [C]	Exhaust Smoke [HSU or BU]	Diesel Consumption Rate [kg/h]
		kW = $\frac{\rho g Q H^{\oplus}}{\eta}$		kWe						
		Q [m^3/s]	H [m]	kVA	ϕ					

*50-500 cc depending on size of engine

$^{\oplus}\rho$ = *Density of water [kg/m^3]*

η = *efficiency of pump [%]*

ϕ *is power factor*

A-2 DUAL-FUEL OPERATION

Performance evaluation under Dual-fuel operation is the other part of **PETs** in both, Mechanical and Electrical applications. Proceed as follows:

1) Note down the following parameters on the gasifier set up **[TABLE-5]**

TABLE-5 INITIAL GASIFIER / GAS PARAMETERS

	PET1	PET2
a) Gas temperature at gasifier outlet [C]	_____	_____
b) Gas temperature at engine inlet [C]	_____	_____
c) ΔP across gasifier [mm of WC]	_____	_____
d) ΔP across cooling and cleaning system [mm of WC]	_____	_____

Up to this point the gas is not given to the engine which is operating at rated load. Producer-gas is being flared and is ready to be given to the engine.

2) Open the gas supply valve and let the gas flow into the engine, increasing the quantity gradually. To be able to increase the gas inflow rate, in some cases, it might be necessary to restrict the air passage by closing the air inlet valve. **Check the O&M Manual for recommendations of manufacturer and follow the same precisely.**

3) Carry out diesel fuel adjustments only if **recommended in the O&M Manual.** (This is sometimes needed for minimisation of diesel flow rate and to be able to maintain the engine speed).

4) About 15 minutes may be required to reach a steady state, maximum % DR being the basic focus. Constant engine exhaust temperature may be taken as indicator of this steady state. Engine speed must remain constant.

5) Note down the observations as per **TABLE-6** for the stabilisation period every 5 minutes. After reaching the steady state, note down all the observations and check for repeatability of parameters after 30 minutes. Engine is now ready for a **PET**.

Starting Time, the rated output, gas flow rate, pressure drops across the gasifier and across the cooling-cleaning system under rated conditions, to be noted down and compared with the values specified by the manufacturer in the O&M Manual/SIT. The difference between the two must not be more than 10% of the specified values.

6) Top up the gasifier hopper and note the time. Call this as “zero-time” for the rest of the **PET**.

7) Monitor all the parameters after every 30 minutes.

8) Biomass top-up to be carried out after every two hours or **as prescribed by the manufacturer in the O&M Manual**. Record the weight of biomass filled during each topping along with all other observations **[TABLE-6]**. In case of continuos feeding the rate of biomass consumption is to be noted.

9) Gas quality for Tar contents shall be monitored every 60 minutes as per the procedures given in **Annexure-V. C** and using the set up described there in.

10) Total duration of test shall be 12 hours, out of which at least 10 hours will have to be at the condition defined as Dual-fuel operation (i.e., in all six topping-up operations will be carried out during each **PET**). Load / output must remain unchanged during most part of dual-fuel operation.

11) Testing officer / scientist must record, all the events like 'ramming / poking' 'grate rotation', 'additional shaking', 'Tar sampling, gas sampling, biomass feeding', 'air valve adjustment', 'diesel adjustment' etc, with corresponding time of the day / night. Such a record is important from view-point of making assessment regarding operating attention and manpower / technical expertise / training requirement for the system. Any changes in temperatures, pressure drops and speed must be noted. These must be a part of the operating procedure prescribed in the O&M Manual.

    Gas sampling and Tar sampling need to be sequenced and not carried out simultaneously since the same disturb the gas flow to the engine and cause engine speed and load variation. Tar and gas sampling should be the last observations to be recorded in a given set.

12) **Follow the stopping instructions of the manufacturer as prescribed in O&M Manual**.

13) Let the engine run on diesel mode for about 15 minutes before unloading and stopping. During these 15 minutes a set of observations must be recorded as under diesel operation. This set provides for comparison with the pre dual fuelling conditions and thus acts as indicator of any changes that might have taken place during Dual-fuel operation.

14) Let the gasifier cool down completely before the second 12 hour test cycle is taken up. Remove the ash and restart the gasifier following exactly the

same procedure as in **Starting Test** + **PET1**. This would enable consolidation of 24 hours of operating time by end of **PET2**.

The ash as well as residual charcoal particles in the ash must be preserved for final mass balance and efficiency calculations. Specific observation regarding presence of 'clinker' in the ash must be noted.

15) The observations and results of the two tests must be analyzed. Final results must be tabulated as in **TABLE-6a & 6b** and compared. Adequacy of performance and comparability of results of the two tests are essential conditions for proceeding on to **LDT**. If the results do not conform to the claims of the manufacturer and are not as per the prescribed performance levels specified in the O&M Manual/SIT, **Testing Is To Be Abandoned.**

Observations to be noted about Ash and Charcoal at the end of each 12h Run of PET1 & PET2

	PET1	PET2
a) Weight (dry) of Ash Collected in 12 hours [kg]	_____	_____
b) Weight (dry) of charcoal collected [kg]	_____	_____
c) Size and condition of charcoal		
Color	_____	_____
Density	_____	_____
Size	_____	_____
d) Effluent Water Analysis	_____	_____

ANY OTHER OBSERVATIONS:

_____

_____

_____

_____

_____

ANNEXURE-IV

LONG DURATION TESTING OF GASIFIER-ENGINE SYSTEMS [LDT]
(30 hours Performance Evaluation)

Long duration test is carried out to evaluate consistency of operation and to assess the long duration continuous operational capability of the system. The maintenance requirements under long duration continuous operation of different components sub-systems: gasifier, gas processing train, connecting pipes & fitting and the engine also gets evaluated through this **LDT**. Endurance of the gasifier equipment against thermal deformation is another important aspect that gets evaluated through this test. This test follows the **PET2** and is of 30 hour duration.

The **LDT** consists of the following component-procedures and steps:

I INSPECTION AND PREPARATION

1) THE ENGINE

a) Fuel injection nozzles of the diesel engine to be dual-fueled are checked for the opening pressure setting and spray quality. Adjustments are made if necessary.

b) Inspect inlet and exhaust channels and manifolds of the engine for ash and tar deposits. Clean if necessary. Take photographs, examine and weigh the removed matter for reporting in the final test report.

c) Change the lubricating oil of the engine. Measure the quantity of the removed oil and keep it for TAN / TBN and metal content analysis. Fill fresh engine oil.

2) THE GASIFIER SYSTEM

a) Get the gasifier system completely emptied and cleaned. Inspect the system, particularly the oxidation zone and air nozzles, for any thermal deformity. The gas chamber below the reduction zone and the gas outlet pipe also need to be examined for any indication of overheating. *For larger systems, if complete emptying and cleaning is not feasible, the inspection procedure may need to be decided by the Testing Agency on a case to case basis.*

The critical parts to be examined will be different for updraft gasifiers and also for rice husk gasifiers. Each design and type of gasifier will need to be examined separately on this count.

b) Examine the gas pipes and pipe fitting for ash and tar deposits. Clean them thoroughly. Save the removed material for further analysis and record.

c) Carefully inspect the cooling-cleaning system. Clean the connecting pipes and change the filter material.

