"India is a leader in Biomass Gasification technology" – True? Realizable?

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Plan of the presentation

- Background
- The Gasification Technology
- Basic studies in Char conversion
- Producer gas as a fuel and engine combustion processes
- Some systems in the field and their performance
- What should be done for India to be a leader

Background

- Industrial environment of India for the forty years after independence has been filled with license manufacture and purchase of designs
    - Car manufacturers, other chemical industries
    - PSUs like BHEL

Almost to the point of asking:

Can we do any original conceptual design ourselves at all?

The first break in the dismal scene has been the contribution of ISRO in building launch vehicles and satellites – a complex electro-mechanical system – with native talent when SLV – 3 flew successfully in 1982 (*Dr. A P J Abdul Kalam, the current President of India, was the project director for the SLV- 3 project*).

- Liberalization, Globalization and Privatization (LPG) has made it difficult for local manufacture to compete due to larger cost of energy and other elements of the product.
    - Review of "import" of technologies and licensed manufacture since that does not help manufacture in a cheaper way.
    - In some cases, is the high level of extraction of finances for the technology and dealing the "receiver" with some disdain for "technology" supply has contributed a part to inward examination of talents.
    - Has led to "looking around" before shopping abroad.
- Even with all this development, most of what has happened mostly is catching up with developed nations by doing the same thing or a similar thing indigenously.
- Quite often, if things have been built in India it is because it is cheaper to build; the IT hype belongs in part to this category.
- What more, look at the new establishments of the holy Aerospace companies of the USA - General Electric Company, and Pratt and Whitney?
    - Most of the work done in India is actually done here for the cheaper and a more committed labor – the $/Re ratio being the key driver.

Therefore……

- The technological self esteem of a country cannot be raised by these features.
- Careful study reveals that the number of new things developed *originally* here is small.
- One contribution to a "new thing" that has happened in this country and "technology development and export" has taken place to the developed world is the "Biomass gasification technology".

What has happened?…

- Technology development arose out of and supported by fundamental research
- Scientific studies at the laboratory.
- Scientific verification by scientists in India and from overseas – Switzerland and others
- Technology transfer to some *Indian industries*
    - also to *Switzerland, Japan, Thailand and others*
- Several field installations with learning from the field performance for improvement in design.
- International training program in which about *30 scientists from 10 countries* have learnt the science by coming to the Indian Institute of Science.
-

Let us see…

- What this technology is, its defining features and what is crucial in it?
- What is it that is new now that was not there earlier?
- Why have we not got drowned by big brothers?
- What is required to provide leadership role?

What is this technology?, What is its defining feature?

- Biomass gasification technology is a technology that converts solid biomass using a thermo-chemical process into a combustible gas.
- *A single reactor* can handle all the biomass – solid material to be sized and fine material to be briquetted, the material including agro-residues, plantation residues and *urban solid wastes that may have a fraction of non-biodegradable organics (polythene, rubber tires, tubes, foot wear, etc) – Power delivered depending on the feed.*
- A cooling and advanced cleaning system to produce "clean" and **dry** gas with 80 % of the initial energy.

- A package that limits the emissions both by default and design – both gaseous emissions as well as liquid effluents

Clean – tar and particulates, the permanent "problem stuff" limited to parts per billion levels.

The rigorous scientific base

- Experimental tools – measurement of on-line composition and temperatures, flow rates; tar and particulates, tar-signature.
- Basic studies on biomass and char and modeling of the gasification system.
- Characterize the gasifier behavior for moisture-in-biomass and ash fusion aspects.
- Characterizing producer gas as a gaseous fuel
- Characterizing engine behavior in gas-alone mode through modeling efforts – 0-D to 3-D CFD tools.
- Understand the gasifier – engine behavior on load changes
- Determine the issues related to effluent treatment for recycling the water used as a coolant. Determine what is required to meet the gaseous emissions from the thermal system/engine.

The fuels

- Rice husk and Rice straw – for India, China, S-E Asia
- Other straws, Sugarcane trash (& Bagasse), Peanut shells,
    - --------------- These are light (~100 kg/m3), fine sized (a few mm), high ash (5 to 20 %), highly alkaline ash – Potassiumfrom the fertilizer application, Moisture roblem not serious (because of thin walls)
    - ------------- Coconut shells, Cotton stalk, mustard stalk, weeds like Ipomia, Parthenium (properties like woody fuels)

Biomass

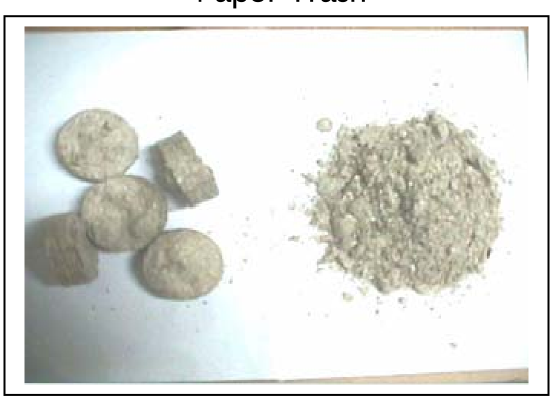
Coconut Shells

Coffee Husk

Dry Grass

Marigold Pellets

Paper Trash



Pine Needles

Rice Husk

Saw Dust

Sugar Cane Trash

Wood

Quality of the gas demanded of the gasifier

For woody biomass: Cold gasification efficiency ~ 80 % +

Composition (%) – CO~20, H_2 ~ 18, CH_4 ~1.5, CO_2 ~ 12, rest N_2 (Calorific value of 5 ± 0.2 MJ/n.m^3)

Particulates and Tar ~ as low as possible – 50 mg/m^3 or less, Liquid effluents must be treatable with moderate cost.

Enable use of the same gasifier for all *individual biomass or a mix in solid form since agro-residues are seasonal.*

