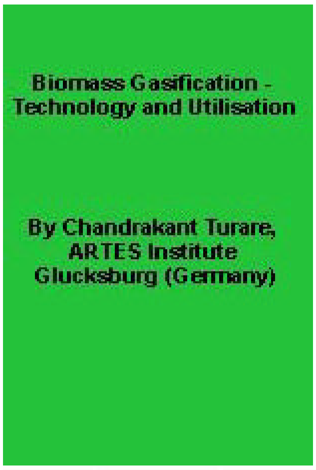
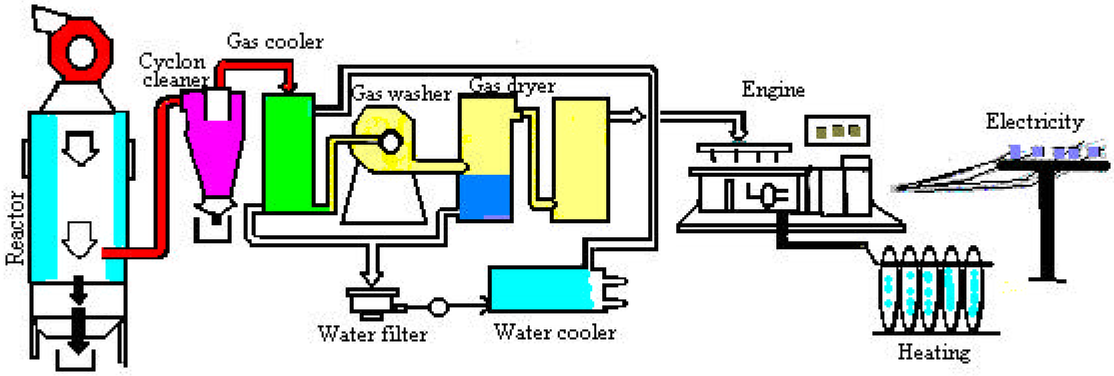


Biomass Gasification - Technology and Utilisation

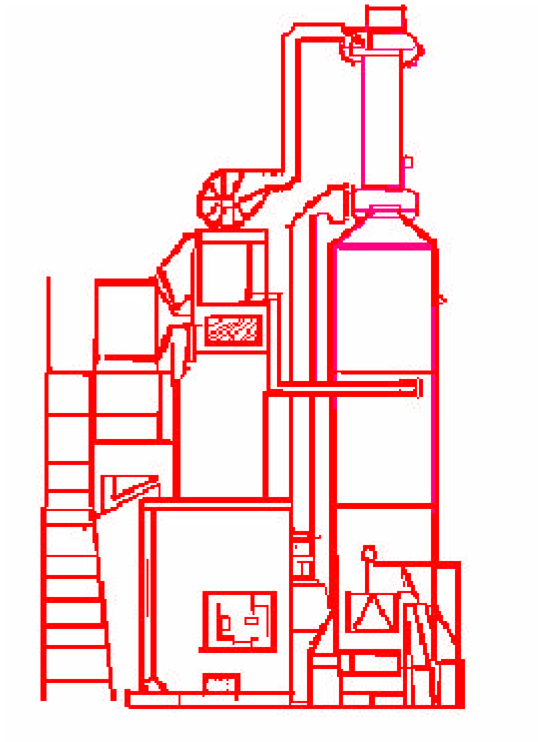
Biomass Gasification - Technology and Utilisation

By Chandrakant Turare, ARTES Institute, Glucksburg (Germany)



Image

Biomass gasification, a century old technology, is viewed today as an alternative to conventional fuel. In gasification process, wood, charcoal and other biomass materials are gasified to generate so called ´producer gas´ for power or electricity generation. Gasification system basically consists of a gasifier unit, purification system and energy converters - burner or engine. This internet documentation gives total insight into gasification technology.



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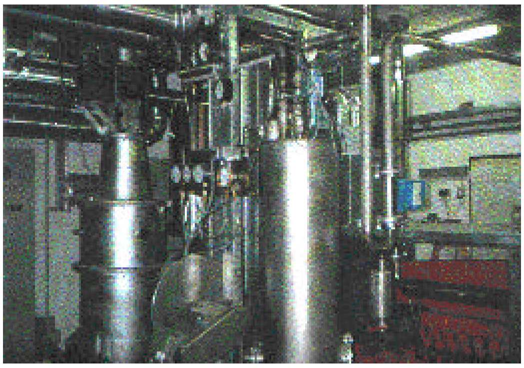
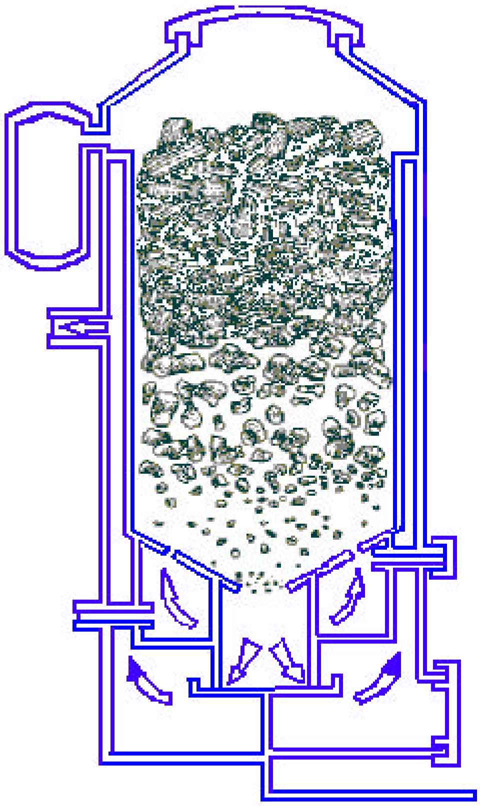
Overview of Gasification Technology



Wood gasifier for co-gen set

Image

Gasification is a century old technology, which flourished quite well before and during the second world war. The technology disappeared soon after the second world war, when liquid fuel became easily available. The interests in the gasification technology has undergone many ups and downs in running century. Today, because of increased fuel prices and environmental concern, there is renewed interest in this century old technology. Gasification has become more modern and quite sophisticated technology.



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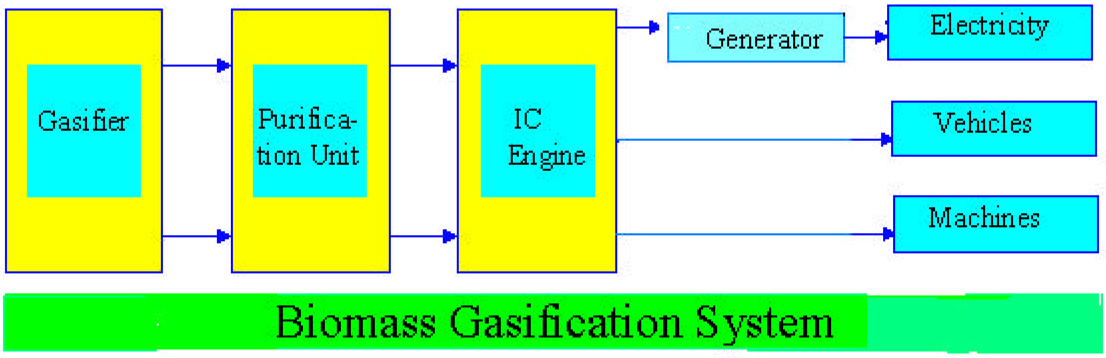
The advantage of this technology is decentralized energy conversion system which operates economically even for small scale .A gas producer is a simple device consisting of usually cylindrical container with space for fuel, air inlet, gas exit and grate. It can be made of fire bricks, steel or concrete and oil barrels. The design of gasifier depends upon type of fuel used and whether gasifier is portable or stationary. Gasifier alone itself is of little use. The complete gasification system consists of gasification unit (gasifier), purification unit and energy converter - burners or internal combustion engine.