Take photographs wherever necessary.

d) Assemble the system. Connect the engine, the gas processing train and the gasifier. **Carryout a leak check to assure leak-proof-ness of the system. (Usually the soap bubble technique and a high flow high speed blower is used for this purpose.)**

Assembly and Leak Check must be carried out as per the procedure prescribed in the O&M Manual.

Leak-proof-ness is one of the most important conditions required to be complied with, in order to achieve trouble free operation. Manufacturers have to take care of this aspect while laying down the assembly and dissembly procedures and supply of spare packing etc. Since most of the systems work under suction leakage could lead to air suction into the system which in turn cause overheating depending upon the point of leakage. Malfunction of engine is also caused by leakage.

II THE TEST

DUAL-FUEL ENGINE

The first step consists of generation of the base performance data under diesel operation.

a) If the application is electricity generation, a load test is required to be conducted on the engine under diesel operation, **(Annexure-V*. D)**. In case of other constant speed, constant load type of applications like water pumping, observations are to be recorded only at one load point corresponding to the constant connected load.

b) Simultaneous with starting of the engine, the gasifier system has to undergo the **Starting Test** similar to the one conducted under **PETs (Annexure–II)**. After starting the gasifier, it should continue to operate on blower mode, till the engine is ready after the Load Test. The following observations are to be noted under the blower-mode** operation of the gasifier:

   i) Gas outlet temperature [C]
      (to be noted every 15 minutes)
   ii) Biomass consumption rate [kg/h]
      (by topping up method, feeding every 2 hours)

**Reference IS 10000(Parts I to X) 1980.*

***In case blower is not provided, the blower-mode operation should be replaced by starting mode prescribed by the manufacturer*.

c) At the end of Load Test the engine will be running at the rated load or constant load under diesel operation. Start gas supply to the engine and increase it slowly. Generally, if the engine governor is

sensitive, supply of gas should not change the engine speed or load. Note down the change, if any, during the process of changing to Dual-fuel operation. Decrease the load if necessary i.e., if there is difficulty in maintaining the rated speed. Wait for 30 minutes. The engine should by this time, achieve a thermal stability. It is indicated by a steady value of the exhaust temperature. Record the following:

i) Engine Speed [RPM] _____

ii) Load on Engine [kW/kWe] _____

iii) Engine Exhaust Temperature [C] _____

d) Top-up the gasifier with biomass at this point and start the clock and call it as zero time.

By this instant, the time lapsed after starting the engine would be between 3-4 hours in generator application or about 1 to 1½ hours in constant load application like water pumping.

e) Continue operating the system and noting all the observations for 30 continuous hours as in **TABLE-6,** following the procedure described for **PETs** in **Annexure-III**, under para "Dual-fuel Operation" (items 7-9).

f) Make note of every event that takes place. Make special note of: Time [am/pm] of biomass feeding, time period required for filling the biomass, amount of biomass filled every time, stoppages with reasons, ramming carried out, frequency and effect of ramming, filter material change time [am/pm] and the duration required for charging, attention demanded by cooling system i.e. any choking, clogging etc. Record also the quantity of the oil topping if carried out. All this information is to be entered in the remarks column of the **TABLE-6** to be checked and compared with procedures given in the O&M Manual.

g) Stop gas flow to the engine after 30 hours of Dual-fuel operation. Revert back to blower mode operation of the gasifier and diesel mode operation of the engine.

h) Repeat the load test on the engine under diesel operation this time with reducing load in steps of 20% of the rated power. Test the gasifier on blower mode as in the beginning. Note the observations in the **TABLE-6**. Note the final results in **TABLE-6c**.

The results of the Load Test conducted in the beginning of the **LDT** need to be compared with those obtained at the end of **LDT**.

i) Remove the lubricating oil and test it for:

i) Viscosity

iv) Particulate contents

ii) Moisture content

iii) TAN / TBN

v) Metal contents

j) Open the engine cylinder head. Inspect the combustion space, valves, piston and inlet & exhaust channels for deposits and general conditions. Inspect liners and pistons of the engine for any visible wear. Check conditions of the piston rings and groves and note down the special findings.

Check the fuel injection nozzle for opening pressure setting, spray quality and signs of overheating and dribbling etc.

It is most desirable to photograph all these components of the engine before and after **LDT**.

k) Any other special observations:

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

In case of Dual-fuel operation all the results obtained over 30 hours are to be summarised and averaged to calculate total kWh generated, total biomass consumed, total ash produced etc. The average summarised values are to be used for finding the overall gasification efficiency as well as system efficiency. System efficiency includes the efficiency of the Dual-

fuel engine. % Diesel replacement is to be worked out on the average basis for the period of Dual-fuel operation.

Note :

1) ***The gas outlet temperature and the biomass consumption rates at the end of the test should compare well with those measured in the beginning. Same level of gas temperature and biomass consumption rates indicate no deterioration in gasifier condition***.

2) ***Diesel consumption rates under diesel operation at different loads should remain same after 30 hours of operation as at the beginning of the test. If so, there has been no significant deterioration in the engine condition during LDT***.

ANNEXURE-V

MEASURING DEVICES, THE TEST SET-UPS & PROCEDURES

A) MEASURING DEVICES

Given below is the list of the measuring instruments / devices / set-ups and procedures needed to be used for qualifying laboratory and field testing of the system as per the methodology discussed in previous pages.

1) Digital temperature indicators

a) 0-1000 C Range	:	10 Nos.
b) 0-200 C Range	:	4 Nos.

2) H_2, HC, CH_4, CO_2, O_2 ,CO & NOx Monitoring equipment like on-line gas Chromatograph or direct indicating type Gas Analysers : 1 No.

3) Calibrated Orifice meters with Flow sensors for measurement of gas flow and air flow rates. : 3 Nos.

4) On-line pressure sensors for measurement of pressure drops at and across various sub-systems : 10 Nos.

5) Diesel consumption measuring-Calibrated pipette arrangement or direct indicating type fuel flow meters : 1 Nos.

6) Digital Stop Watches with integration Facility : 2 Nos.

7) Precision weighing machines / spring balances

0-10 kg range	:	1 No.
0-250 kg range	:	1 No.

8) Smokemeter (Hartridge or Bosch) : 1 No.

9) On-line gas calorimeter or Junkers : 1 No.

Gas Calorimeter with a sampling pump

10) Tar and Particulate sampling apparatus : THT type Tar Sampler

11) Precision micro-balance with 0.01 mg least count : 1No.

12) Infra-red moisture meter

13) Oxygen bomb calorimeter

14) Lubricating oil test facility
   a) Viscometer
   b) Potentiometric titrator
   c) Centrifuge for particulate measurement
   d) Oil filtration set-up with vacuum pump

15) Orsat apparatus with oxidation pipette : 1No.