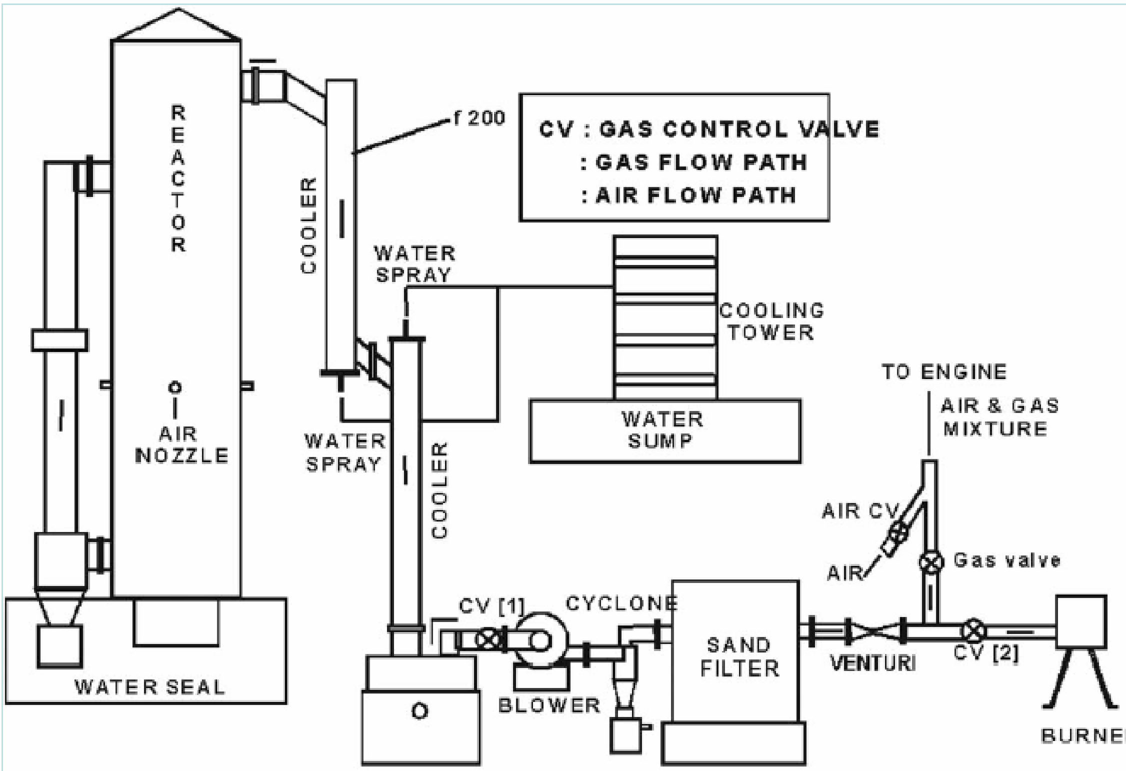
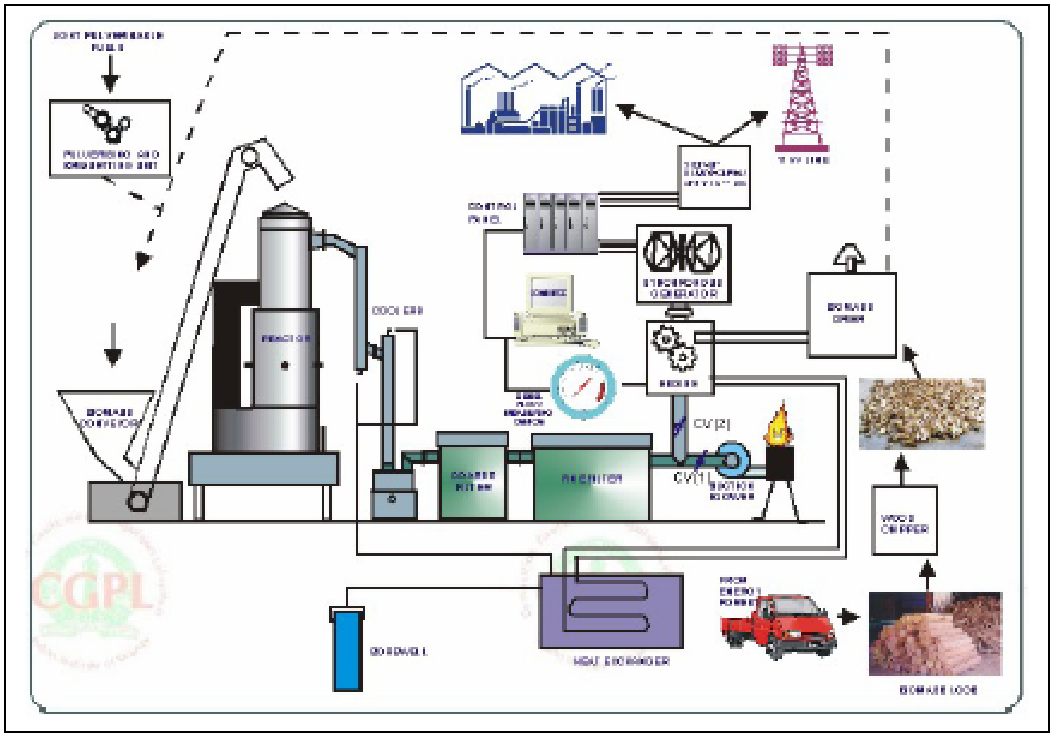
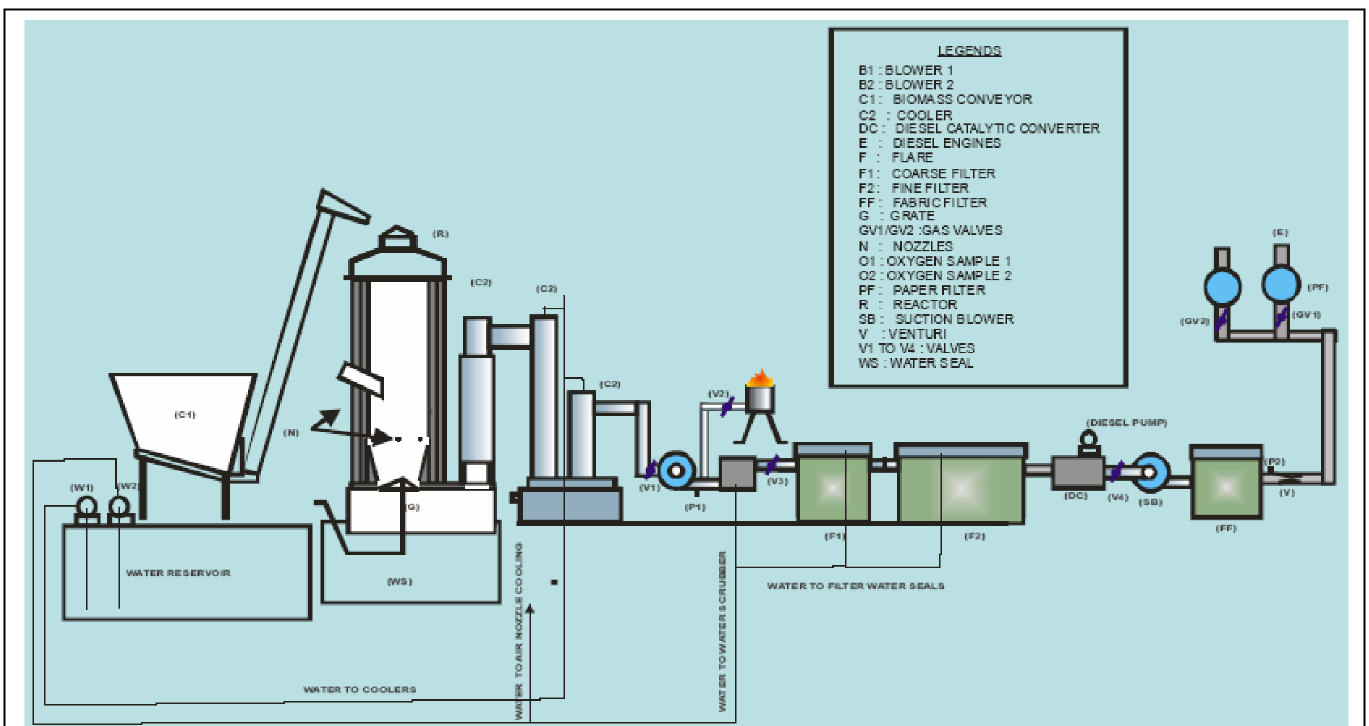


Fig. 2 SCHEMATIC OF WOOD GASIFIER FOR POWER GENERATION APPLICATION

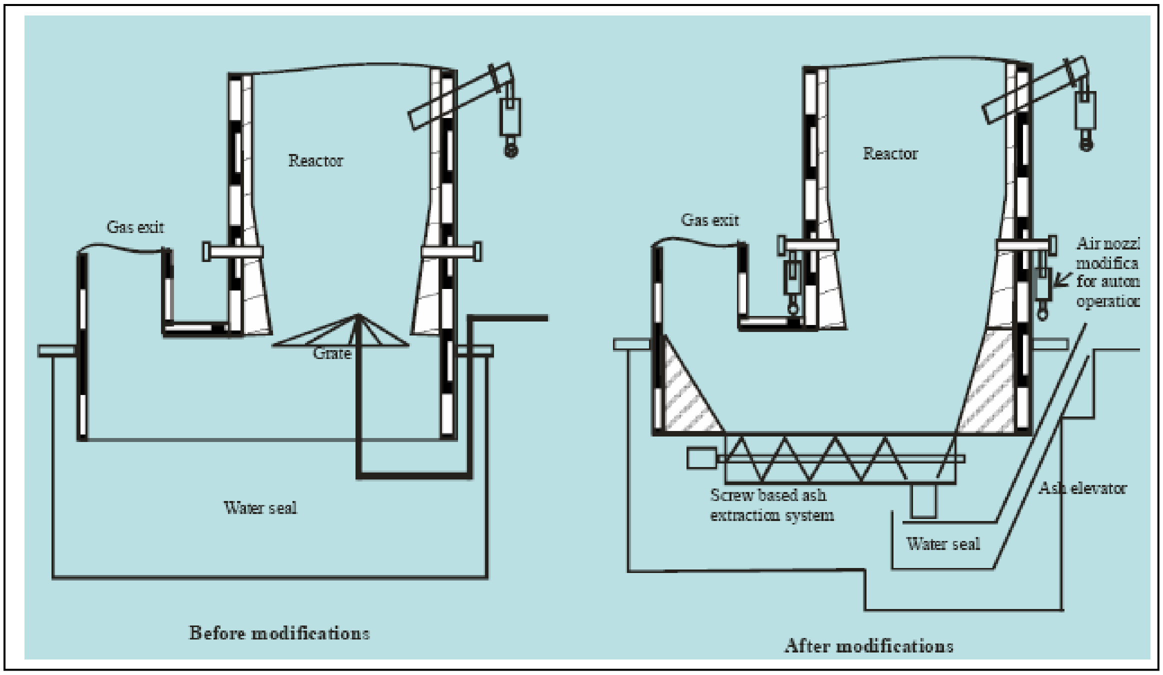
The system is an open top reburn reactor (with air supply from the top as well as the side nozzles). It has a grate at the bottom of the reactor.

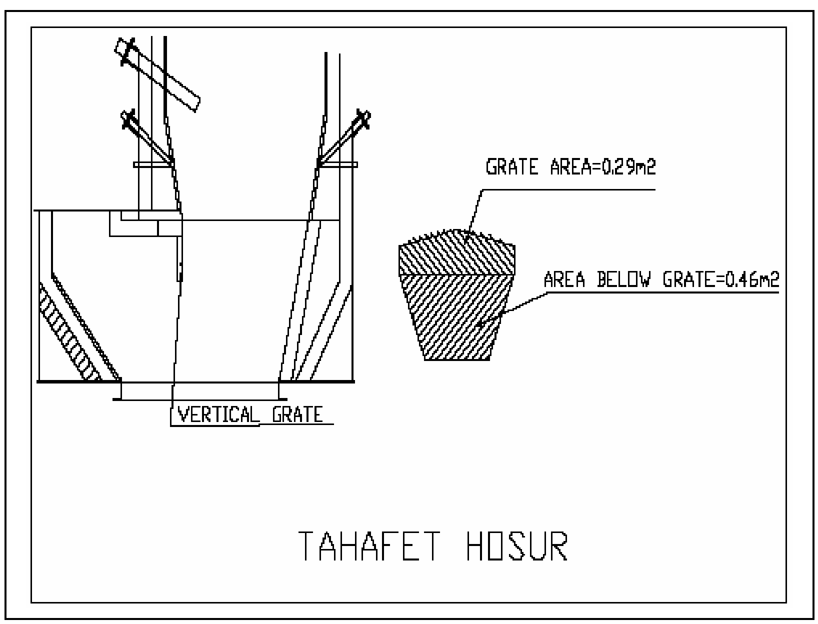
Technology status and Systems in market place