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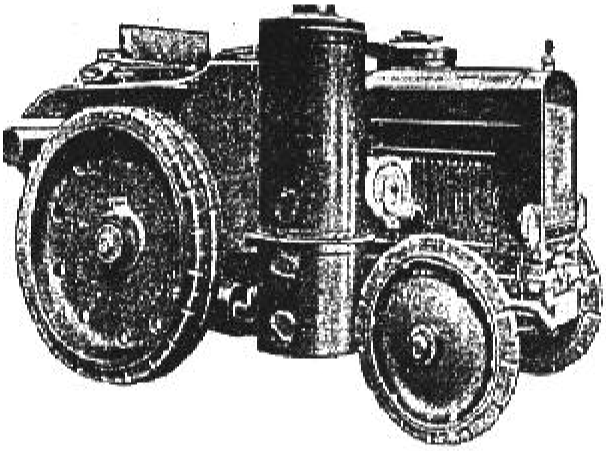
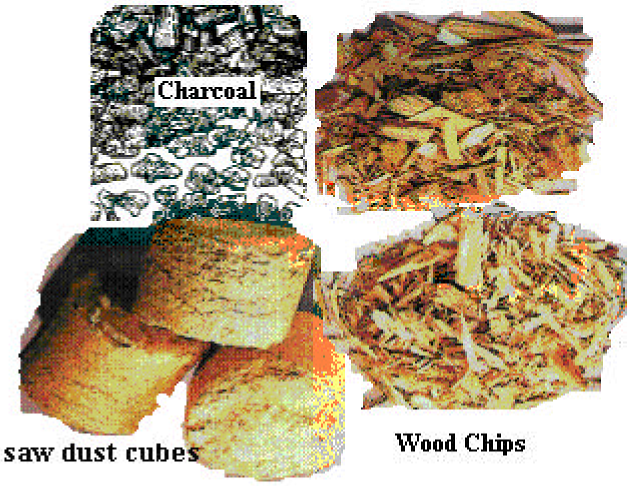
Gasification is basically a thermochemical process which converts biomass materials into gasesous component. The results of gasification is the producer gas, containing carbon monoxide, hydrogen, methane and some other inert gases. Mixed with air, the producer gas can be used in gasoline or diesel engine with little modifications.



Based on the design of gasifiers and type of fuels used, there exists different kinds of gasifiers. Portable gasifiers are mostly used for running vehicles. Stationary gasifiers combined with engines are widely used in rural areas of developing countries for many purpose including generation of electricity and running irrigation pumps. Technologies such biomass gasification which allow utilization of biomass fuel are of great importance.

Image

Theoretically, almost all kinds of biomass with moisture content of 5-30% can be gasified, however, not every biomass fuel can lead to the successful gasification. Most of the development work is carried out with common fuels such as coal, charcoal and wood. It was recognized that fuel properties such as surface, size, shape as well as moisture content, volatile matter and carbon conent influence gasification.



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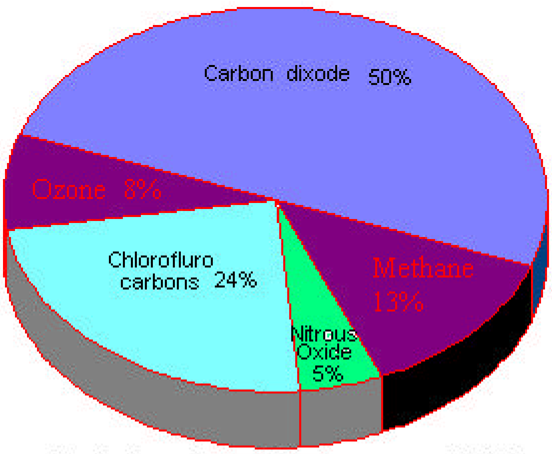
The key to a successful design of gasifier is to understand the properties and thermal behvaiour of the fuel as fed to the gasifier. Operation of gasification system demands knowledgeable and skilled operator. Those interested in this technology must remember that it requires hard work and tolerence. Compared to conventional system such as liquid fuel run engines, biomass gasification technology is incovenient. But it is economical at many places and may lead to self-reliance in the crucial time of fuel crisis.

Biomass as Gasification Fuel



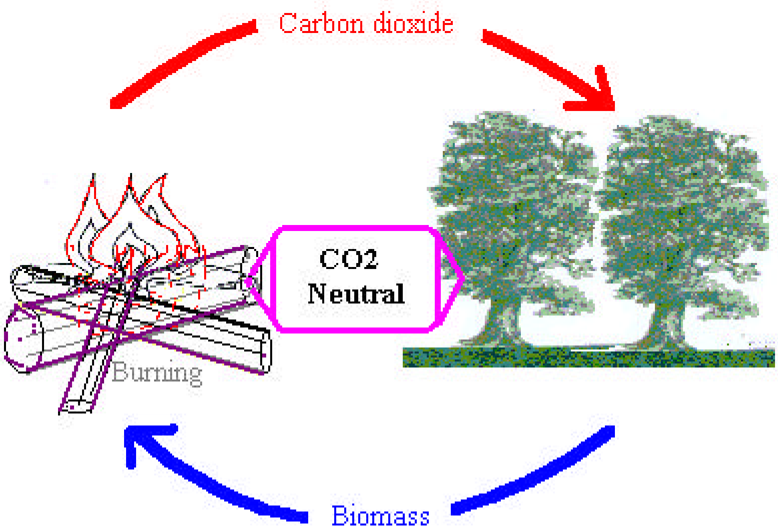
Emission of greenhouse gases (1980)

Image

Great environmental concern is expressed over the release of CO_2 from the burning of fossil fuels. When fossil fuels are burnt, carbon from fuels react with oxygen from air and produce CO_2 . This is the reason for steady increasing CO_2 content of atmosphere. Carbon dioxide contributes to 50% of green house effect.

Image

One of the remedies to limit the rising content of CO_2 in the atmopshere is energetic use of biomass fuel. Biomass is basically an organic material, which includes wood, crop residues, solid waste, animal wastes, sewage, and waste from food processing. Biomass is made up of mainly carbon and hydrogen.



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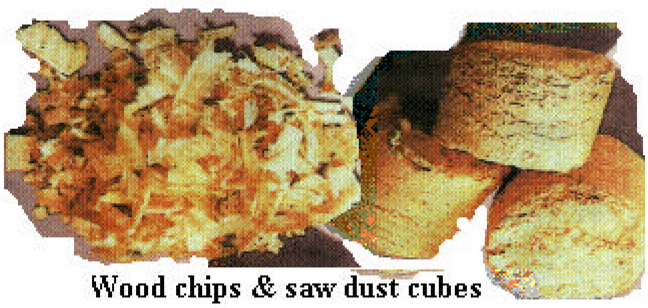
When biomass is burnt, CO_2 is released in the atmosphere. Released CO_2 is absorbed by growing plants during the photosynthesis, keeping CO_2 content in the atmosphere same. Biomass gasification is one of the technologies of energetic use of biomass.



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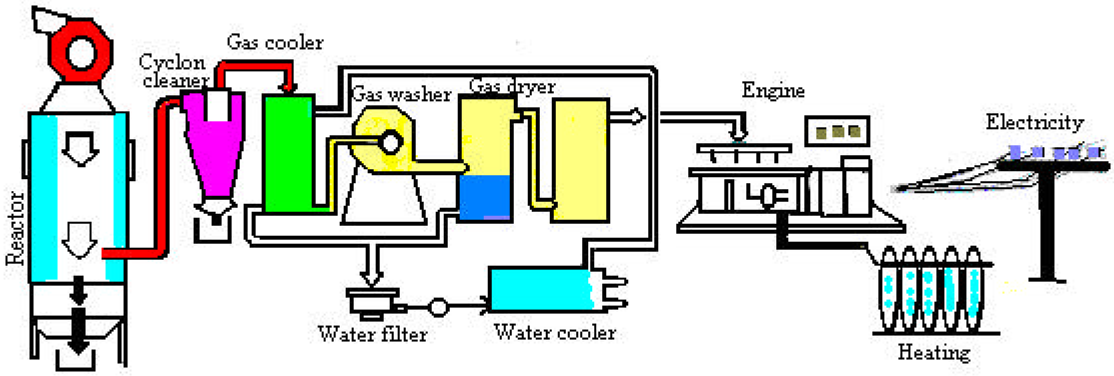
Theoretically, any biomass material with moisture content of 5-30% can be gasified as the basic composition of carbon, hydrogen and oxygen is same. This means that agricultural wastes such as cotton stalks, saw dust, nutshells, coconut husks, rice husks and forestry residues - bark, branches and trunk can be used for gasification.

Gasification for Energy Supply

Rural areas in the developing countries are characterized by disperse population and a lack of infrastructure . Energy is the basic mean in improving the living standard and productivity. Energy is required in household for lighting and running electrical appratus such as TV and Radio. Energy is also demanded in agriculture for operating irrigation pumps and other machinery such as thresher.