16) Tachometers (Non-contact type) : 2 Nos.

B) THE SYSTEM TO BE TESTED

The system to be tested must be provided with tappings for pressure / pressure drop measurements, temperature measurements, iso-kinetic sampling of tar in gas and gas sampling for analysis. Fig.-1 overleaf is the schematic of the general test set-up. List of provisions to be made by the gasifier manufacturer for laboratory or field testing for referral systems are the following:

1) Pet-cock arrangement with 4 mm diameter pet-cock hole;
   a) at gasifier outlet for gas temperature measurement (T_g).
   b) at cooler-cleaner outlet for gas temp. Measurement (T_c).
   c) engine exhaust pipe for measurement of engine exhaust temperature (T_e).

2) Pressure tappings at gasifier outlet, after cooler & cleaner and at the engine inlet & engine exhaust (ΔP_g, ΔP_C & ΔP_{ei}, ΔP_{ee}).

3) Gas sampling tapping with a cock, with a 'tee' to be connected to the gas sampler and gas calorimeter after the cooling cleaning system (please refer Figure).

4) A 'tee' connection at the bend in the engine exhaust line for smoke density measurement.

5) A flanged connection in the gas line with screwed-on flanges (to be replaced by a calibrated orifice meter by the testing agency).

6) D X 25 mm reducer 'tee' connections in the gas line with plugs for making connections to the tar apparatus, D being the diameter of gas pipe before and after the cooling-cleaning system.

C) GAS QUALITY ASSESSMENT FOR TAR & PARTICULATE CONTENTS

1) IIT BOMBAY TAR SAMPLING METHOD

A schematic diagram of the tar and particulate sampling system is given in Fig.2a. The system consists of a filter thimble for removing particulate and condensing system for tar condensation and estimation.

Sampling Procedure :

Test the system for leakage before starting. Use soap bubble technique for leak-checking. Weigh the clean filter cartridge and record its weight (W_1). Remove the filter holder and place the clean filter into the holder. Keep the filter holder temperature at 110^{o}C. Sampling should not be done until at least 15 minutes after the filter holder heater is switched ON to ensure stabilisation of its temperature. Switch ON the cold water pump. Record the initial gas-meter reading and time. Switch ON the vacuum pump and sample a total of 3 Nm^3 of producer gas. Switch OFF the heater and remove the filter cartridge after the filter chamber is cooled. Weigh the cartridge filter and record the weight (W_2). The difference in weights (W_2-W_1) gives the Weight of particulates and tar collected in the filter cartridge.

Rinse the condenser and the connecting pipe with Acetone or Dichloro-methane and collect all the washings. Rinse the filter cartridge removed from the filter holder by Acetone. Tar dissolves in acetone and only particulates remain in the filter cartridge. Weigh the cartridge and record its weight (W_3). W_3-W_1 gives the weight of particulates in that volume of gas sampled. Heat the washings of the filter cartridge and those from condenser to 55^{o}C in a solvent recovery apparatus. Tar then settles at the bottom of the flask. Weigh the flask. Let this be W_5. Let W_4 be the weight of empty dry flask. Then (W_5-W_4) = weight of tar. Tar content of gas in mg/Nm^3=(W_5-W_4)/Volume of sample gas in normal cubic meters.

2) IISc BANGALORE TAR SAMPLING METHOD

Particulate and Tar measurement:

This is performed by a procedure identified by the Swiss group, which had surveyed several sampling procedures prior to adopting and further modifying through subsequent experimentation. In the version adopted, 2.0 m^3/hr of gas is drawn from the main gas stream and is bubbled through distilled water and a solvent to extract dust and tar separately. The particulate and tar analysis is performed both at the hot and the cold ends of the gasifier. The elements used for the sampling are shown in Fig 2b. Gas bubblers containing liquids as mentioned above form one end of the gas sampling circuit. Whereas, the other end has an inter-changeable sampling nozzle, to draw the producer gas from the mains gas stream. The nozzle is sized according to the flow rate of the gasifier (power rating of the gasifier), so as to maintain comparable velocities through the nozzle as that of in the main ducting. This is done so as to ensure that nearly the same levels of dust concentration in the main stream are drawn into the sampling circuit. This procedure is known as iso-kinetic sampling. The gas sampling circuit consists of a nozzle, gas bubblers, and thimble filter, vacuum pump followed by a gas flow meter and a burner. The gas bubbler section consists of a bottle containing distilled water. The gas bubbles through this and moves onto an empty bottle where any moisture or water droplet carried over from the previous system is trapped. The next three bottles contain a solvent, namely anisole (methoxy benzene) followed by an empty bottle as a trap. All the bottles are placed in an ice and salt bath. The gas finally passes through a thimble filter prior to its passage through the vacuum pump to the burner. The thimble filter provided has to be large enough to ensure that the fine dust collection does not pose unmanageable pressure drop on the suction pump. The thimble area could be about 300 cm^2 for about 2 to 3 hours of sampling. The gas after being pumped out of the system passes through a positive displacement flow integrator before going to a swirl burner. The burner introduced in the circuit has two important features, one is to ensure that the gas is burnt, and secondly to ensue that gas burns in a diffusion mode. If there is any air leakage in the sampling train, it will be evident in the burner.

Post-Sampling Procedures & Analysis:

Washing procedure with water

a) Disconnect nozzle, water cooler, diving pipe and piping to the tar-condensing bottle from the water-condensing bottle.

b) Determine the total weight of the condensing bottle.

c) Wash the water cooler (inner passage only) and the diving pipe with as little water as possible (the mass of the wash water used should be known). Pour the wash water into the water-condensing bottle.
d) Allow the content of washing bottle to settle for approximately half an hour (1/2h) for phase separation. Withdraw a sample of the aqueous phase for the water analysis and put it in a glass bottle with gas tight cover (sample identification: WA; s.a.). The liquid mixture for the water analysis should contain no particles and no organic phase. Until the water analysis, the glass bottle is stored in the

refrigerator. The analysis should be done as quickly as possible to avoid undesired reactions in the water.

e) Pour the residual aqueous phase from bottle into the shaking bottle.

Washing procedure with methoxy benzene (anisole)

a) After the water washing procedure, wash the nozzle (inner passage only), the water cooler (inner passage only) and the diving pipe with as little methoxy benzene as possible (the mass of the methoxy benzene used should be known). Pour the solvent into the water-condensing bottle.

b) Determine the total weight of the tar washing bottles.

c) Disconnect the piping between the tar condensing bottles. Pour the content of the first and second bottle into the water-condensing bottle. Use the methoxy benzene of the last washing bottle to clean the first and second tar-condensing bottle.

d) Use fresh methoxy benzene (the mass of the methoxy benzene used should also be determined) to wash all tar condensing and the drop separator bottle as well as the piping connections. Use as few methoxy benzene as possible.

e) Pour methoxy benzene washing solution into the washing bottle.

f) Pour the content of the washing bottle into the shaking bottle.

g) Use fresh methoxy benzene (the mass of the methoxy benzene used should also be determined) to wash the bottle and add it to the shaking bottle. Use as little methoxy benzene as possible.