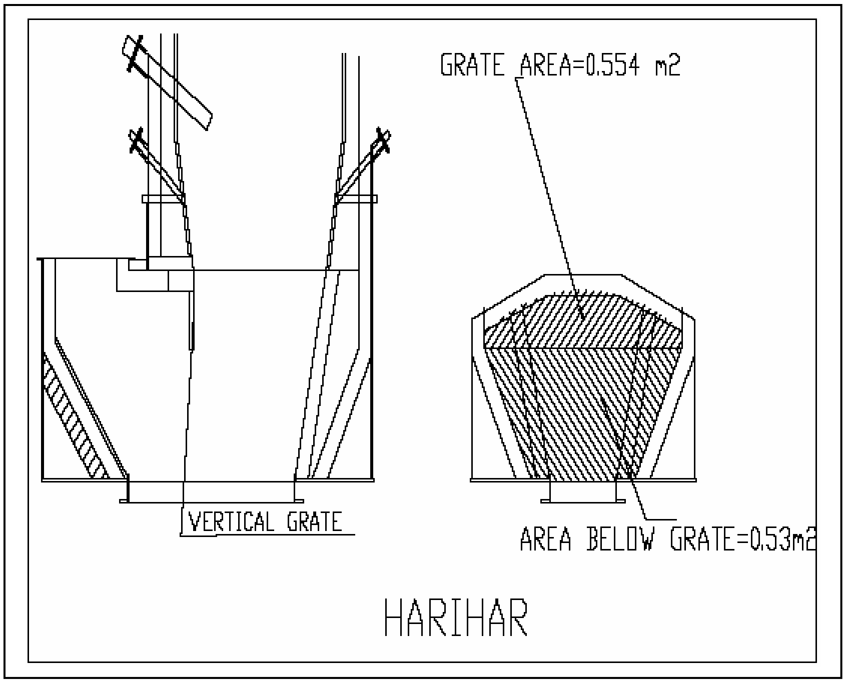


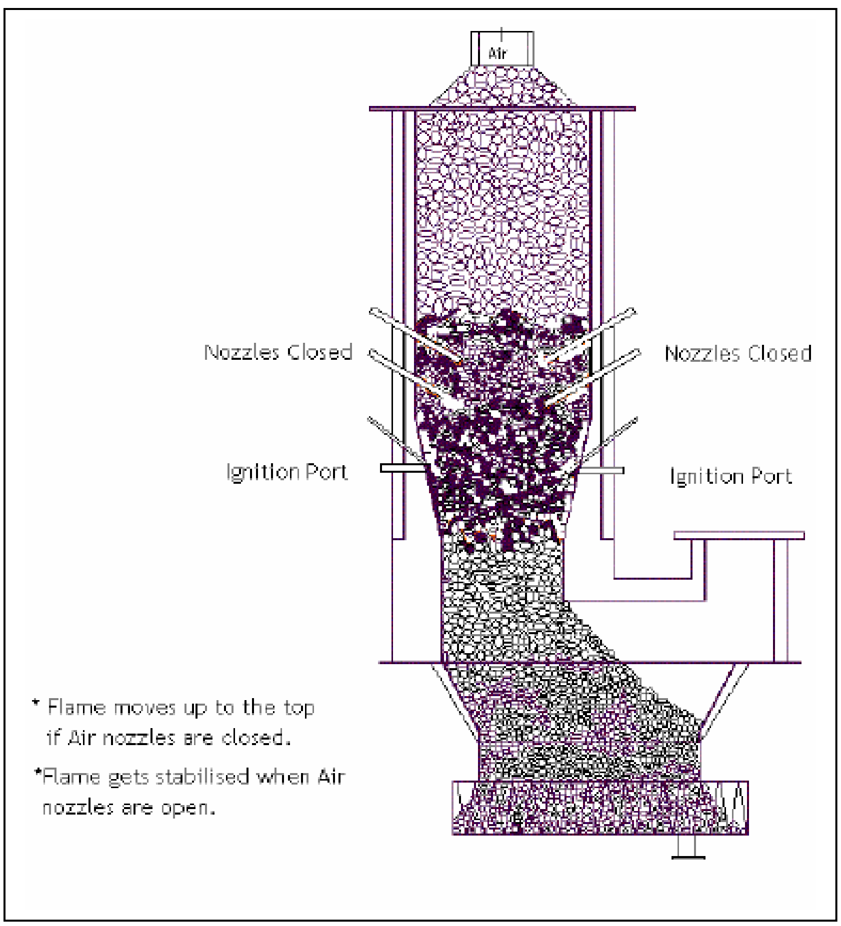


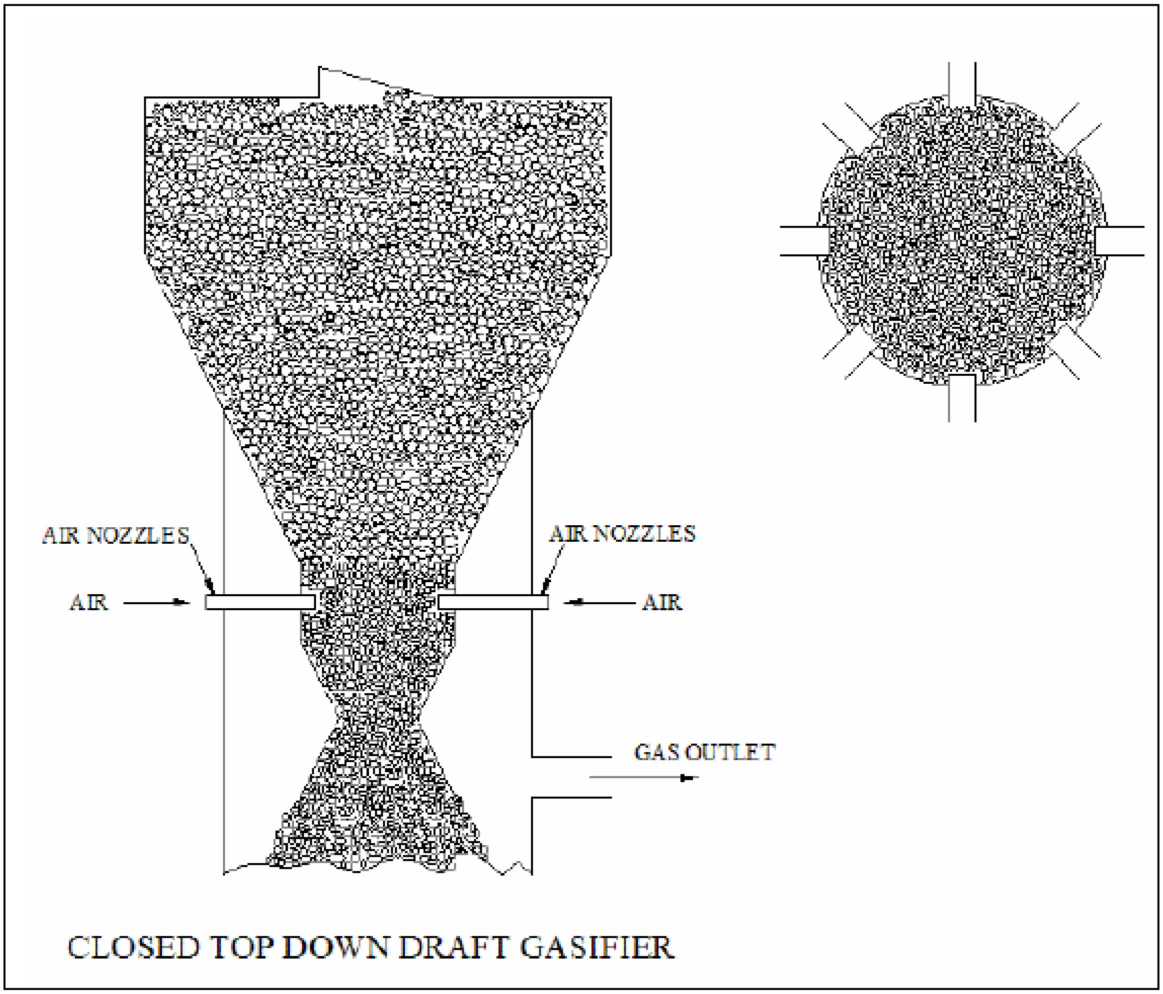
SCHEMATIC OF 500 KG/HR SOLID BIO-RESIDUE GASIFIER SYSTEM


Reactor
Gas exit
Grate
Water seal
Before modifications
Reactor
Gas exit
Air nozzl
modifica
for auton
operation
Screw based ash
extraction system
Ash elevator
Water seal
After modifications


GRATE AREA=0.29m2
AREA BELOW GRATE=0.46m2
VERTICAL GRATE
TAHAFET HOSUR


GRATE AREA=0.554 m2
VERTICAL GRATE
AREA BELOW GRATE=0.53m2
HARIHAR


Air
Nozzles Closed
Nozzles Closed
Ignition Port
Ignition Port
* Flame moves up to the top
if Air nozzles are closed.
*Flame gets stabilised when Air
nozzles are open.



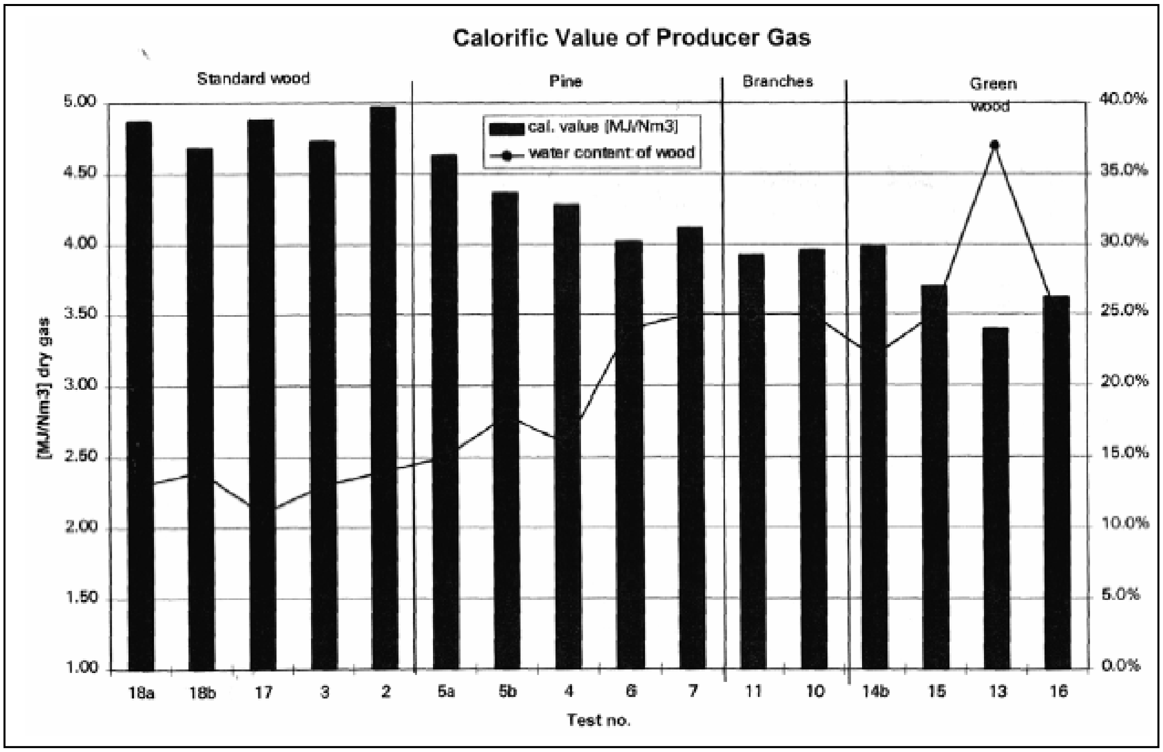
Summary of the results on the tests of the gasifier