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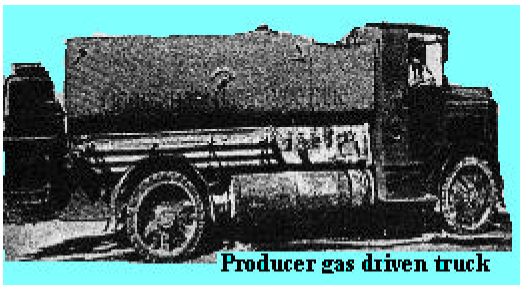
Gasifier-engine system combined with generator provides electrical energy for lighting, and other household purposes. Small scale gasifier system (10-30 kw) would be appropriate for multitudes of village applications in developing countries.



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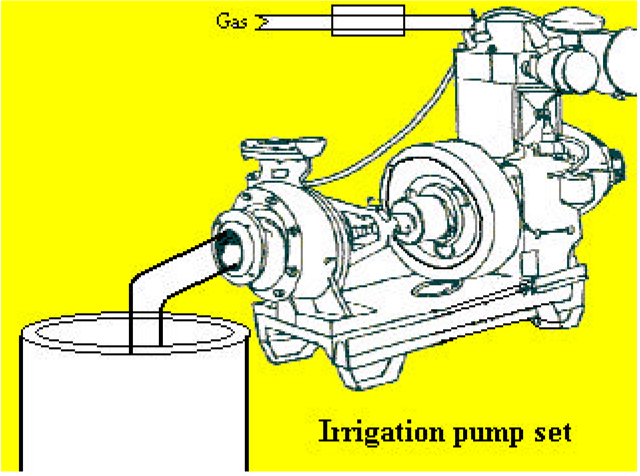
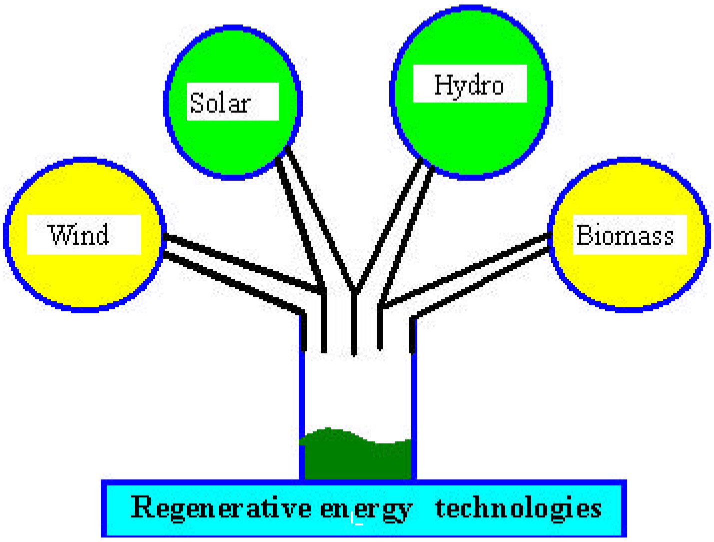
Gasifiers, when integrated with engines, provide mechanical power which can be used for running automobiles and many other stationary machinery. The use of downdraft gasifiers fueled with wood or charcoal to power cars, lorries, buses, trains, boats and ships has already proved it´s worth in the past. Before and during second world war, gasifiers were largely used to power vehicles. Most of the gasoline and diesel driven vehicles during this period were converted to producer gas drive.



Image

Reseach in the past shows that compared to gasifiers fueled with wood or agricultural residues, charcoal gasifiers present less operational problems and are be recommeded for village level applications. Micro scale gasification systems (1-10 kw) can be used by small and medium farmers for providing power to irrigation system. The equipment shall be small, cheap, simple and transportable.



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If firewood is available in sufficient amount without any danger to forest, gasifier can serve as an option for energy supply in remote areas. Because of great concern for conservation of forests and availability of fossil fuels, gasification is not seen as universally applicable technology, but act as a component within range of available regnerative energies. It can be a valuable supplement to wind, solar and hydropower.

Gasification History and Development

The history of gasification dates back to seventeenth century. Since the conception of idea, gasification has passed through several phases of development. Yearwise development of the technology is given below.

1969	Thomas Shirley conducted crude experiments with carborated hydrogen
1699	Dean Clayton obtained coal gas from pyrolitic experiment

1788 Robert Gardner obtained the first patent with regard to gasification

1792 First confirmed use of producer gas reported, Murdoc used the gas generated from coal to light a room in his house. Since then, for many years coal gas was used for cooking and heating

1801 Lampodium proved the possibility of using waste gases escaping from charring of wood

1804 Fourcroy found the water gas by reaction of water with a hot carbon

1812 developed first gas producer which uses oil as fuel

1840 First commercially used gasifier was built in France

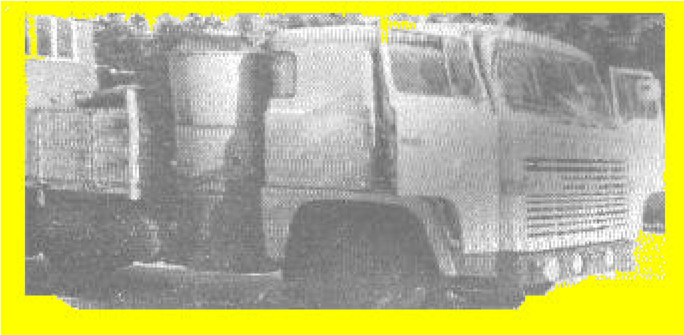
1861 Real breakthrough in technology with introduction of Siemens gasifier. This gasifier is considered to be first successful unit

1878 Gasifiers were successfully used with engines for power generation

1900 First 600 hp gasifier was exhibited in Paris. Thereafter, larger engines upto 5400 hp were put into service

1901 J.W. Parker run a passenger vehicle with producer gas

after 1901



Image

In the period 1901-1920, many gasifier-engine systems were sold and used for power and electricity generation