The shaking bottle now contains the aqueous phase and all the organic phase as well as the particles.

Remark: If the laboratory analysis cannot be made immediately after the sampling or in case of long transport distances, the liquids can remain in bottle instead of transferring them into shaking bottle. Then the washing procedures have to be adapted.

Sample preparation in the laboratory

Extraction procedures

a) Extract the organics dissolved in the water phase with the shaking bottle.

b) Pour the heavier phase (aqueous phase) from bottle through a paper filter named F (the filter must be dried to constant mass in a given atmosphere) to remove particles into the flask named AP (aqueous phase).

c) Pour the lighter phase (methoxy benzene phase) from bottle through the same paper filter to remove particles into the flask named OP (organic phase).

d) Clean the shaking bottle with fresh water (the amount used must be known), pour the washing solution through the paper filter F and add it to the flask named AP. Determine the total mass of the aqueous phase.

e) Clean the shaking bottle with fresh methoxy benzene (the amount used must be known), pour the washing solution through the paper filter and add it to the flask name OP. Determine the total mass of the organic phase.

f) The paper filter F is then preferably transferred into the soxhlet filter tube.

Tar determination procedure

g) The organic phase should be dried over a solid drying medium (e.g. dried sodium sulfate anhydrous or calcium oxide).

h) Pour the dried organic solution over a paper filter and transfer the liquid into the distillation flask.

i) Rectify the methoxy benzene, preferably under vacuum. The temperature should be as low as possible.

j) Determine the mass of the rectification residue. This value is used for the calculation of the tar content of the gasifier gas.

Solid determination procedure

k) Evaporate the water from the flask named AP.

l) Determine the mass of the solid residue A.

m) The paper filter F (together with the soxhlet filter tube) is placed into the soxhlet apparatus. Then the methoxy benzene extracts the solid residue.

n) The mass of the filter paper F is determined (same temperature and atmosphere as for initial weight determination). Then the mass of the solid residue B is known.

o) The masses of the solid residue A and B are used for the calculation of the particle content of the gasifier gas.

D) LOAD TEST ON THE ENGINE

1) Check the fuel injection nozzle, record its opening pressure setting. Check and re-assemble the engine intake system. Start the engine and let it get warmed up for 15-20 minutes.

2) Load it to the maximum or usual field load. Note down the observations as per observation table given in **Annexure-III** after 20-30 minutes of loading. Steady engine exhaust temperature should be an indication for stability of engine and therefore its readiness for observation noting.

3) In case of electrical-generator application, reduce load in steps of 20 p.c. of the rated value of load, wait for thermal stability and note the observations, till the no-load point.

4) In case it is a constant load application like water pumping, part-load testing is not to be carried out, so only one set of readings at full load will be taken.

ANNEXURE –VI

FINAL RESULTS AND RECOMMENDATIONS

1) STARTING CHARACTERISTICS

Starting time [am/pm]	:	
Time taken for flaring / bed ignition	:	
Time lapsed for being ready for Engine	:	
Remark	:	Acceptable / Not acceptable

2) OPERATING TIME DETAILS

Duration of Diesel operation	:	h
Duration of Dual-fuel operation	:	h
Down time	:	h
Total test duration	:	h
Ratio of Operating time to Total Test time	:	

3) SUMMARY OF LOAD OF ENGINE

Load on the Engine	:	% of rated value
Total kW-h generated	:	kWh
Total biomass consumed	:	kg
Average biomass consumption rate	:	kg/h
Total diesel consumption	:	lit.
Diesel consumed in diesel Operation	:	lit.
Diesel consumed in dual- fuel Operation	:	lit.
Diesel saved	:	lit.
Average biomass consumption per Liter of diesel saved	:	kg/lit.

4) SUMMARY OF GASIFIER PERFORMANCE

Total hours of operation at rated condition	:	
Total charcoal fed to gasifier	:	kg
Size and type of charcoal	:	
Total wood fed to gasifier	:	kg
Moisture content of the wood / biomass	:	%
Total ash removed	:	kg
Total charcoal removed	:	kg
Calorific value of charcoal / ash removed	:	kcal/kg
Total gas produced	:	m^3
Average calorific value of the gas	:	kcal/ m^3
Average gas output temperature	:	C
Cold gas efficiency	:	%
Hot gas efficiency	:	%

5) OVERALL SUMMARY OF RESULTS

	Measured values Max. Min. Avg.	**As specified by Manufacturer**	**Qualifying and acceptable values**
% DR			
Tar [mg/nm^3]			
Particulates [mg/m^3]			
Wood cons. Per litre of diesel replaced			

6) INSPECTION REPORT / REMARKS

a) **Engine**

(i) Nozzle

(ii) Piston rings

(iii) Piston

(iv) Liner

(v) Valves / channels

b) **Gasifier (Thermal deformation and / or mechanical failure)**

(i) Reaction space / cone

(ii) Grate etc.

(iii) Pipes / pipe fittings

(iv) Any other

7) FINAL RECOMMENDATIONS

THE SYSTEM PERFORMANCE IS WITHIN ACCEPTABLE RANGE ☐

THE SYSTEM IS REJECTED ☐

_____

Signature of Testing Agency Representative

Date :

Place:

ANNEXURE -VII

ASSUMPTIONS / DATA

Cal. value of Biomass (wet basis)	:	Woody - 16-18 MJ/kg Rice Husk - 12-15 MJ/kg
Cal. value of diesel	:	42 MJ/kg [~34 MJ/litre]

Engine Efficiency

i)	Diesel Operation	:	30% [SFC 286gm/kWh]
ii)	Dual-fuel operation	:	18* - 21%

** Lower efficiency values refer to rice-husk gasification units*

Wood equivalent of diesel replaced
in a gasifier dual-fuel operation at rated load
1 litre of Diesel = 3 kg of wood OR 4 kg of Rice Husk

ANNEXURE-VIII

SPECIAL OBSERVATIONS/REMARKS/SUGGESTIONS

ANNEXURE-IX

DEFINITIONS

1 TURN DOWN RATIO OF GASIFIER

Ratio of the Rated Output to the Lowest Output Level Achievable for steady operation without undue drop of performance.