10 x 10 hours tests at Bangalore

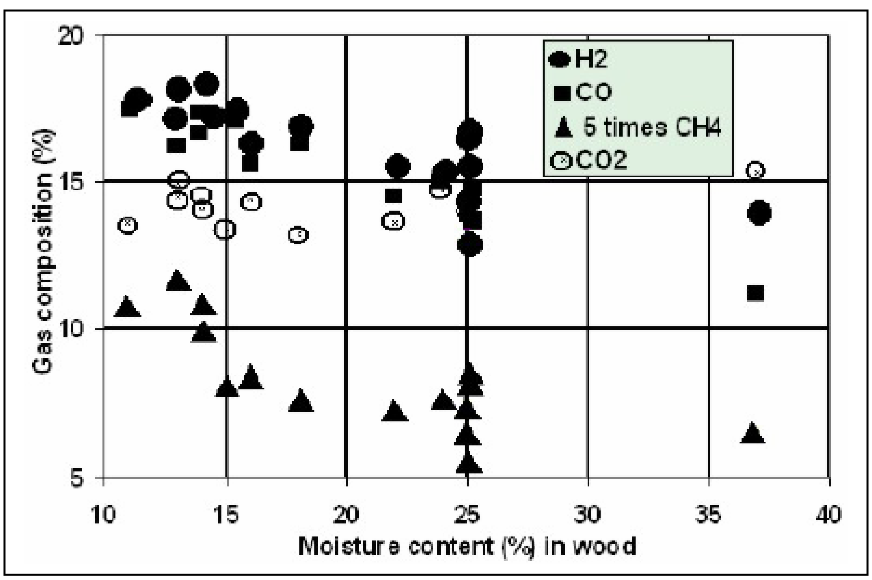
10 x 10 hour tests at Chatel-St-Denis, Switzerland

Biomass, moisture content, size effects

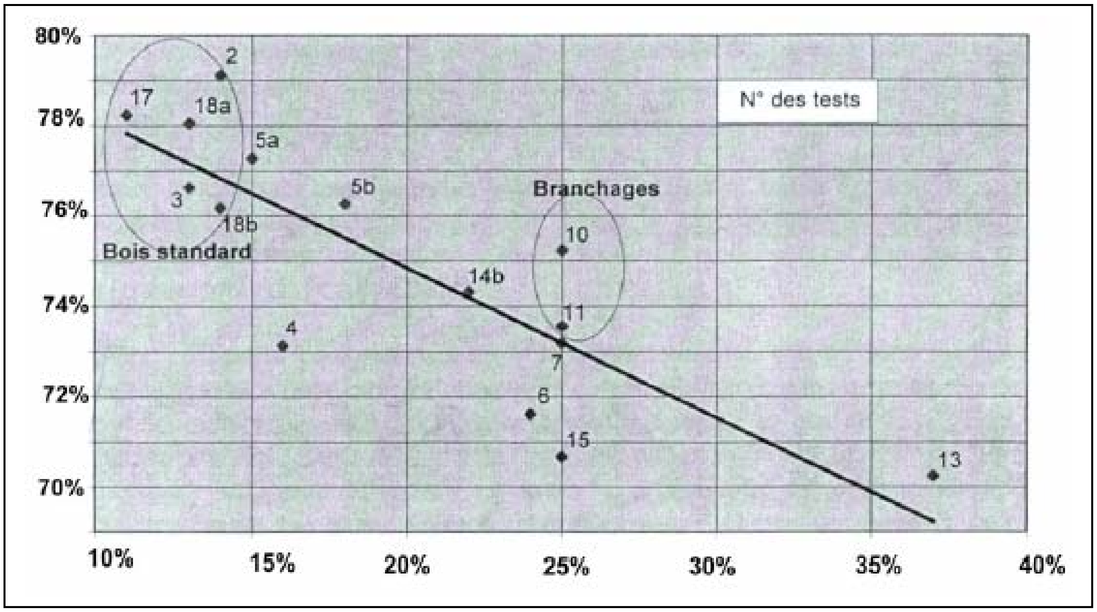
Calorific Value (gas) vs Wood Species



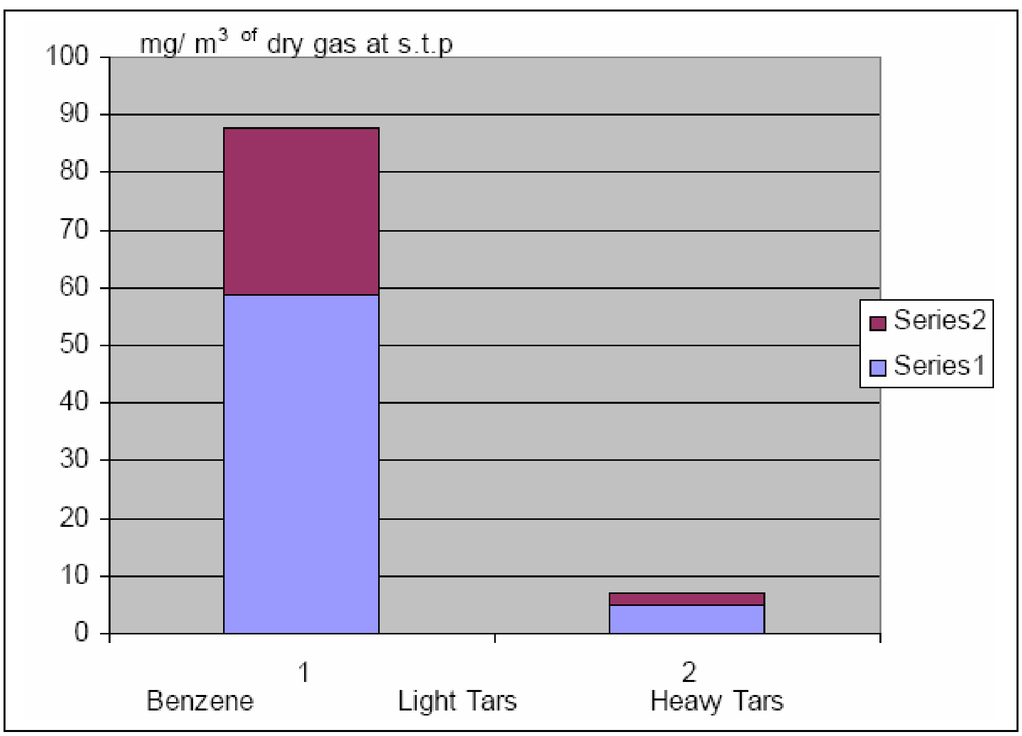
Composition vs Moisture in wood



Gasification Efficiency vs Moisture in Wood



Tar Composition for the ambient pressure Gasifier of IISc design



No$_x$ from Gasifier Based Furnace and Emission Standard

Size	NO, g/MJ	Particulates
Large > 250 X 106 kJ/h	0.09	0.014
Small < 250 X 106 kJ/h	-	0.068
Furnace in lab	0.07	-

Comparison of emissions from gasification based system and various standards for stationary applications

Parameter/Country	USA	EU	Japan	India
CO, g/MJ	3.06	1.4 - 1.8	1.67	1.25
NOx, g/MJ	2.56	2.56	2.6 – 3.06	2.22
HC, g/MJ	0.36	0.36	0.4 – 0.56	0.3
PM, g/MJ	0.15	0.15 – 0.24	-	0.1 – 0.2
20 kWe Gas engine, Ø - 1.1				
Parameter/CR	**17.0**	**14.5**	**13.5**	**11.5**
CO, g/MJ	1.1 – 11.0	11.0 – 15.0	4.0 – 16.0	9.0 – 14.0
NOx, g/MJ	0.03 – 0.28	0.02 – 0.22	0.03 – 0.20	0.05
HC & PM, g/MJ	< 0.01			
200 kVA Gas engine, C.R 12, Ø - 0.9				
CO, g/MJ	0.58 – 1.2			
NOx, g/MJ	0.32 – 0.7			
HC & PM, g/MJ	< 0.01			
20 kWe dual fuel engine				
CO, g/MJ	3.3 ± 0.2			
NOx, g/MJ	0.4			
HC & PM, g/MJ	< 0.01			

Liquid Effluents and their treatment to PCB norms

The actual magnitude of effluents

Item	**P & T**	**COD**	**Phenol**	**DOC**	**NH_3/NH_4 +**
g/kg (mf) wood	1.45	1.9	0.077	2.32	1.72