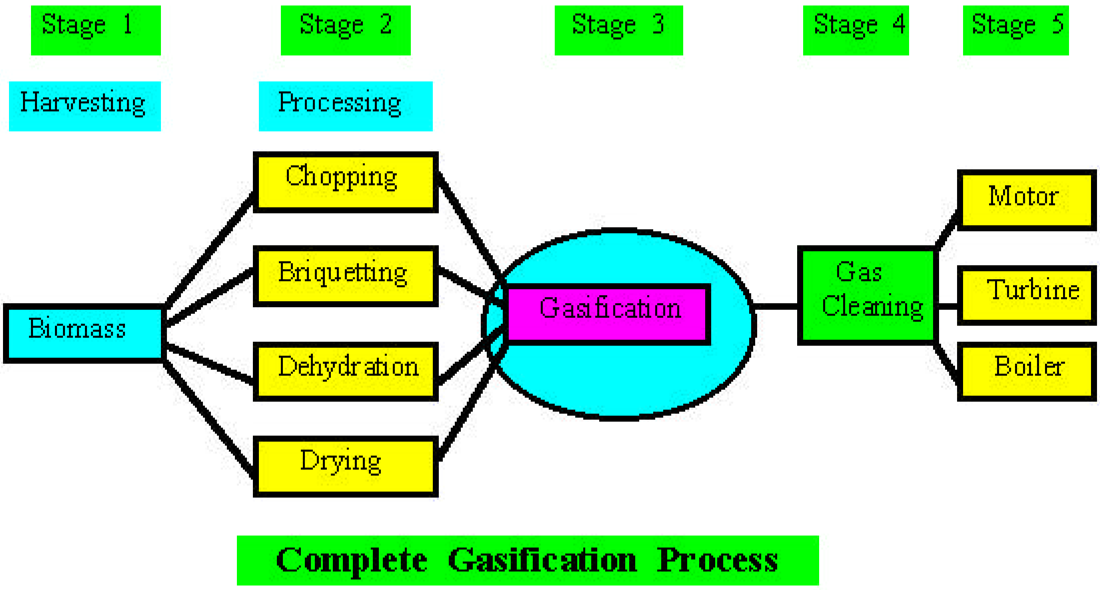
1930

Historical gasifiers in Gemany

Image

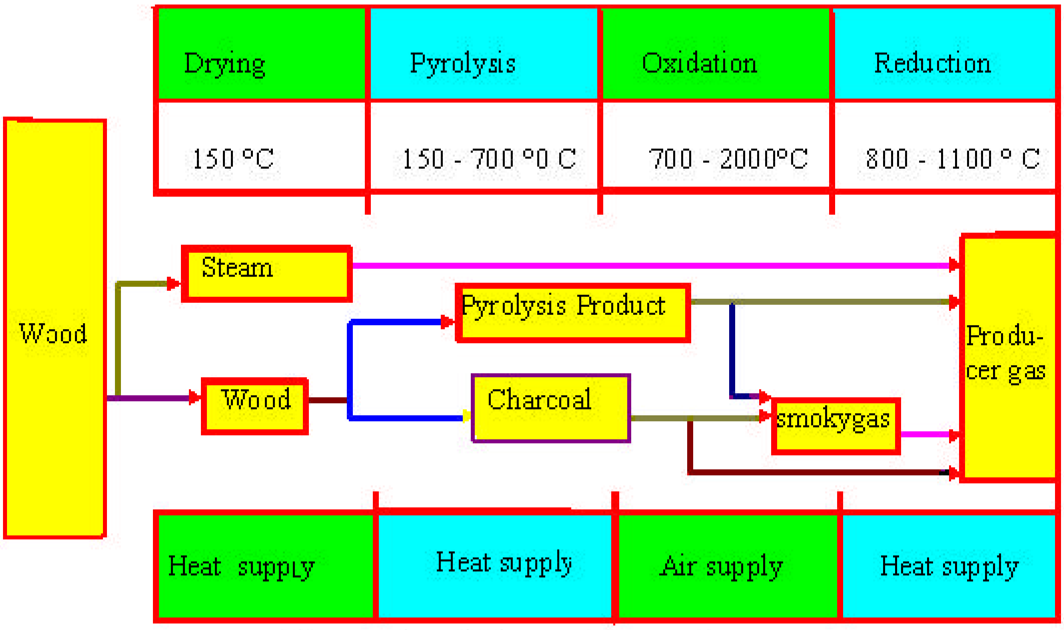
Nazi Germany accelerated effort to convert existing vehicles to producer gas drive as part of plan for national security and independence from imported oil

1030 Began development for small automotive and portable gas producer. British and French Government felt that automotive charcoal gas producer is more suitable for their colonies where supply of gasoline was scarce and wood that could charred to charcoal was readily available

1939	 Image About 2,50,000 vehicles were registered in the Sweden. Out of them, 90 % were converted to producer gas drive. Almost all of the 20,000 tractors were operated on producer gas. 40 % of the fuel used was wood and remainder charcoal
After 1945	After end of second world war, with plentiful gasoline and diesel available at cheap cost, gasificaton technology lost glory and importance
1950-1970	During this decades, gasification was " Forgotten Technology ". Many goverments in europe to felt that consumption of wood at the prevailing rate will reduce the forest, creating several environmental problems
After 1970	The year 1970´s brought a renewed interest in the technology for power generation at small scale. Since then work is also concentrated to use fuels other than wood and charcoal.

Gasification Process

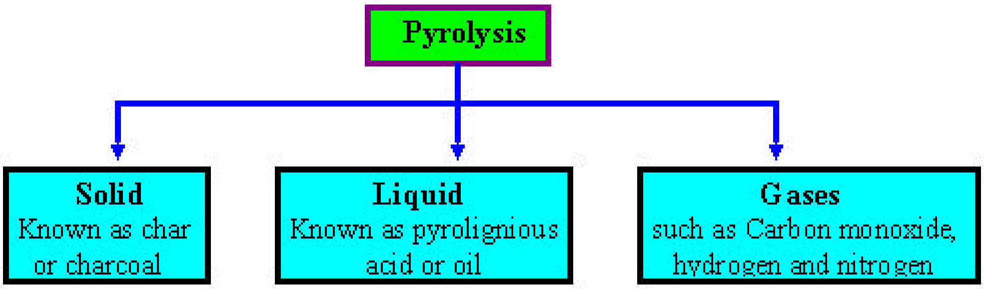
The essence of gasification process is the conversion of solid carbon fuels into carbon monoxide by thermochemical process. The gasification of solid fuel is accomplished in air sealed, closed chamber, under slight suction or pressure relative to ambient pressure. Gasification process occuring in general explained in this section.



Conversion of biomass into producer gas

Image

Gasification is quite complex thermochemical process. Splitting of the gasifier into strictly separate zones is not realistic, but neverthless conceptully essential. Gasification stages occurs at the same time in different parts of gasifier.



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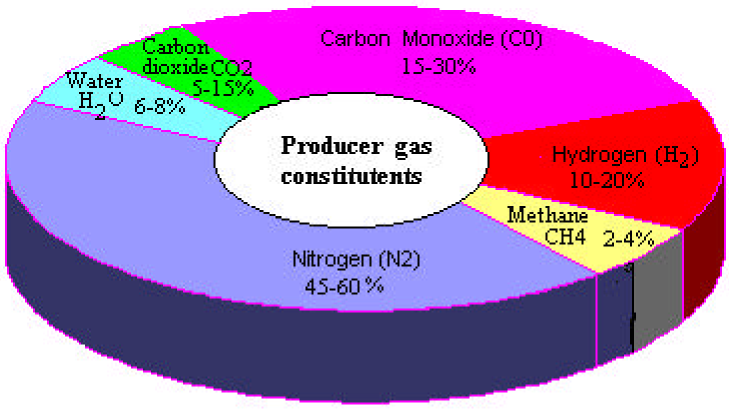
Drying

Biomass fuels consist of moisture ranging from 5 to 35%. At the temperature above 100°C, the water is removed and converted into steam. In the drying , fuels do not experience any kind of decomposition.

Pyrolysis

Pyrolysis is the themal decomposition of biomass fuels in the absence of oxygen. Pyrolysis involves release of three kinds of products : solid, liquid and gases. The ratio of products is influenced by the chemical composition of biomass fuels and the operating conditions. The heating value of gas produced during the pyrolysis process is low (3.5 - 8.9 MJ/m^3).



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It is noted that no matter how gasifier is built, there will always be a low temperature zone, where pyrolysis takes place, generating condensable hydrocarbon.

Oxidation

Introduced air in the oxidation zone contains, besides oxygen and water vapours, inert gases such as nitrogen and argon. These inert gases are considered to be non-reactive with fuel constituents. The oxidation takes place at the temperature of 700-2000^o c.

Heterogenous reaction takes place between oxygen in the air and solid carbonized fuel, producing carbon monoxide. Plus and minus sign indicate the release and supply of heat energy during the process respectively

$C + O_2 = CO_2 + 406$ [MJ/kmol]

In reaction 12.01 kg of carbon is completely combusted with 22.39 m^3 of oxygen supplied by air blast to yield 22.26 m^3 of carbon dioxide and 393.8 MJ of heat.

Hydrogen in fuel reacts with oxygen in the air blast, producing steam .

$H_2 + ½ O_2 = H_2O + 242$ [MJ/kmol]

Reduction

In reduction zone, a number of high temperature chemical reactions take place in the absence of oxygen. The principal reactions that takes place in reduction are mentioned below.

Boudouard reaction

$CO_2 + C = 2CO - 172.6$ [MJ/kmol]

Water-gas reaction

$C + H_2O = CO + H_2 - 131.4$ [MJ/kmol]

Water shift reaction

$CO_2 + H_2 = CO + H_2O + 41.2$ [MJ/kmol]

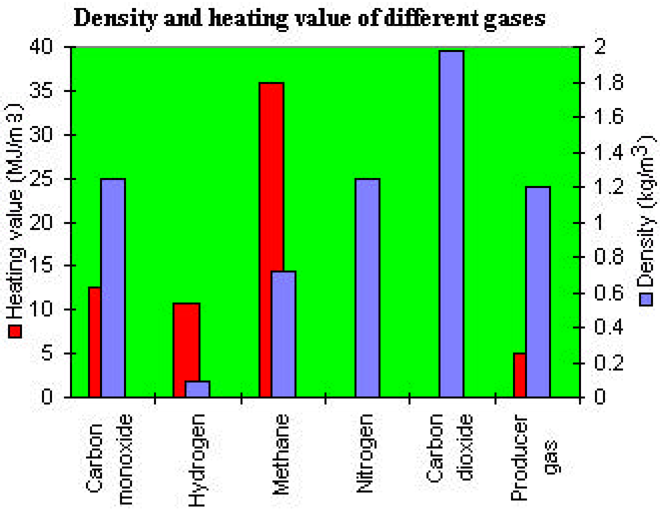
Methane production reaction

$C + 2H_2 = CH_4 + 75$ [MJ/kmol]

Main reactions show that heat is required during the reduction process. Hence, the temperature of gas goes down during this stage. If complete gasification takes place, all the carbon is burned or reduced to carbon monoxide, a combustible gas and some other mineral matter is vaporized. The remains are ash and some char (unburned cabon)

Producer Gas and it´s Constituents

Producer gas is the mixture of combustible and non-combustible gases. The quantity of gases constituents of producer gas depends upon the type of fuel and operating condition.