2 GASIFICATION EFFICIENCY *[Hot gas]*

Ratio of the output rate [in terms of the energy content of the hot gas] to the Energy input through biomass consumption rate.

$$\frac{(CV)_g[kcal/nm^3] \bullet V_g\ [nm^3/kg] + h_s[kJ/nm^3]}{(CV)_B\ [kcal/kg]}$$

Where:

$(CV)_g$	Cal. Value of Gas [kcal/nm^3]
V_g	Gas produced per kg of Biomass [nm^3/kg]
h_s	Sensible heat of the gas - C_V (Tg-Ts)XV_g
$(CV)_B$	Cal. value of Biomass [kcal/kg]
C_V	Volumetric Specific heat of producer gas [kcal/nm^3]
T_g	Temperature of Producer gas at the gasifier outlet [C]
T_s	Standard temperature [C]

3 GASIFICATION EFFICIENCY *[Cold gas]*

Ratio of the output rate [in terms of the energy content of the cold gas] to the Energy input through biomass consumption rate.

$$\frac{(CV)_g[kcal/nm^3] \bullet V_g\ [nm^3/kg]}{(CV)_B\ [kcal/kg]}$$

4 PERCENTAGE DIESEL REPLACEMENT (%DR)

%DR is specified at the rated load. It can however be defined for any operating condition.

%DR is the ratio of the diesel fuel saved per unit time OR per unit Power generated at rated load, to the diesel consumption rate under diesel operation under the same load and in the same units.

$$\%DR = \frac{(DCR)_{Diesel} - (DCR)_{Dual\text{-}fuel}}{(DCR)_{Diesel}}$$

Where

$(DCR)_{Diesel}$ Diesel Consumption Rate [kg/h] under diesel operation

$(DCR)_{Dual\text{-}fuel}$ Diesel Consumption Rate [kg/h] under dual-fuel operation

5 OVERALL SYSTEM EFFICIENCY

The overall system efficiency is the net efficiency taking into account the gasification as well as the end- use application efficiency.

ANNEXURE -X

DRAFT AGREEMENT BETWEEN TESTING AGENCY AND MANUFACTURER FOR TESTING OF THE BIOMASS GASIFIER BASED SYSTEMS AT THE PREMISES OF THE TESTING AGENCY

This agreement is executed on this _____ day of _____ at _____ between

NAME, ADDRESS AND LEGAL STATUS OF THE MANUFACTURER (hereinafter called 'Manufacturer') represented by its authorised representative _____

AND

NAME, ADDRESS AND LEGAL STATUS OF THE TESTING AGENCY (hereinafter called 'Testing Agency') represented by its authorised representative _____.

It is agreed upon between the Manufacturer and the Testing Agency to carry out the testing of the biomass gasifier based system (hereinafter called the 'system') of the Manufacturer as per the Ministry of Non Conventional Energy Sources (hereinafter called MNES) Test Procedure No. I for the purpose of approval of the system and its components by MNES under its promotional programme in accordance with the following clauses, terms and conditions:

1) The Manufacturer shall make available the system of _____ capacity of _____ configuration / application, as described in the "System Introduction Test (SIT)" as per the attached **Annexure I** (of the Test Procedure No. I).

2) The Testing Agency shall undertake the testing of the above system as per the "Test Procedure No. I" and the clauses appearing hereinafter.

3) The Manufacturer shall undertake that the system to be tested and the accompanying documentation conforms to the "Pre-requisites to Testing" as mentioned in the attached **Annexure-XII**. If, any time during the course of testing schedule, the information provided by the Manufacturer is found to be incorrect or non-conforming to the last supplied information prior to physical testing of the systems, the Testing Agency shall reserve the right to terminate the testing.

4) The Manufacturer agrees to pay the testing charges, in advance, to the Testing Agency as per the schedule prescribed by MNES and mentioned in the attached **Annexure-XIII.** The Manufacturer further agrees that he shall forfeit the charges deposited in the event of termination of testing due to any of the reasons mentioned in subsequent clauses of this agreement.

5) The Testing Agency shall fix up the date of commencement of testing schedule as per the mutual convenience of the Testing Agency and the Manufacturer, within two months of conveyance of satisfactorily completed information as per **Annexure-I**, indicative of the expectation that the system, when tested, will satisfy the qualifying norms of MNES and performance claims of the Manufacturer.

6) The Manufacturer shall, at his own cost, deliver, unpack, erect and/or assemble the system at the premises of the Testing Agency, as per the pre-decided schedule. The freight and insurance of transporting the gasifier system to the premises of Testing Agency shall be borne by the Manufacturer. While unpacking of the system, verification of the packing list shall be jointly carried out by the Manufacturer's representative and personnel from the Testing Agency. Manufacturer shall make up for the short falls, if any, in the shortest possible time to avoid delay in commencement of testing schedule.

7) The Manufacturer shall supply, at his own cost, pre-processed biomass, lubricants, diesel and charcoal as required, in accordance with the design specifications in quantities (with overages) adequate for test schedule, along with the gasifier system to the premises of the Testing Agency.

8) The Manufacturer, shall at his own cost make provisions on the system for measurements, as per hardware matching requirements prescribed by the Testing Agency, prior to dispatch from his manufacturing works. This will be as per the testing requirements, considered necessary and specific to the gasifier system, under consideration for ensuring reliable operation.

9) The Testing Agency shall use its own instruments and consumables for calibrations and measurements of weights, volumes, temperatures, pressures, gas / air flows, gas composition, contaminants in gas, emissions, effluents, etc. Whereas measurements at several locations can be taken by the Testing Agency for assessment of long term reliable operation, the qualifying criteria set out in the qualifying norms will be the prime basis for inclusion in the promotional programmes of MNES.

10) The Manufacturer shall, after assembly of the system at the testing site, on the premises of Testing Agency, confirm its readiness for commencement for testing schedule, based on the supply of water (connection) and matching load by the test centre.

11) The Manufacturer shall supervise the ITR, utilising the skilled and unskilled manpower of the Testing Agency, to demonstrate the operating/maintenance procedure. This has to be in strict conformity with the O & M manual of the Manufacturer.

12) After the completion of ITR, the Manufacturer shall continue to operate the system for subsequent tests but the entire event recording and taking of

measurements shall be done only by the Testing Agency. The operation of the system by the Manufacturer shall be in strict conformity with the procedure as laid down in the O&M Manual. The Testing Agency shall reserve the rights of terminating the testing in case of any deviation from the operating procedure as laid down in the O&M Manual. *The Manufacturer's operation of the system will ensure no infringement of Intellectual Property Rights, but Manufacturer will not be permitted to interfere with taking of system performance measurements*. **Only the readings / records / conclusions of the Testing Agency will be final and binding**.

13) The Manufacturer shall not carry out any maintenance of the system, whatsoever, other than the routine operational schedules mentioned in the O & M manual. No intermediate dismantling and/or dimensional recording will be carried out other than the essential 'initial', before **LDT** and at 'end of testing' condition monitoring assessment readings and photographic evidence for establishing the wear rate of critical components as required to be documented by the Testing Agency as per the Test Procedures.

14) The Testing Agency shall not provide any technical advice during the course of hardware testing. Manufacturer will only be provided with technical comments (during SIT) on corrective measures to render the system fit for the subsequent testing. It is the responsibility of the Manufacturer to ensure compliance and readiness of the system for physical testing including necessary updation of O&M manual, as required, to incorporate the observations of the Testing Agency as observed during testing.