No	Substance / characteristics	Spec. mg/l (max)	Amount in the effluent before treatment (mg/l)	Amount after treatment (mg/l)
1.	Total dissolved solids (TDS)	2100	**729±3**	**798±8***
2	BOD – 3 days at 270 C	**30**	**51±1**	**17±1**
3	Free ammonia	5	**229±2**	**109±2**
4	Sulphides as S	2.0	**4.56±0.14**	**0.82±0.04**
5	Cyanides as CN	**0.2**	**0.68±0.02**	**NIL**
6	Dissolved Phosphates (PO_4)	**5.0**	**5.6±0.05**	**1.81±0.03**
7	Phenols as C_6H_5OH	**1.0**	**3.41±0.09**	**0.40±0.02**

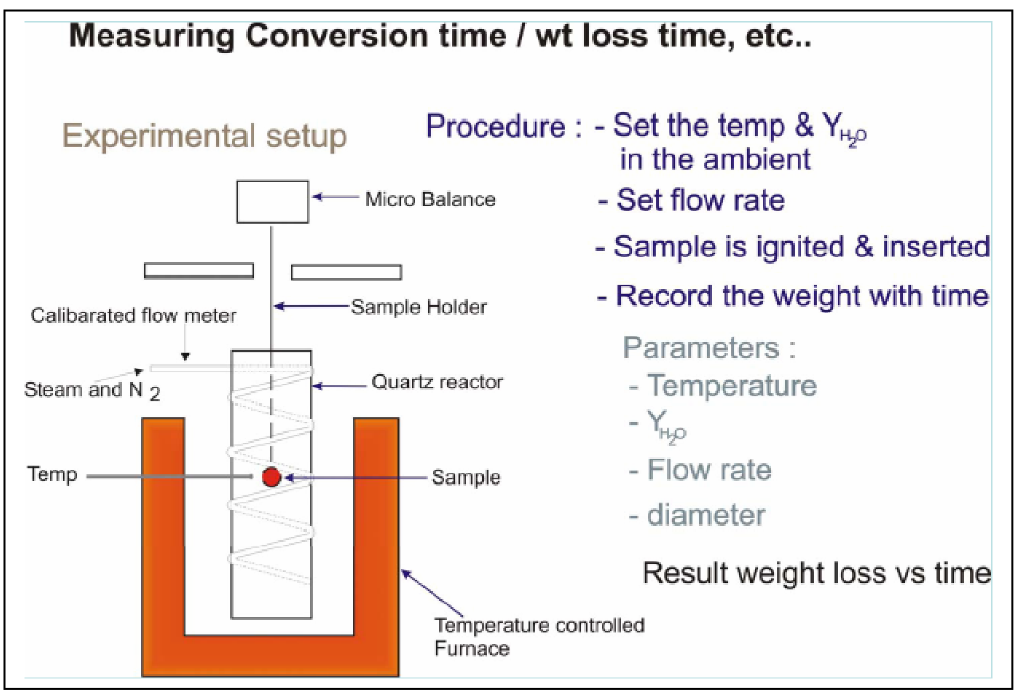
* Note that the TDS has increased after treatment because of the addition of the coagulants. The sample after treatment meets the pollution control norms.

Basic Studies on Biomass Char conversion

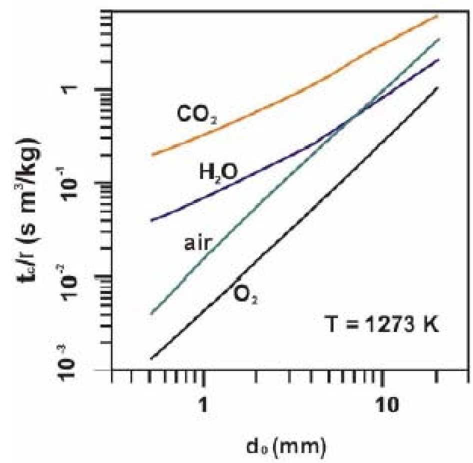
Single particle combustion and inferences for gasification

a. A series of studies were initiated (1984 to 1998) on Biomass sphere flaming combustion
b. Biomass char glowing combustion in O_2 – N_2 environment
c. Char sphere conversion with mixtures of CO_2, H_2O, O_2 and N_2.

Aim: Spherical geometry is clean; mathematics will be simpler.



Comparison of Conversion time with diameter



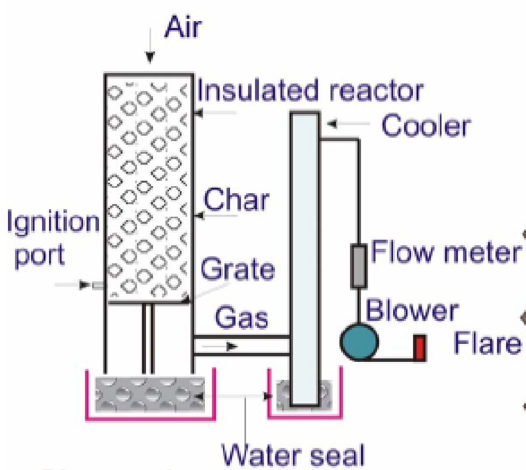
Reactants : (a) CO_2 (b) H_2O (c) air (d) O_2

$t_b \sim d_0^{1.03}$	CO_2	Kinetic and diffusion dependence
$t_b \sim d_0^{1.2-1.3}$	H_2O	Kinetic and diffusion dependence
$t_b \sim d_0^{1.9}$	air	diffusion limited
$t_b \sim d_0^{2}$	O_2	diffusion limited

Conversion time for char reaction with

1. **CO_2 is 3-4 times that of H_2O**
2. **H_2O is comparable to air at d_p > 8 mm**

Experimental setup for the packed bed



One-fortieth scale version of wood gasifier of 275 kWth

Procedure

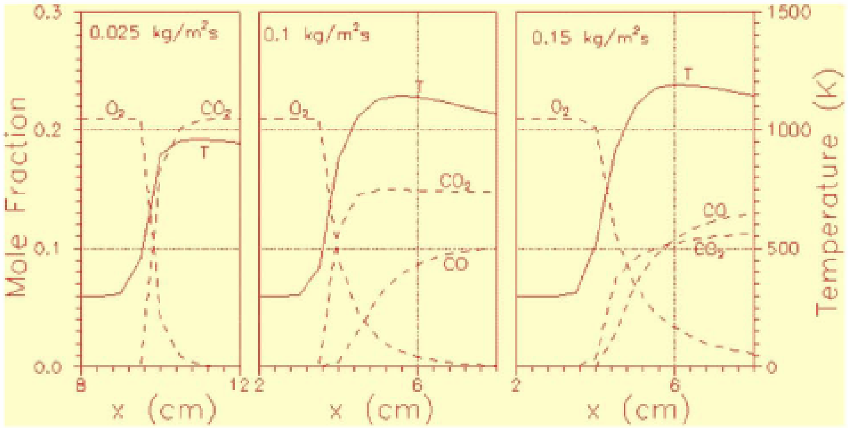
- Charcoal pieces of approximately 8 mm dia was used
- Initial light-up through ignition port and close it later
- At a fixed flow rate, flame front movement upwards was measured

Observation

- Glowing zone was approximately 25 - 30 mm (3-4 particle depth)
- Peak bed temperature measured in the range of 1000 - 1200 K depending upon the mass flux

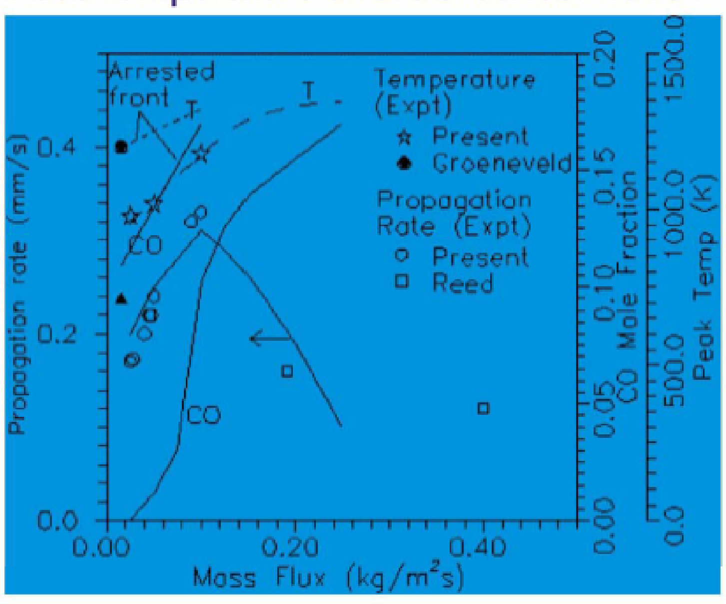
Temperature and reactant profile in the bed near the reaction zone for different air mass flux

- Profile chosen when the rate of propagation of the reaction front through the bed is constant



- Peak temperature increases as the air mass flux increases
- Thickness of the propagation front increases with air flux; consistent with the qualitative observation during the present experiments and earlier references[5]
- At low air flux CO concentration is low and increases with air flux

Propagation rate vs mass flux in a packed bed char reactor with peak bed temperature and CO concentration



- With increase in mass flux the front velocity initially increases and then reduces
- With increase in mass flux the CO concentration in the exit gas increases

A Question:

- Chinese gasifiers –With as received rice husk in an open top cylindrical reactor without the intermediate air-nozzles have been famous – in Thailand and India. At least two Indian manufacturers are using these concepts.
- The char at the bottom is taken out by a rotating screw in a water seal. Discharge occurs in a manner that may violate pollution control norms.
- Experiments at IISc and field assessment indicate to inconsistent performance over long durations – implying changing gas quality.
- Briquetted rice husk works without these problems.

- Why?

To answer this question, specially designed Experiments were made

a. Rice husk
b. Sawdust with 20 % Silica (to simulate the inert fraction)
c. Pulverized rice husk
d. Sawdust
e. Briquettes of Sawdust and Rice husk.