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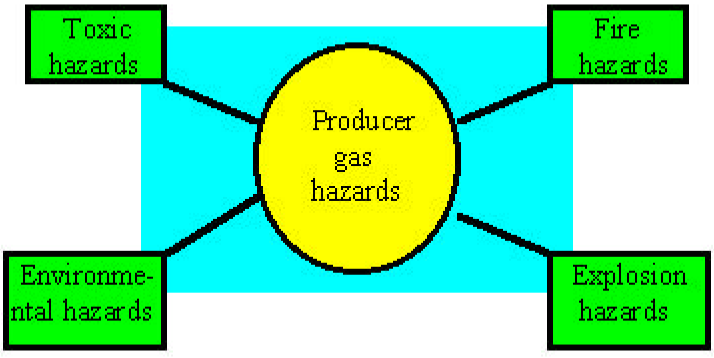
The heating value of producer gas varies from 4.5 to 6 MJ/m ^{3} depending upon the quantity of it´s constituents. Carbon monoxide is produced from the reduction of carbon dioxide and it´s quantity varies from 15 to 30 % by volume basis . Although carbon monoxide possses higher octane number of 106, it´s ignition speed is low. This gas is toxic in nature. Hence, human operator need to be careful while handling the gas .



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Hydrogen is also a product of reduction process in the gasifier. Hydrogen posseses the octane number of 60-66 and it increases the ignition ability of producer gas. Methane and hydrogen are responsible for higher heating value of producer gas. Amount of methane present in producer gas is very less (upto 4 %). Carbon dioxide and nitrogen are non-combustible gases present in the producer gas. Compared to other gas constituents, producer gas contains highest amount (45-60 %)of nitrogen. The amount of carbon dioxide varies from 5 to 15 %. Higher percentage of carbon dioxide indicates incomplete reduction . Water vapours in the proudcer gas occurs due to moisture content of air introduced during oxidation process, injection of steam in gasifier or moisture content of biomass fuels.

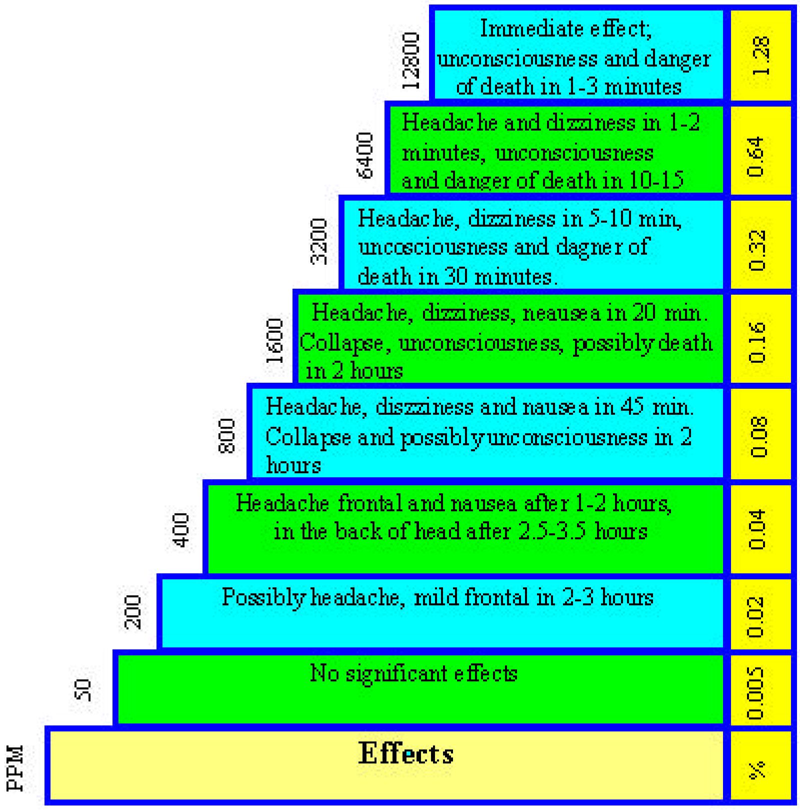
Hazards with Producer Gas

Sources of fire hazards
High surface temperatue
Sparks during refuelling
Flames through gasifier

Image

Producer gas, the mixture of carbon monoxide, hydrogen, methane and other gases, is hazardious, if it is not handled and used properly. Poisonous component of producer gas is carbon monoxide. All hazards associated with use of producer gas are described here.

Fire hazards



Poisonous steps of carbon monoxide

Image

Fire risks can be minimized by taking following precautions

- Insulation of hot parts of system

- Insulation of double sluice filling device

- Installation of back-firing valve in gasifier inlet

Explosion hazards

Explosion can occur if the producer gas is mixed with sufficient amount of air to form explosive mixture. This may happens because of following several reasons :

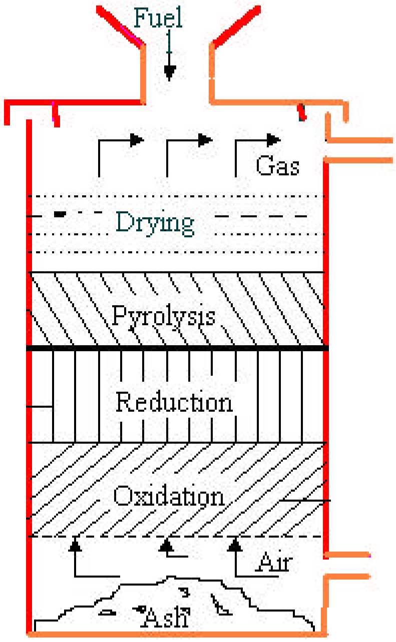
- Air leakage into the gas system

- Air penetration during refuelling

- Air leakage into cold gasifier still containing gas which can ignite

Air leakage into the gas system does not generally give rise to explosions. To avoid the chance of explosion due presence of producer gas, if any, in cold system, it is necessary to ventilate cold system before igniting the fuel.

Toxic hazards



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Producer gas consists of carbon monoxide, which is extremely toxic and dangerous as it combine with haemoglobin in the blood, preventing oxygen absorption and distribution. Carbon monoxide concentration of 50 PPM produce no effect. As concentration increases, there arises problems of headache, dizziness and even death also. No chronic symptoms can occur as the result of prolonged inhalation of relatively small amounts of carbon monoxide. Fortunately, there is less chance of gas escape during operation as gasification system works under suction. However, situation is quite different during starting and closing installations. To avoid the trapping of gas, it is recommended to install the gasifier plant in the open air

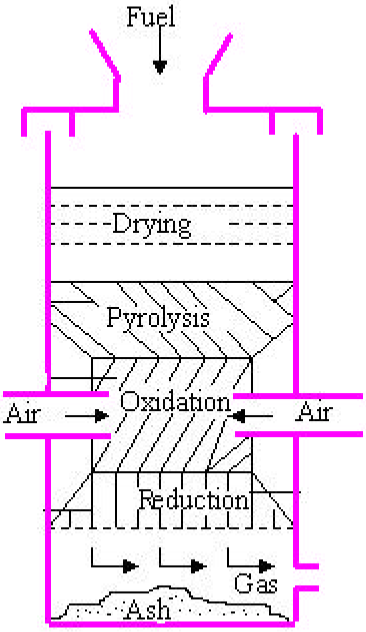
Environmental hazards

During the gasification of biomass, ashes and condensate (mainly water) are produced. Ashes do not contribute to any environmental hazards and can be safely disposed. However, for the tar containing condensate, the situation is different and disposal of those form can have undesirable environmental effects. No specific information is available about the bio-degradation of the phenolic and tarry constituents of the condensates. Properties of exhuast emmission of engines running on producer gas is generally acceptable.