15) The Testing Agency shall reserve the right of terminating the testing in case of failure of the gasifier system or any of its sub-systems during the course of test schedule. The reason for failed system shall also be reported to MNES by the Testing Agency.

16) The Manufacturer shall not be permitted to submit his system for physical testing to the Testing Agency on the basis of SIT of any other approved Testing Agency. It is mandatory to have complete testing (including SIT) done from a single Testing Agency. In case a system fails to qualify for any reason, at any stage of testing schedule at a Testing Agency, it will be mandatory for the manufacturer, if desirous of re-submitting for testing, to submit it for physical re-testing to the same Testing Agency where the previous testing was carried out.

17) The Testing Agency shall not be required to make provisions for special supports or foundation for erection / stability of the system and it is understood that such (small) capacity systems are intended to be of self-supporting / free standing design.

18) On intimation of completion of the testing by the Testing Agency, the Manufacturer will be required to lift the system from the premises of the Testing Agency within a period of 2 calendar weeks. Dissembly, packing and

transporting the system shall be the responsibility of the Manufacturer. If the system is not collected within the stipulated time, the Testing Agency shall not be responsible for any damage or loss and shall reserve the right of scrapping / disposal the system, without any claim thereof by the Manufacturer.

19) The Testing Agency shall send five signed copies of the test report to MNES under intimation to the Manufacturer and Technology Provider, if any, (four copies for MNES plus one for the Manufacturer) along with the recorded data, summary of results / recommendations and clear statement about the performance and the system or sub-system compliance with the prescribed norms. The Testing Agency shall also specify reasons in case of non-acceptance of the system. Manufacturer shall obtain his test report copy from MNES only.

20) In case of any dispute arising before, during or after the testing, the matter shall be referred to MNES for resolution within three months whose decision shall be final and binding.

_____	_____
Signature of Manufacturer's Representative	Signature of Testing Agency Representative
Date:	
Place:	
Witness 1: Name	Witness 1: Name
Address	Address
Witness 2: Name	Witness 2: Name
Address	Address

ANNEXURE -XI

DRAFT AGREEMENT BETWEEN TESTING AGENCY AND MANUFACTURER FOR TESTING OF THE BIOMASS GASIFIER BASED SYSTEMS AT THE PREMISES OF THE MANUFACTURER / END-USER

This agreement is executed on this _____ day of _____ at _____ between

NAME, ADDRESS AND LEGAL STATUS OF THE MANUFACTURER (hereinafter called 'Manufacturer') represented by its authorised representative _____.

AND

NAME, ADDRESS AND LEGAL STATUS OF THE TESTING AGENCY (hereinafter called 'Testing Agency') represented by its authorised representative _____.

It is agreed upon between the Manufacturer and the Testing Agency to carry out the testing of the biomass gasifier based system (hereinafter called the 'system') of the Manufacturer as per the Ministry of Non Conventional Energy Sources (hereinafter called MNES) Test Procedure No. I for the purpose of approval of the system and its components by MNES under its promotional programme in accordance with the following clauses, terms and conditions:

1) The Manufacturer shall make available an installed system of _____ capacity of _____ configuration / application, as described in the "System Introduction Test (SIT)" as per the attached **Annexure-I** of the Test Procedure No. I, at his own / user premises or at a convenient location for testing by the Testing Agency.

2) The Testing Agency shall undertake the testing of the above system as per the "Test Procedure No. I″ and the clauses appearing hereinafter.

3) The Manufacturer shall undertake to inform the Testing Agency regarding readiness of the system and all required utilities / loads, as prescribed. On receipt of such undertaking, the Testing Agency shall arrange to confirm adequacy of the field testing preparations made by the Manufacturer by sending a representative to the testing site, whose lodging, boarding and local conveyance expenses shall be borne by the Manufacturer. Subsequently the Testing Agency shall fix up the date of commencement of testing schedule as per the mutual convenience of Testing Agency, Manufacturer and / or System Owner, within two months of conveyance of system readiness and satisfactory completion of **Annexure-I** requirements, indicative of the expectation that the system, when tested, will satisfy the qualifying norms of MNES and performance claims of the Manufacturer. Based on this schedule, the testing team shall visit the site accordingly.

4) The Manufacturer shall undertake that the system to be tested and the accompanying documentation conforms to the "Pre-requisites to Testing" as mentioned in the attached **Annexure-XII**. If, any time during the course of testing schedule, the information provided by the Manufacturer is found incorrect or non-conforming to the last supplied information prior to physical testing of the systems, the Testing Agency shall reserve the right to terminate the testing.

5) The Manufacturer shall, at his own cost, arrange for lodging, boarding and local conveyance for the visiting testing team for the entire duration of the site testing. The accommodation and other arrangements shall be made in accordance with the eligibility of the team members in their parent organisation, as best available at the category of site where the testing is to be carried out and the same shall be confirmed / shown by the Manufacturer to the representative of the Testing Agency who visits the site for confirming adequacy of preparations (point 3 above) and obtain written acceptance of readiness from the representative.

6) The Manufacturer agrees to pay the testing charges, in advance, to the Testing Agency as per the schedule prescribed by MNES and mentioned in the attached **Annexure-XIII**. The Manufacturer further agrees that he shall forfeit the charges deposited in the event of termination of testing due to any of the reasons mentioned in subsequent clauses of this agreement.

7) The Manufacturer shall, at his own cost, arrange for pre-processed biomass, lubricants, diesel and charcoal, as required, in accordance with the design specifications and quantities (with overages) adequate for complete testing schedule.

8) The Manufacturer shall, at his own cost, make provisions on the system for measurements, as per the hardware matching prescribed by the Testing Agency. This will be as per the testing requirements, considered necessary and specific to the gasifier system under consideration for ensuring reliable operation.

9) The Testing Agency shall use its own instruments and consumables for calibrations and measurements of weights, volumes, temperatures, pressures, gas / air flows, gas composition, contaminants in gas, emissions, effluents, etc. Whereas measurements at several locations can be taken by the Testing Agency for assessment of long term reliable operation, the qualifying criteria set out in the qualifying norms will be the prime basis for inclusion in promotional programmes of MNES.

10) The Manufacturer, shall at his own cost, carryout the ITR to demonstrate the operating / maintenance procedure. This has to be in strict conformity with the O & M manual of the Manufacturer.

11) After the completion of ITR, the Manufacturer shall continue to operate the system for subsequent tests but the entire event recording and taking of

measurements shall be done only by the Testing Agency. The operation of the system by the Manufacturer shall be in strict conformity with the procedure as laid down in the O&M Manual. The Testing Agency shall reserve the rights of terminating the testing in case of any deviation from the operating procedure as laid down in the O&M Manual. *The Manufacturer's operation of the system will ensure no infringement of Intellectual Property Rights, but Manufacturer will not be permitted to interfere with taking of system performance measurements*. **Only the readings / records / conclusions of the Testing Agency will be final and binding**.