Rice Husk

Sample being ignited

Sample with the Flame

Ultimate Product

Percentage Residue=31.3

Sawdust with 20% Silica

Sample being ignited

Sample with the Flame

Ultimate Product Formed

Percentage Residue= 18.3

Pulverized Rice Husk

Sample being Ignited

Sample with the Flame

Ultimate Product Formed

Percentage Residue= 31.3

Saw Dust

Sample being Ignited

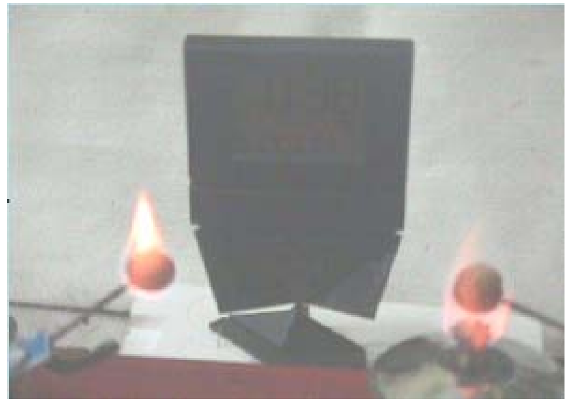
Sample with the Flame

Ultimate Product Formed

Percentage Residue= 6.9

Wood sphere catching the flame and briquette sphere being ignited

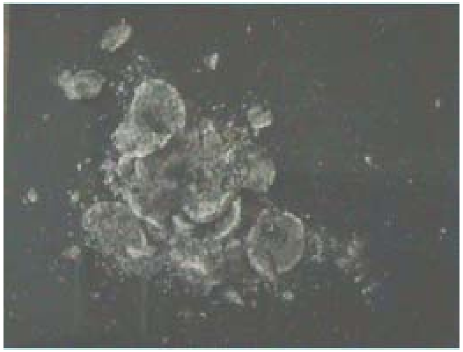
Percentage Residue =1.7



Wood sphere burning and the briquette starting to burn.

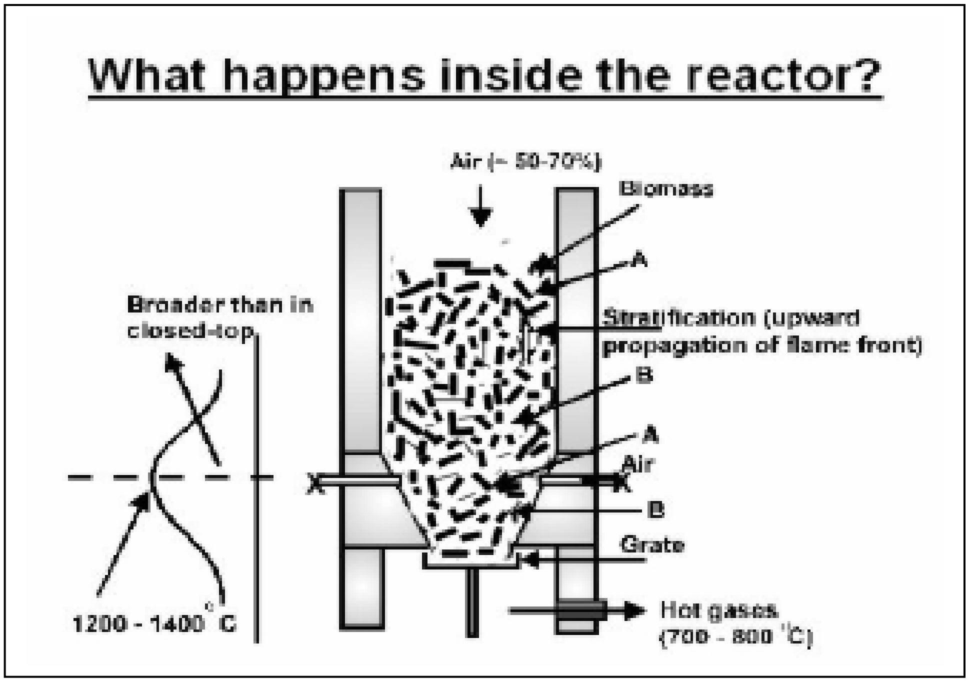
Percentage Residue = 21.0

Glowing wood sphere and the flame dying away in case of briquette.

Ash formed from wood sphere	Ash formed from Rice husk briquette Sphere
	
Percentage Residue= 1.69 Process Time: Ignition = 36 s Flame = 108 s Glow = 604 s	Percentage Residue= 21.0 Process Time: Ignition = 68 s Flame = 195 s Glow = 1332 s

Relevance to Rice Husk gasifiers

- The conversion of rice husk char is slower than of wood char.
- It occurs only at very slow heating rates and T < 800 0C.
- Rice husk char is structurally more complex than wood char. It has 40 to 50 % inert. The Silica (~95 % inert – ash) is molecularly interspersed with carbon making carbon more inaccessible to conversion by O2 and for sure, CO2 and H_2O as these are less reactive with endothermicity.
- One can therefore expect that rice husk gasifiers using as-received rice husk to work virtually as pyrolisers with limited cracking at high temperatures.
- One can therefore expect more tarry gas.



- *Fluid mechanical effects tunneling of air through the bed of rice husk.*
- *This leads to varying quality of the gas over the operating period.*

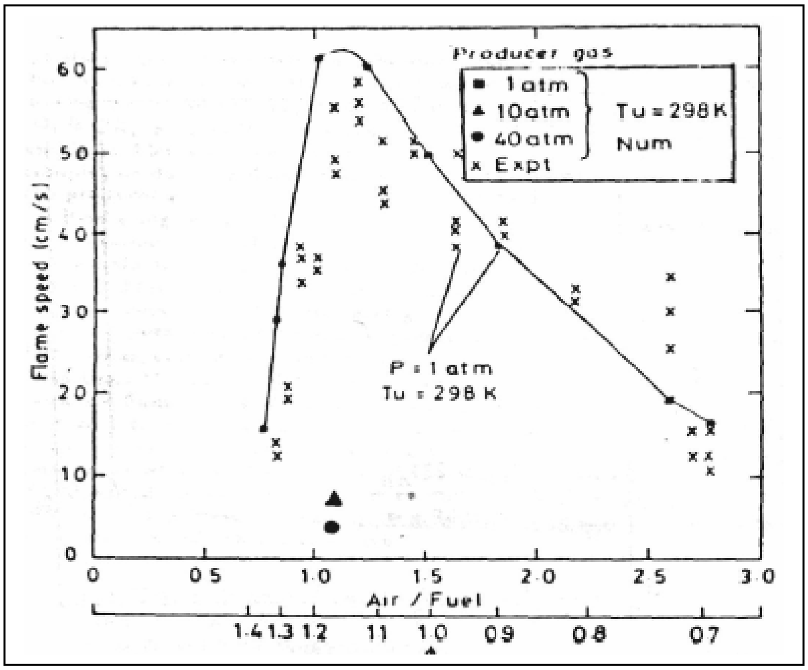
Use of briquettes whose mechanical Integrity is good leads to uniform flow of air and gases through the porous bed.

Conversion can be expected to be higher inferred from single particle studies.

Performance of the reactor will be more robust and reliable.