Gas Producers (Gasifiers)

Design of gasifier depends upon type of fuel used and whether gasifier is portable or stationary. Gas producers are classified according to how the air blast is introduced in the fuel column. History of gasification reveals serveral designs of gasifiers. The most commonly built gasifiers are classied as :

Updraft gas producer



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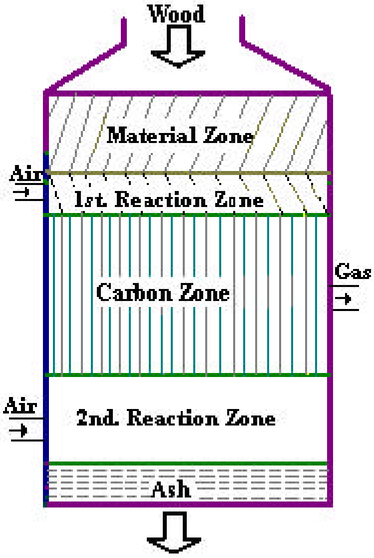
An updraft gasifier has clearly defined zones for partial combustion, reduction, and pyrolysis. Air is introduced at the bottom and act as countercurrent to fuel flow. The gas is drawn at higher location. The updraft gasifier achieves the highest efficiency as the hot gas passes through fuel bed and leaves the gasifier at low temperature. The sensible heat given by gas is used to preheat and dry fuel. Disadvantages of updraft gas producer are excessive amount of tar in raw gas and poor loading capability. Hence it is not suitable for running vehicle.

Downdraft gas producer



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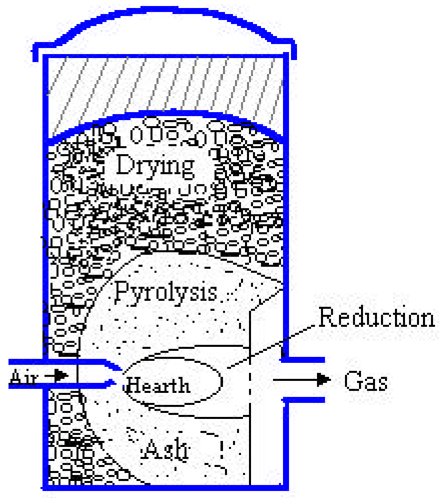
In the updraft gasifier, gas leaves the gasifier with high tar vapour which may seriously interfer the operation of internal combustion engine. This problem is minimized in downdraft gasifier. In this type, air is introduced into downward flowing packed bed or solid fuels and gas is drawn off at the bottom. A lower overall efficiency and difficulties in handling higher moisture and ash content are common problems in small downdraft gas producers. The time (20-30 minutes) needed to ignite and bring plant to working temperature with good gas quality is shorter than updraft gas producer. This gasifier is preferred to updraft gasifier for internal combustion engines

Twin-fire gas producer



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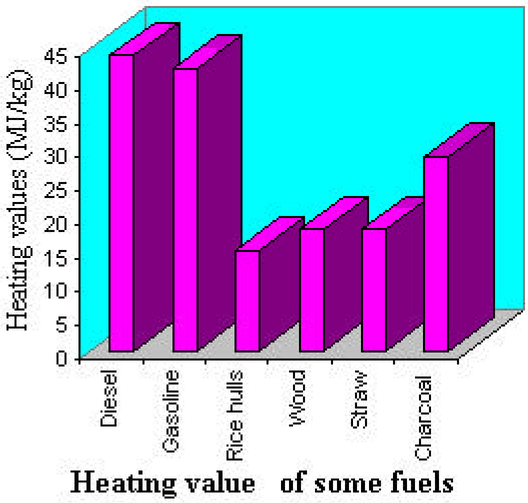
The advantage of co-current and counter-current gasifiers are combined in a so a called twin-fire gasifier. It consists of two defined reaction zones. Drying, low-temperature carbonisation, and cracking of gases occur in the upper zone, while permanent gasification of charcoal takes in lower zone. The gas temperature lies between 460 to 520 ^{o} C. Total process takes place with under pressure of -30 mbar. Twin-fire gasifier produces fairly clean gas.

Crossdraft gas producer



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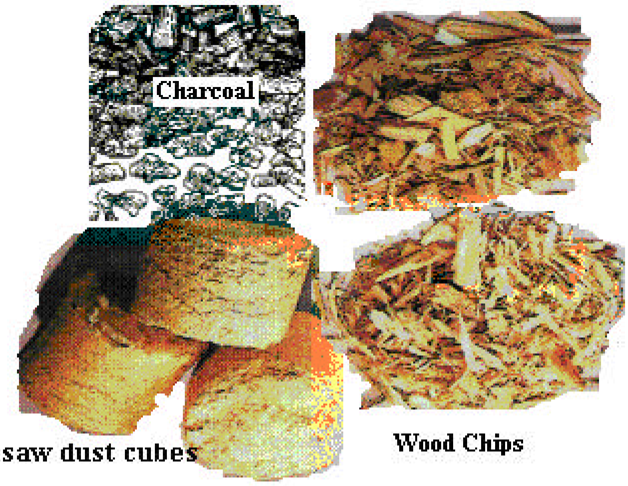
Crossdraft gas producers, although they have certain advantages over updraft and downdraft gasifiers, they are not of ideal type. The disadvantages such as high exit gas temperature, poor CO_2 reduction and high gas velocity are the consequence of the design. Unlike downdraft and updraft gasifiers, the ash bin, fire and reduction zone in crossdraft gasifiers are separated. This design characteristics limit the type of fuel for operation to low ash fuels such as wood, charcoal and coke. The load following ability of crossdraft gasifier is quite good due to concentrated partial zones which operates at temperatures up to 2000 ^{o} c. Start up time (5-10 minutes) is much faster than that of downdraft and updraft units. The relatively higher temperature in cross draft gas producer has an obvious effect on gas composition such as high carbon monoxide, and low hydrogen and methane content when dry fuel such as charcoal is used. Crossdraft gasifier operates well on dry air blast and dry fuel.

Other gas producers

Although updraft, downdraft or crossdraft gas producers have been the most commonly built types, there is a wide variety of gasifiers which do not really fit into any of these categories and are classified as other gas producers . Some units are built to combine the advantages of crossdraft with downdraft or updraft gas producers.

Impact of Fuel Properties on Gasification

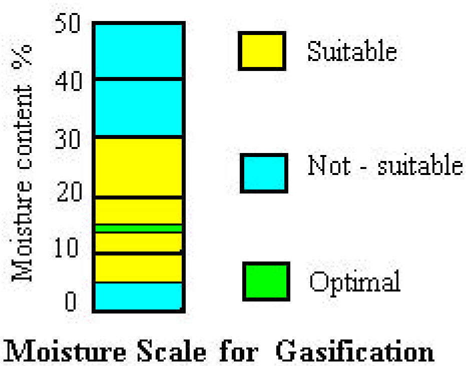


Image

A wide range of biomass fuels such as wood, charcoal, wood waste (branches, roots, bark, saw dust) as well agricultural residues- maize cobs, coconut shells, cereal straws, rice husks, can be used as fuel for biomass gasification. Theoretically, almost all kinds of biomass with moisture content of 5-30% can be gasified; however, not every biomass fuel lead to the successful gasification. Most of the development work is carried out with common fuels such as coal, charcoal and wood. Key to a successful design of gasifier is to understand properties and thermal behaviour of fuel as fed to the gasifier. The properties of fuel which influnce the gasification are described below.

Energy content of fuel

Energy content of fuel is obtained in most cases in an adiabatic, constant volume bomb calorimeter. The values obtained are higher heating values which include the heat of condensation from water formed in the combustion of fuel. The heating values are also reported on moisture and ash basis. Fuel with higher energy content is always better for gasification. The most of the biomass fuels (wood, straw) has heating value in the ragne of 10-16 MJ/kg, whereas liquid fuel (diesel, gasoline) posses higher heating value.