12) The Manufacturer shall not carryout any maintenance of the system whatsoever, other than the routine operational schedules mentioned in the O & M manual. No intermediate dismantling and/or dimensional recording will be carried out other than the essential 'initial', before **LDT** and 'end of testing' condition monitoring assessment readings and photographic evidence for establishing the wear rate of critical components as required to be documented by the Testing Agency as per the Test Procedures.

13) The Testing Agency shall not provide any technical advice during the course of hardware testing. Manufacturer will only be provided with technical comments (during SIT) on corrective measures to render the system fit for the subsequent testing. It is the responsibility of the Manufacturer to ensure compliance and readiness of the system for physical testing including necessary updation of O&M manual, as required, to incorporate the observations of the Testing Agency as observed during testing.

14) The Testing Agency shall reserve the right of terminating the testing in case of failure of the gasifier system or any of its sub-systems during the course of test schedule. The reason for failed system shall also be reported by the Testing Agency.

15) The Manufacturer shall not be permitted to submit his system for physical testing to the Testing Agency on the basis of SIT of any other approved Testing Agency. It is mandatory to have complete testing (including SIT) done from a single Testing Agency. In case a system fails to qualify for any reason, at any stage of testing schedule at a Testing Agency, it will be mandatory for the manufacturer, if desirous of re-submitting for testing, to submit it for physical re-testing to the same Testing Agency where the previous testing was carried out.

16) The Testing Agency shall send five signed copies of the test report to MNES under intimation to the Manufacturer and Technology Provider, if any, (four copies for MNES plus one for the Manufacturer) along with the recorded data, summary of results / recommendations and clear statement about the performance and the system or sub-system compliance with the prescribed norms. The Testing Agency shall also specify reasons in case of non-acceptance of the system. Manufacturer shall obtain his test report copy from MNES only.

17) In case of any dispute arising before, during or after the testing, the matter shall be referred to a committee duly constituted by MNES for resolution within three months whose decision shall be final and binding.

_____	_____
Signature of Manufacturer's Representative	Signature of Testing Agency Representative
Date:	
Place:	
Witness 1: Name	Witness 1: Name
Address	Address
Witness 2: Name	Witness 2: Name
Address	Address

ANNEXURE-XII

PRE-REQUISITES TO TESTING

1) The System Introduction Test (SIT) format shall be completely filled in by the Manufacturer and submitted to the Testing Agency, barring those items of information which the Manufacturer considers to be proprietary information, which shall be indicated as 'Proprietary'. However, only design and constructional features, which are not in the realm of common and published knowledge can be considered under the category of proprietary information and not the claimed performance (test results as conducted by or for, the Manufacturer) of the overall system or its component sub-systems.

2) Undertaking by the Manufacturer that the SIT data is based on actual tests conducted by or in the presence of the Manufacturer or his authorised representative.

3) Undertaking by the Manufacturer that gasifier system performance complies with the qualifying norms prescribed in the MNES Test Procedure No. I

4) Submission of schematic of the system / layout with clear indication of gas, air and water flow directions, overall dimensions of the system and subsystems to the Testing Agency.

5) Submission of O& M manual (with the minimum contents as per the attached **Annexure-XIV**) to the Testing Agency.

ANNEXURE-XIII

SCHEDULE OF TESTING CHARGES

The following schedule of testing charges given below are prescribed by MNES, for encouraging growth of the biomass based industry, on a shared cost basis w.e.f. 1/4/2000 valid till 31.3.2002. Costs and corresponding charges are based on a step-by-step systems examination and testing procedure and make it necessary for the industry and development institutions and/or testing centers to assume a responsibility for any system designed and offered for testing and for services offered by test centers. Where the cost/charge is to be borne by the manufacturers and is required to be paid to the test center, the same should be paid by Demand Draft prior to test center taking up the activity paid for

Sr. No.	Activity	Fee (Rs.)	To be paid by/Remarks
1.	Biomass characterisation study and supply of complete Test Report in triplicate	500/-	Manufacturer/ User
2.	Examination of complete documentation submitted for SIT and issue of acceptance for further testing/ comments on inadequacies in system not accepted for testing	2,000/- For systems less than or equal to 20kWe or equivalent 5,000/- For systems greater than 20kWe and lower than or equal to 100kWe or equivalent 10,000/-For systems with capacity of greater than 100 kWe or equivalent and greater.	Manufacturer
3.	Re-examination (each time) of corrections made to complete documentation submitted for SIT to remove system deficiencies communicated earlier and issue of acceptance for further testing/comments on remaining inadequacies in system not accepted for testing	50 % of charges for Item 2	Manufacturer

Sr. No.	Activity	Fee (Rs.)	To be paid by/Remarks
4.			
4.1	Type test at Test Center :		
	a) System transportation, Loading/unloading assembly /dissembly, freight, insurance, supply of biomass and consumables (other than chemicals for measurements) tests, board and lodging and local transportation for his own staff.	NIL	Manufacturer
	b) Use of skilled/unskilled labor and supervision for operation and taking of measurements , use of instruments, chemicals, utilities and consumables of Test Centers and preparation and submission of Test Reports	NIL	Expenses to be met by Testing Agency out of GARP funds.
4.2	Type Test at Manufacturers / Users works: a) In station local conveyance, to-and-fro travel, packing/ forwarding, freight, insurance, loading / Unloading, assembly, dissembly for all measurement consumables, instruments and equipments; provision of supervision of skilled operators for taking measurements and preparation/submission of Test Report.	NIL	Expenses to be met by Testing Agency out of GARP funds

Sr. No.	Activity	Fee (Rs.)	To be paid by/Remarks
	b) Local conveyance at station of testing, arrangements for and board plus lodging for entire Testing Agency team, provision of requested manpower during testing and operation under supervision of Testing Agency	At Cost	Manufacturer/ User
5.	Performance monitoring testing (after SIT and type test) at manufacturers / users works of repeat order systems : For systems with no changes to SIT and Type Test conditions as in 4.2 above for all activities except without carrying out detailed Tar & Particulate measurements	NIL	Expenses to be met by Testing Agency out of GARP funds.

ANNEXURE - XIV

MINIMUM REQUIREMENTS OF O&M MANUALS PROVIDED BY MANUFACTURERS TO THE TESTING AGENCY / USERS

In the interest of promoting the Gasifier-based-Industry and the safe operation by the users, it is required that the manufacturer keeps in view the points listed below when finalising his O&M Manual.

Without proper coverage of the mentioned points in the O&M Manuals, Testing Agency may decline to accept the system for testing, when reviewing the documentation submitted for System Introduction Test (SIT).