Producer gas Combustion features for Engine applications

Flame speed vs air-to-fuel ratio

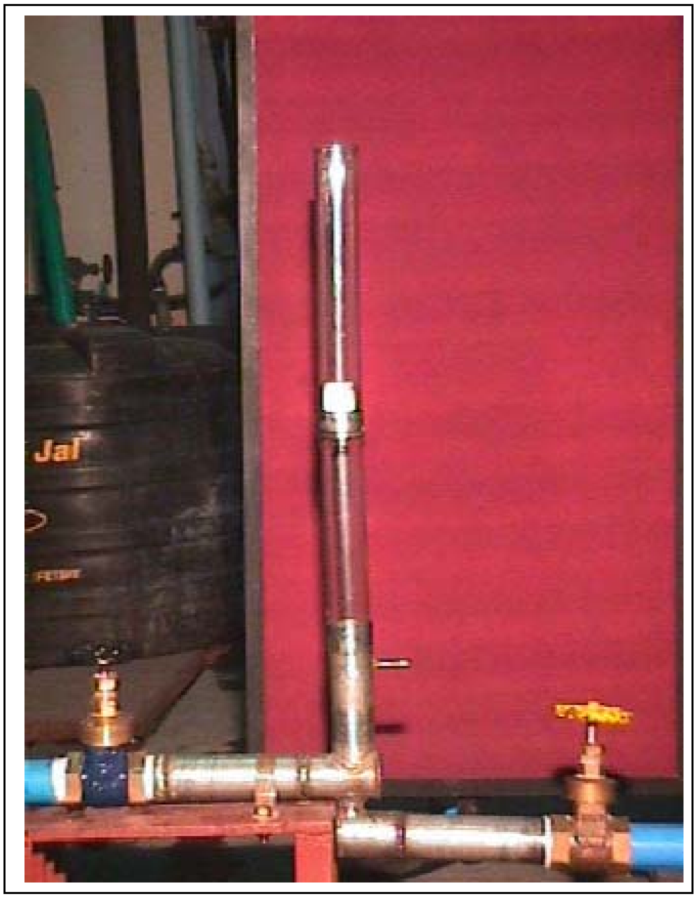


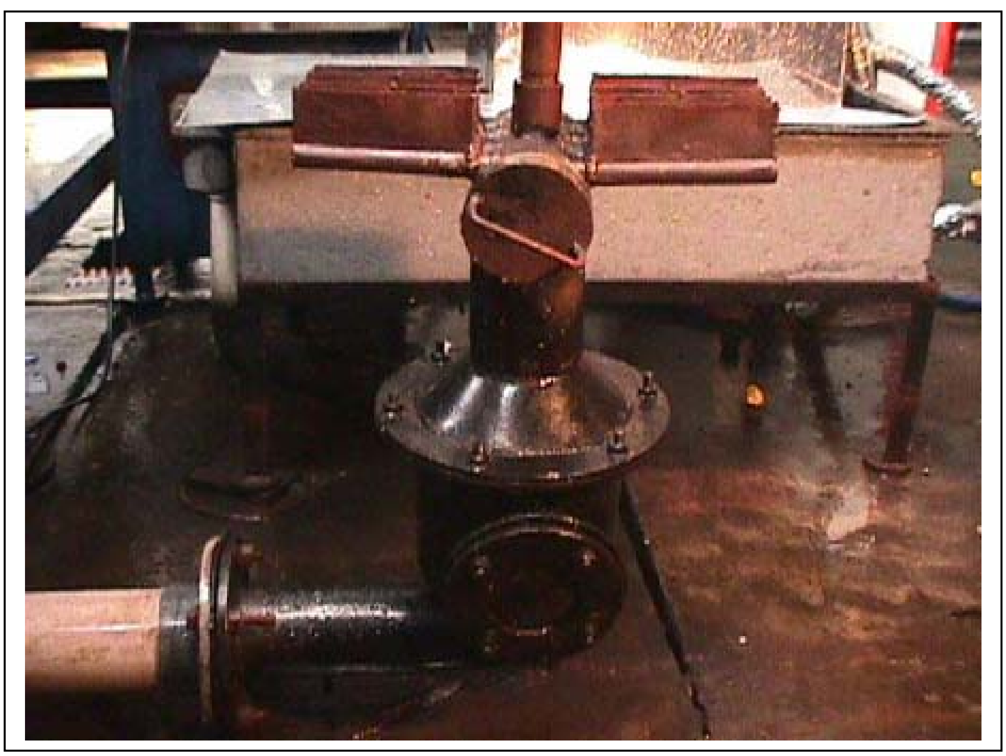
Peak Flame speed ~ 0.6 m/s

A/F at peak flame speed ~ 1.3

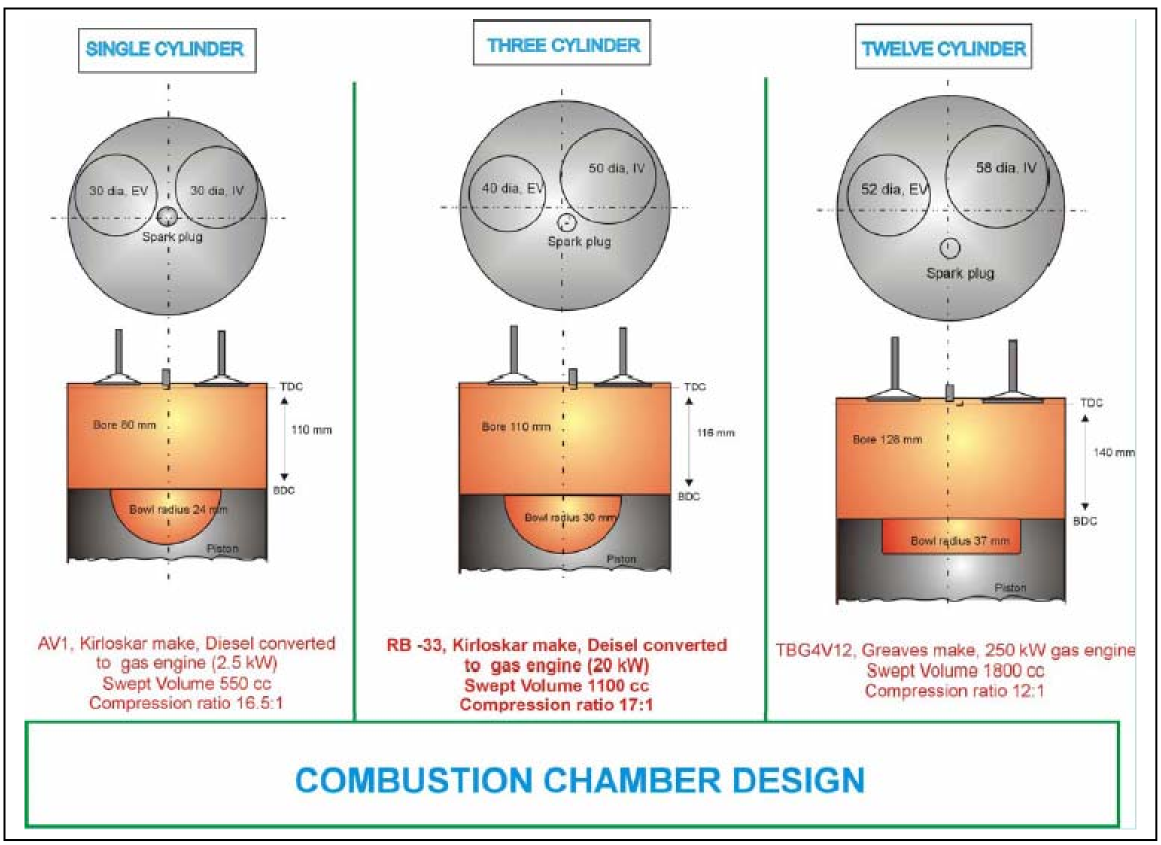
Rich Limit for A/F ~ 0.7

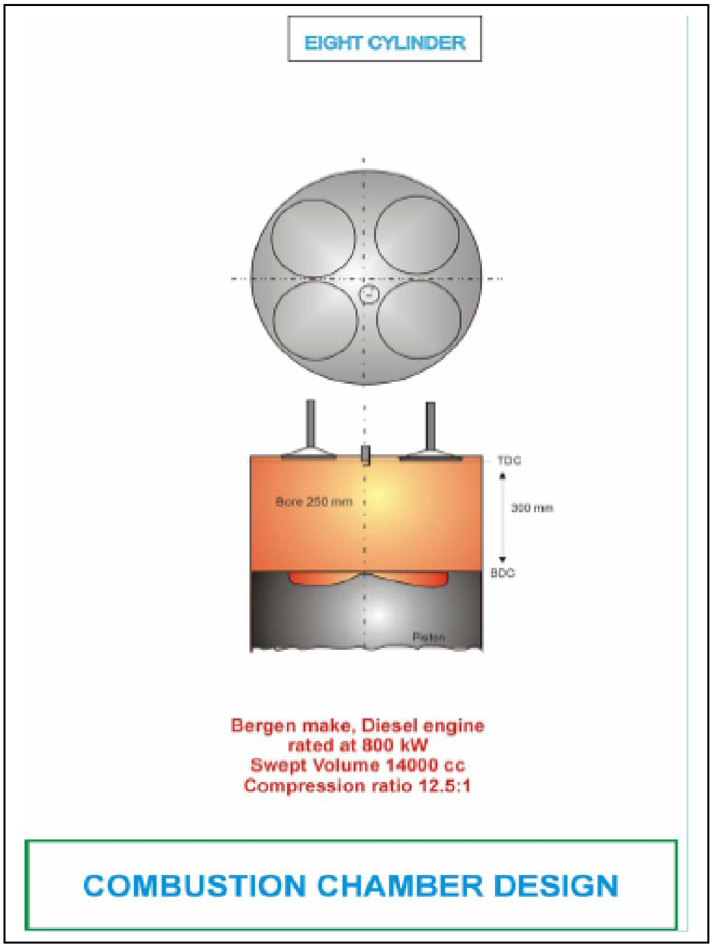
Lean Limit for A/F ~ 2.8

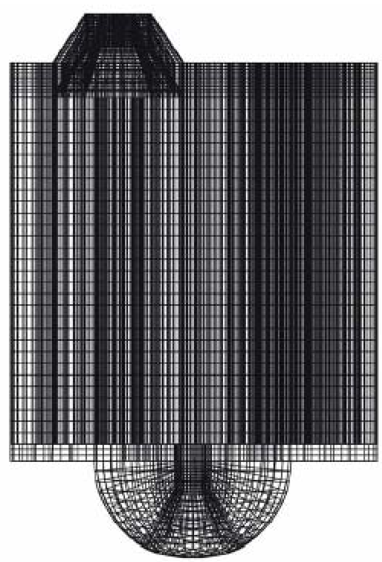

Jal



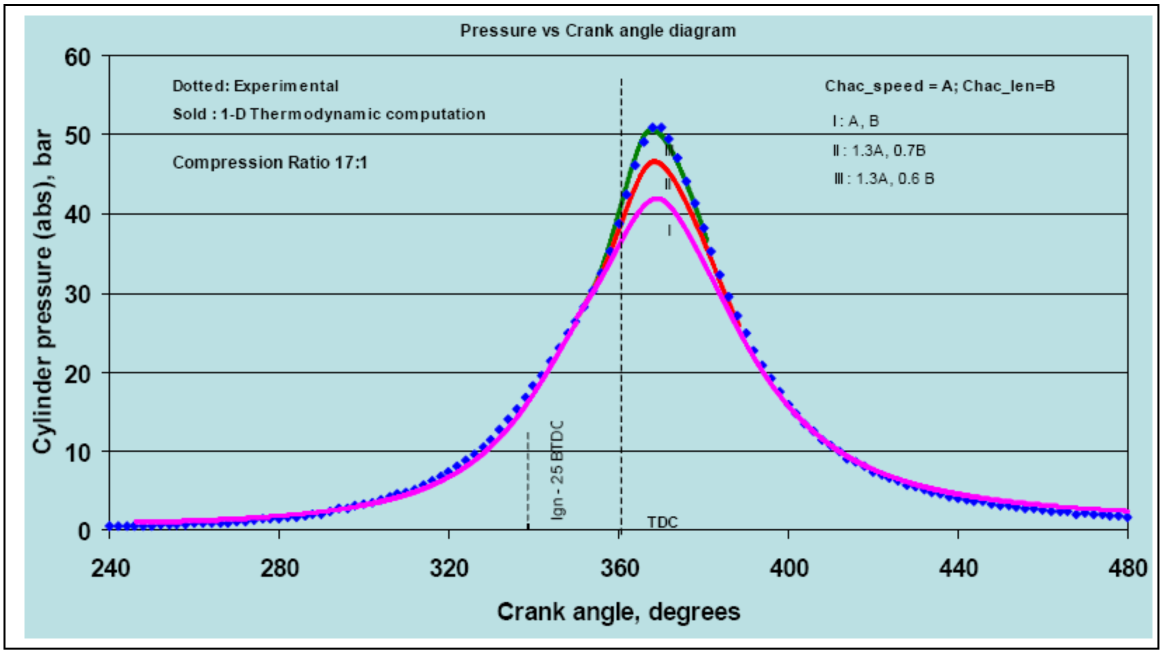
Modeling of combustion in reciprocating engines







Computational grid arrangement of engine combustion chamber, 100150 cells



Some Gasifier installations using the new technology

Examples of Installations where follow up on performance is done and data are available

- *Research and development*
- *Village electrification*
- *Thermal systems*
- *Industrial electrical systems*

The 1 kg/hr working gasifier model

A 3.7 kWe Gasifier, test setup at the laboratory

A 20 kWe Gasifier in service of lighting, drinking water, grinding grains & irrigation water at Hosahalli Karnataka.