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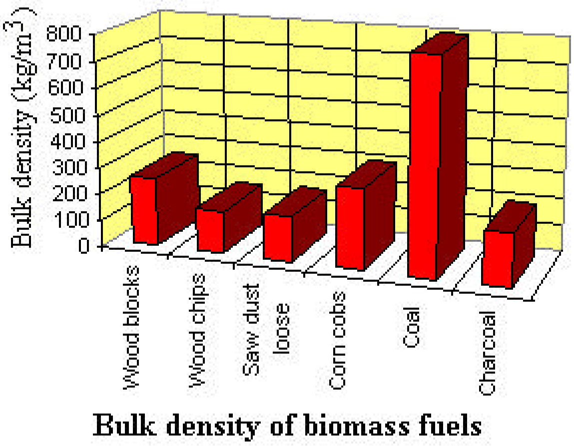
Fuel moisture content

Image

The moisture content of the most biomass fuel depends on the type of fuel, it´s origin and treatment before it is used for gasification. Moisture content of the fuel is usually referred to inherent moisture plus surface moisture. The moisture content below 15% by weight is desirable for trouble free and economical operation of the gasifier. Higher moisture contents reduce the thermal efficiency of gasifier and results in low gas heating values. Igniting the fuel with higher moisture content becomes increasingly difficult, and the gas quality and the yield are also poor .

Particle size and distribution



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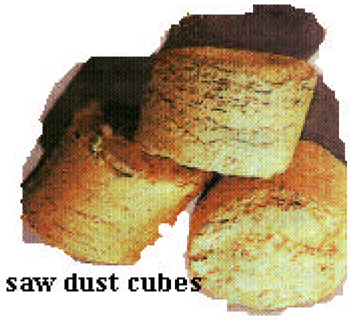
The fuel size affect the pressure drop across the gasifier and power that must be supplied to draw the air and gas through gasifier. Large pressure drops will lead to reduction of the gas load in downdraft gasifier, resulting in low temperature and tar production. Excessively large sizes of particles give rise to reduced reactivity of fuel, causing start-up problem and poor gas quality.

Acceptable fuel sizes depend to certain extent on the design of gasifier. In general, wood gasifier work well on wood blocks and wood chips ranging from 80x40x40 mm to 10x5x5 mm. For charcoal gasifier, charcoal with size ranging from 10x10x10 mm to 30x30x30 mm is quite suitable.

Bulk density of fuel

Bulk density is defined as the weight per unit volume of loosely tipped fuel. Bulk density varies significantly with moisture content and particle size of fuel. Volume occupied by stored fuel depends on not only the bulk density of fuel, but also on the manner in which fuel is piled. It is also recognised that bulk density has considerable impact on gas quality, as it influences the fuel residence time in the fire box, fuel velocity and gas flow rate.



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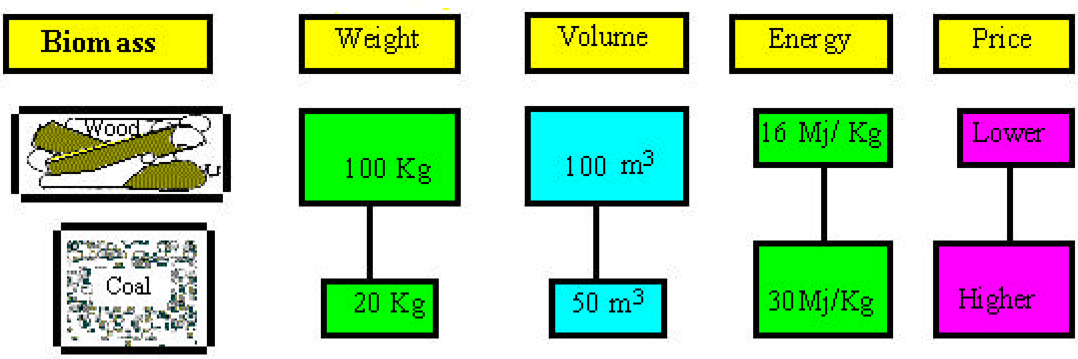
Fuel form



Difference between wood and charcoal

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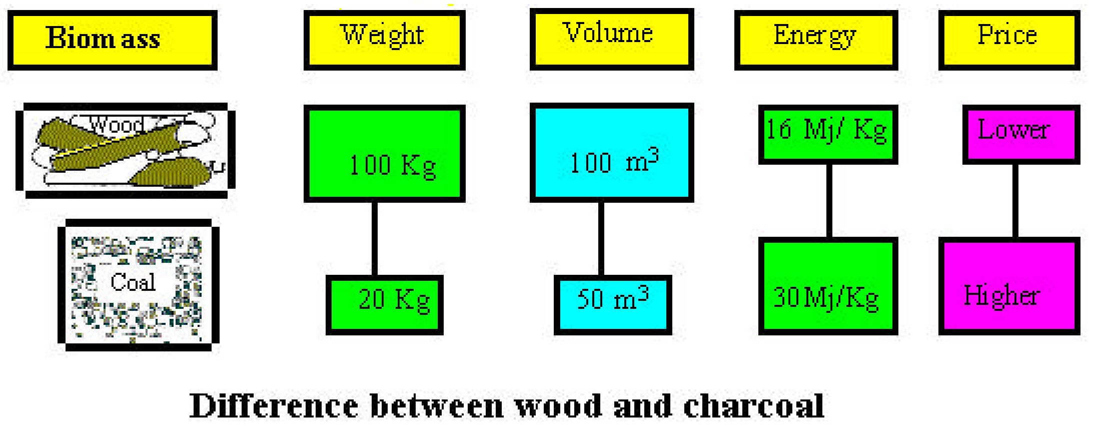

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The form in which fuel is fed to gasifier has an economical impact on gasification. Densifying biomass has been practiced in the US for the past 40 years. Cupers and Pelletizers densify all kinds of biomass and municipal waste into " energy cubes". These cubes are available in cylindrical or cubic form and have a high density of 600-1000 kg/m ^{3} The specific volumetric content of cubes is much higher than the raw material from which they are made.

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than the ra material from whi they are made.

Volatile matter content of fuel

Volatite matter and inherantly bound water in the fuel are given up in pyrolyis zone at the temperatures of 100-150°C forming a vopour consisting of water, tar, oils and gases. Fuel with high volatile matter content produces more tar, causing problems to internal combustion engine. Volatile matters in the fuel determine the design of gasifier for removal of tar. Compared to other biomass materials (crop residue : 63-80 %, Wood : 72-78 %, Peat : 70 %, Coal: upto 40 %), charcoal contains least percentage of volatile matter (3-30 %)

Ash content of fuel

Mineral contents of fuel which remians in oxidized form after combustion of fuel is called ash. In practice, ash also contain some unburned fuel. Ash content and ash composition have impact on smooth running of gasifier. Melting and agglormeration of ashes in reactor causes slagging and clinker formation. If no measures are taken, slagging or clinker formation lead to excessive tar formation or complete blocking of reactor. In general, no slagging occurs with fuel having ash content below 5 %. Ash content varies fuel to fuel. Wood chips has contains 0.1% ash, while rice hust contains high amount of ash (16-23%)

Fuels and their ash content

Fuel	**Ash content** **% weight**	**Fuel**	**Ash content** **% weight**
Alfalfa seed straw	6.0	peanut husks	0.9
Barley straw	10.3	Rice hulls	16-23
Charcoal	2-5	Safflower straw	6.0
Coffee hulls	1.3	Wallnut shell	1.1
Coal	5-17	Wheat stalks	7.4
Cotton grin thrash	17.2	Wood chips	0.1

Reactivity of fuel

Reactivity determines the rate of reduction of carbon dioxide to carbon monoxide in the gasifier. Reactivity depends upon the type of fuel. It has found that wood and charcoal are more reactive than coal. There is relationship between reactivity and the number of active places on the char surfaces.

It is well known fact that reactivity of char surface can be improved through various processes including stream treatment (activated carbon) or treatment with lime and sodium carbonate. There are number of elements which act as catalyst and influence the gasification process. Small quantities of potassium, sodium and zink can have large influence on reactivity of the fuel.

Suitability of Some Biomass Fuels

The quality of producer gas depends upon the several factors including type of fuel. The assessment of suitability of some of the important biomass fuels for gasification is given below

Charcoal

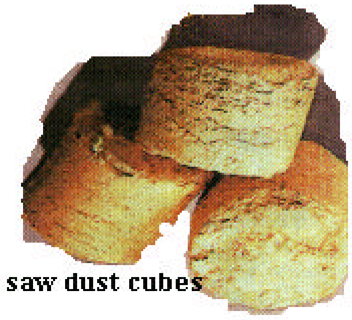
Charcoal is a product of wood carbonisation (absense of air). By burning around 5 tonn of firewood, 1 tonn of charcoal is produced. Chracoal offers twice as much as heat produced by wood. Energy lost during the conversion of wood to charcoal can be compensated by using efficient charocal oven or cookstove. Unlike firewood, it burns slowly and does not produce any smoke

Image

Good quality charcoal does not contain any tar, hence it is quite feasible for all kinds of gasifiers. Charcoal is also low in mineral matter and does not disintegrate easliy. Compared to other biomass fuels, charcoal is costly. Important disadvantage is that during conversion of wood into charcoal, more than 50% of energy is lost. This is notable factor for those developing countries which suffer in energy crisis.