- Technical specifications, including design life of overall system and codes followed for design / performance of all critical components as well as general components - such as piping system, pressure vessels, etc. (These should conform to BIS / ASTM / equivalent codes, where available).
- Consumption of utilities in total and for different sub-systems, where applicable. This also includes auxiliary consumption of power (under minimum / normal / maximum operating conditions).
- Brief process description of the gasification system (and of clean up system and end use equipment as applicable), highlighting the generation of toxic and inflammable gases, requiring extreme care in handling.
- Description of offered / supplied system, including its sub-systems, with properly labeled diagrams meant to be easily understood and followed by the user / operator. It should be remembered that the operation is normally done by trained operators and matching instructions / labeling should be available in the local language used at the place of installation.
- Clear cut instructions should be available as to when components need to be changed / retired, based on having reached the end of their life / requiring repair, based on measured wear rates. Similarly, instructions on change of lubricating oils, etc. should be identified, matching with the supplier's requirements for bought out components such as engines and generators.
- Where systems need to be assembled at users site, step - by - step instructions of assembly and intermediate testing (by user, if required) are to be detailed out. The same applies for pre-commissioning trials and commissioning runs.
- Startup procedures to include clear instructions for leak test (in both conditions of system being shut down as well as when the system is in operation), initial / subsequent loading of reactor with char, normal expected time for ignition and gas generation (separately for initial startup and subsequent startups) under normal operating conditions.

- Indications of a normal and proper operating system at minimum / normal / maximum load conditions by way of expected pressure, temperature readings, etc., consumption of utilities, biomass, diesel, and the corresponding gas generation rates, quality of effluents and emissions, (and generation of shaft power / electrical power, as applicable).
- Identification of procedures for measuring moisture in biomass.
- Identification of procedures for measuring diesel replacement (as applicable to dual fuel systems) with devices forming part of equipment supplied and instructions on how to improve diesel replacement (DR) and for periodic cleaning of injector nozzles, etc.
- Shut down procedures under normal and emergency conditions and built in provisions, if any.
- Trouble shooting guidelines, preferably with description / diagrams / flow charts, so as to avoid repeated user expense in calling manufacturer's representative repeatedly, which can be difficult in remote areas.
- Maintenance procedures based on observed wear rates and for routine maintenance, mentioning periodicity, for all components, especially reactor, filters, engines.
- Safety requirements for layout (ventilation, minimum distance requirements), surface temperatures, leakage checks, availability of fire fighting equipment, first aid kit.
- Safety requirements for undesirable build up of scale / obstructive matter hindering the performance of system and end use devices.
- Claimed performance parameters vs. measured performance (to be filled in after results of Testing Agency are available) during performance guarantee runs / testing conducted by Test Agency.
- Specifications for main fuel and its preparation,
- Specifications of any other fuel used in the system (in gasifier, engine, burner, etc.)
- List of manufacturer supplied special tools / tackles and list of additional tools required to be kept available by user, including handling tools / tackles for assembly / dismantling.
- Minimum recommended spares, in keeping with wear rates and shelf life of items such as gaskets, packings, refractories, etc.
- List of instruments provided with the system and procedures for user to measure emission and effluent generated. Emission / effluent norms in the State of installation to be annexed (SPCB pollution control norms).
- Overall user friendliness of the O&M Manual.
- Training requirements of operators, especially if operators are likely to be changed frequently. Clear cut laid down procedure for user to train

operators on his own once the training has been imparted to users personnel in accordance with contract between user and manufacturer.

- Logbook format for system being supplied, which is to be maintained by operators, preferably in a single consolidated logbook. Method of calculation of efficiency, DR, cost of power, etc. (as applicable).
- Avoiding contrary instructions in different parts of operating manuals.
- Performance vs time curves of bought out equipment and of overall system.
- Items to be supplied by the user, such as foundations, building, water supply system, fuel storage, etc., with details and specifications
- List of Statutory obligations of the user.
- Test certificates of major bought out components / sub - systems.
- Conformance of system offered to type tested system.

It is emphasised to the manufacturer that preparation of a **comprehensive O&M Manual is an essential exercise on paper, i.e. without having to resort to expensive hardware modifications, by either manufacturer or user at a later stage. This will reduce the possibility of expensive complications and field failures.** It is particularly important that this document be carefully prepared, since a variety of applications can arise, including use (retro-fitting) of existing user equipment, for which it is the responsibility of the manufacturer to ascertain the residual life and performance capability, under the new anticipated operating conditions using producer gas. It is also the responsibility of the Manufacturer to match the system design to user requirements, including those of co-generation. Size matching of various components of the system, based on manufacturer's decision to use **available tested module sizes** is to be a careful and meticulous exercise**. Conformance of system offered, to the type tested system should be ensured.**

Performance tests (by an authorised testing agency) will only be carried out once the system has been in operation for some time and both loads and required system utilities are established as being available on a regular basis.

ANNEXURE - XV

DESIGNATED TEST CENTRES

The Ministry of Non-conventional Energy Sources (MNES) has established the Gasification Action Research Projects (GARP) which consists of trained manpower and total facilities with infrastructural support to enable testing of the gasifier systems. In principle, all the GARPs are qualified to test all types of gasifier systems -- Thermal Systems, Mechanical Shaft Power/Electrical Power Generation Systems, except the ones for which the technology has been developed by them.

The Third Party Agencies (TPA) which have the required trained manpower and total facilities with infrastructural support and which get registered with MNES after meeting the qualifying criteria can also be included in the list.

The following are the designated test centres as of 1st April 2000:

1. GARP, School of Energy Environment & Natural Resources, Madurai Kamraj University, Madurai - 625 021
2. GARP, Dept. of Chemical Engg., IIT Delhi, Hauz Khas, New Delhi-110 016
3. GARP, Dept. of Mech. Engg., IIT Bombay, Powai, Bombay - 470 076
4. GARP, Dept. of Aerospace Engg., IISc, Bangalore - 560 012
5. Technical Backup Centre, SPRERI, P.B. No. 2, Vallabh Vidyanagar, Gujarat - 388 120

However, only the GARPs at IIT Bombay and IISc Bangalore **can currently** take up the testing of the Gasifier- Mechanical/Electrical Systems.

TABLE-6a FINAL RESULTS OF DUAL-FUEL OPERATION [PET1]

Sr. No.	Time [am/pm]	Biomass consumption rate [kg/h]	Gasifier input rate [kcal/h]	Gasifier output rate [kcal/h]	Gasification Efficiency (Cold gas) [%]	Engine Output [kW]	Diesel Consumption Rate [kg/h]	% Diesel replacement	Overall System Efficiency

TABLE-6b FINAL RESULTS OF DUAL-FUEL OPERATION [PET2]

Sr. No.	Time [am/pm]	Biomass consumption rate [kg/h]	Gasifier input rate [kcal/h]	Gasifier output rate [kcal/h]	Gasification Efficiency (Cold gas) [%]	Engine Output [kW]	Diesel Consumption Rate [kg/h]	% Diesel replacement	Overall System Efficiency

TABLE-6c FINAL RESULTS OF DUAL-FUEL OPERATION [LDT]

Sr. No.	Time [am/pm]	Biomass consumption rate [kg/h]	Gasifier input rate [kcal/h]	Gasifier output rate [kcal/h]	Gasification Efficiency (Cold gas) [%]	Engine Output [kW]	Diesel Consumption Rate [kg/h]	% Diesel replacement	Overall System Efficiency