The 20KWe Gasifier in service at Hanumanthanagar , in Karnataka

Sutra 2000

50 kg/hr gasifier at Bethmangala, Kolar

The 100 kg/hr Gasifier under test before shipment to Chatel-St-Denis, Switzerland

The 100 kg/hr Gasifier at Switzerland

A 100 kWe Gasifier in service of electricity needs of a Paper Industry at JHANSI

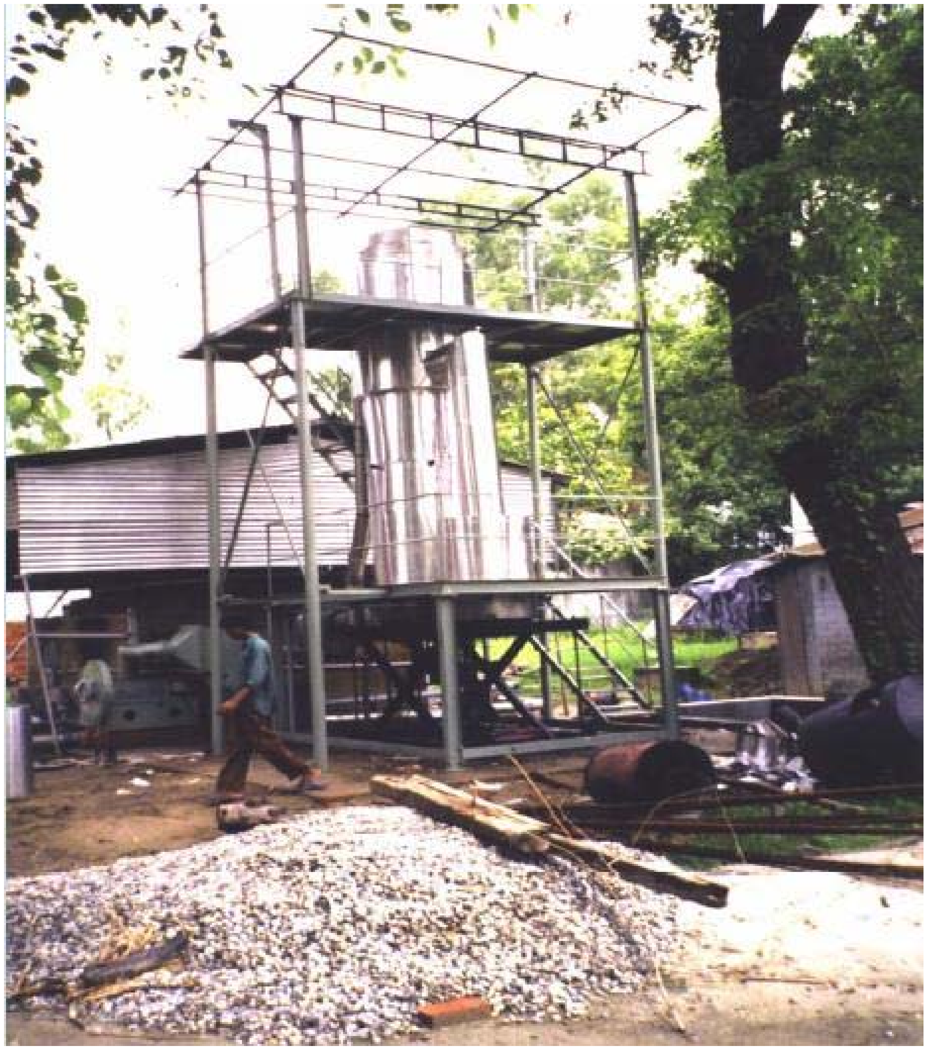
The 450 kg/hr system at Synthite, Karamadai, Coimbatore

Fine chemical extraction from flowers - Marigold + others.
Drying flowers; automated ash-screw extraction system

200 kg/hr Agro bio chem (India) pvt. Ltd. Harihar

Purpose: Marigold drying; Manual operational system

A 200 kg/h Gasifier for Brick making under test at CBRI, Roorkee



A 50 kg/h Gasifier for supply of electricity to a village in a Island (1200 km south of Santiago Chile)

M/s SenapathyWhiteley Pvt Ltd, Ramanagaram, Bangalore Rural district.

Technical Details of performance

Thermal Applications

Location	Capacity	Running from When?	Purpose / Service	Operation Hours	Biomass	Comment
Agrobiochem, Harihar	200 kg/h	1998	Diluted hot gases at 100-1058 C for drying marigold leaves	10,000	Juliflora prosopis	Operational
Synthite chemicals, Coimbatore	450 kg/h	2000	Diluted hot gases at 100-150 C for drying marigold leaves	7500	Briquettes of marigold waste / coconut shells	Operational
Agrobiochem, Harihar	450 kg/h	2001	Diluted hot gases at 100-105 C for drying marigold leaves	3800	Prosopis Juliflora	Operational
Tahafet, Hosur	250 kg/h	2001	Heat treatment furnaces (7 nos) for temperature in the range of 600 to 900 C	6700	Coconut shells	Operational

Village Electrification

Location	Capacity	Running from When?	Purpose / Service	Operation Hours	Biomass	Comment
Hosahalli, Karnataka, India	25 kVA – DG set with 50 kg/h gasifier	1987 – with 5 kW system 1998 – 25 kW system	Lighting, Drinking water, Grinding machine, Irrigation water	1200-1500 per year with irrigation 4000 hours	Pieces from a different species of forest residues	Operational
Hanumanthan agara, Karnataka, India	25 kVA – DG set with 25 kg/h gasifier	1994+	Lighting, Drinking water, Grinding machine, Irrigation water	1200-1500 hrs every year	Pieces from a different species of forest residues	Operational
Butascheques, an Island in Chile	2x25 kVA DG set + 50 kg/h gasifier	1999	Lighting	2120 hours as of Feb 2000	Forest residues	Operational

Water pumping applications in farming

Location	Capacity	Running from When?	Purpose / Service	Operation Hours	Biomass	Comment
Bethamangala, Kolar District	25 kVA DG set 20 kVA GG set + 50 kg/h gasifier	2000	Electricity for pumping water from bore wells distributed over the farm land	2500	Wood chips	Operational
Farm house, Channarayapatna, Karnataka	20 kWe D.G. + 14 kWe gas engine with a 50 kg/h gasifier	1999	Irrigation	750	Wood chips	Operational for irrigation water

Industrial Applications

Location	Capacity	Running from When?	Purpose / Service	Operation Hours	Biomass
Orchha, Madhya Pradesh	2x65 kVA DG with 100 kg/hr gasifier	1997	Electricity for running a paper industry	15, 000	Ipomia weed
Senapathy Whiteley Pvt. Ltd., Ramangararam, Karnataka	2x275 kVA DG sets with 500 kg/h gasifier	1999	Electricity for varying load in the industrial operation	~ 2000 hours	Mulberry stalk + coconut shell
Arashi HiTech Biopower, Coimbatore	1 MWe LDO engine-alt + 850 kg/hr gasifier	2002	Grid electric supply + activated carbon	1300 hours	Coconut shell

Research and Educational purpose

Location	Capacity	Running from When?	Purpose / Service	Biomass
Chatel-St.-Denis, Switzerland	80 kg/h	1997	Incremental R & D, demonstration, power generation	A variety of gasifier including forest residue
Navodaya Vidyalaya, Tumkur District, Karnataka	120 kWe DG set with 100 kg/h gasifier	1997	Lighting	Woody/agro residues
IRTC Pallakkad	3.7 kWe	1999	Electrical system for demonstration	Wood
IIT, Delhi	10 kWe	1999	Electrical system for R&D	Solid bio-residue
CBRI, Roorkee	200 kg/h	1999	Brick curing at 950-1000 C	Cotton stock, wood chips
SuTRA	25 kg/h	2000	Special system, Mobile gas generator	Forest residue / mixed biomass
Chatel-St.-Denis, Switzerland	1 kg/h	2000	R & D and demonstration,	A variety of gasifier including forest residue

We have looked at….

- The Gasification Technology
- Basic studies in Char conversion
- Producer gas as a fuel and engine combustion processes
- Some systems in the field and their performance

Now the final question..

What is to be done for us to become World leaders in Biomass Gasification technologies?

….World leader?

- Create a rigorous and strong scientific base.- if possible, more than one institution.
- Do not favor politeness to avoid scientific controversy – this is particularly an issue in India, more particularly in non-conventional fields.
- In respect of technology, create database of successful systems over at least a five year period.
- Document problems as well, clearly with efforts made to overcome them without sounding as though we are overwhelmed by the problems.
- Argue for government partnership and support particularly in documentation as it hastens acceptability by other countries.
- Aggressively market the systems, then.