Wood

The main combustible components of wood are cellulose and lignine which are compounds of carbon, hydrogen and oxygen. Other minor combustible components in wood are resins and waxes. The major non-combustible component of wood is water which is present upto 50 % in freshly cut wood. Though the ash content is low (less than 1 %), but because of high oxygen content, the calorific value is low (16-20 MJ/kg).



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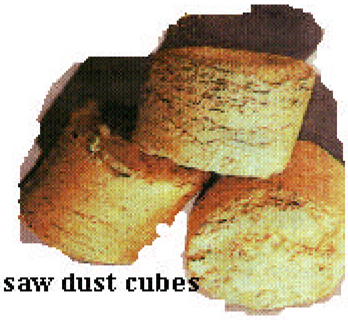
Next to charcoal, wood is quite suitable fuel for fixed bed gasifiers. As wood contains high volatile matter, updraft gasifier system produce the gas containing tar, which need to be cleaned before using in engines. Cleaning of gas is difficult and labour intensive process. Hence, wood is not suitable in updraft gasifier coupeled with internal combustion engines. However, the gas containing tar from updraft gasifier can be used for direct burning.

Downdraft can be designed to produce relatively tar-free gas. After passing the gas through simpel clean-train, it can be used in the internal combustion engines.

Sawdust



Unpellatized sawdust lead to the problems of excessive tar production, inadmissable pressure drop and lack of bunker flow. Such problems can be minimized by use of densified (pelletized) sawdust. Small sawdust particles can be used in fluidized gas proucers to produce burning gas. If this gas is used to be in internal combustion engines, fairly good clean-up system is essential.

Image

Peat

Peat is the first stage of coal formation. It is not strictly a coal or it can be termed as the most immatured coal. Freshly mined peat contains 90 % moisture and 10 % of solid. It cannot be utilised unless air dried to reduce moisture content to 30 % or less. Its heating value (around 20 MJ/kg) is slightly greater than wood.

As peat contains very high level of moisture and ash, it creates problems in the gasification process. Small downdraft gasifiers fueled with dry peat-pallets have been successfully tested in gas-engine system.

Agricultural residues

If wood is scarce and costly, more abundant or accessible but otherwise less favoured fuels is used instead. Agricultural residues are basically biomass materials that are by product of agriculture. It includes cotton stalks, wheat and rice straw, coconut shells, maize and jowar cobs jute sticks, rice husks etc.

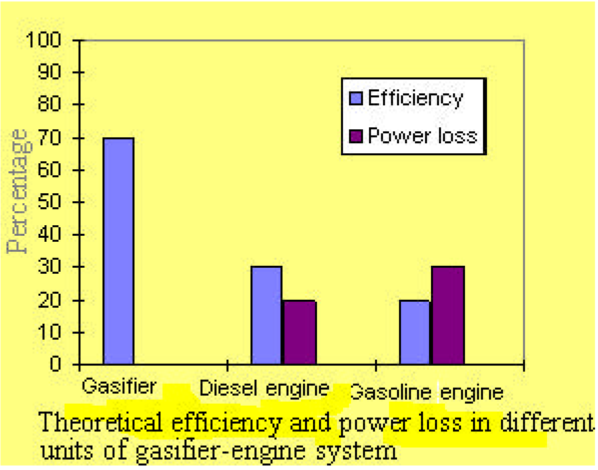
Many developing countries have a wide variety of agricultural residues in ample quantities. Coconut shells and maize cobs have been successfully tested for fixed bed gasifiers and they unlikely creates any problems. Most cereal straws contains ash content above 10% and present slagging problem in downdraft gasifier. Rice husk with ash contents above 20% is difficult to gasify.

Producer Gas Drive Engines

Producer gas is used in internal combustion engine for power or electricity generation. Internal combustion engines are normally designed to run on diesel or gasoline fuel. Properties of of producer gas- mixture is different from that of diesel or gasoline. Use of producer gas in internal combustion engines affects performance and other maintenace features of engines. This sections deals with various following issues concerned with use of producer gas in internal combustion engines.

Peformance of gasifier-engine system

Cold gas efficiency of producer gas in favourable condition can be 70%. In gasifier-engine system, losses also occurs at different stages. Engine performance is expressed in terms of brake thermal efficiency. Overall efficiency of the system is the product of gasifier efficiency and brake thermal efficiency.



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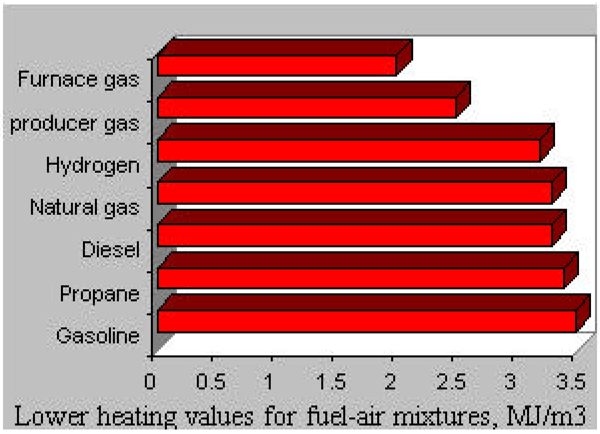
The actual efficiency of engine varies with design, size and running condition. Efficiency of diesel and gasoline engines under good condition are considered to be 30% and 20% respectively. The efficiency of engine run with producer gas goes down owing to lower density of gas-air mixture and other power losses associated with suction of mixture in engines. Theoretically, gasoline and diesel engine operated on producer gas suffer a power loss of 30% and 20 % respectively. In practice, considering a wide range of producer gas quality, a power drop ranging from 25 % to 60 % can be expected when diesel or gasoline engine is run with producer gas

A typical composition of 4.5% CO_2 , 27 % CO, 14% H_2 , 3 % CH_4 and 51% N_2 has a lower heating value of 5.7 MJ/m^3 at normal ambient condition of 15^o C and pressure of 1 atm . The stoichiometric gas-mixture has an energy density of 2.5 MJ/m^3 compared to 3.5 MJ/m ^{3} for gasoline-air mixture and 3.3 MJ/m ^{3} diesel-air mixture.



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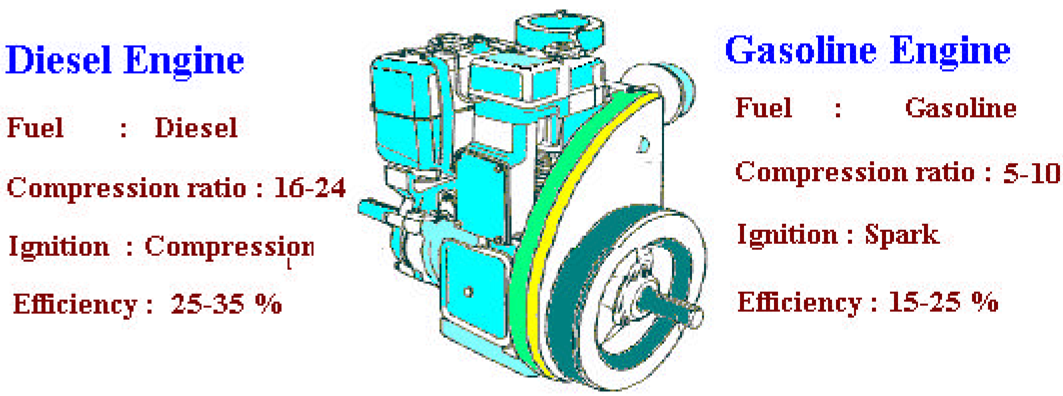
Operational difference between diesel and gasoline engine

There is significant difference between diesel and spark ignition engine system with respect to it´s suitability for producer gas. In diesel engine, diesel is injected at the end of compression stroke and get ignited immediately without any spark ignition. This will not the case with producer gas- air mixture. In fact, diesel engine cannot operate alone on producer gas as temperature and pressure is not sufficient to ignite gas-air mixture. Hence, during the injection of producer-gas mixture, some quantity of diesel is also injected in combustion chamber.



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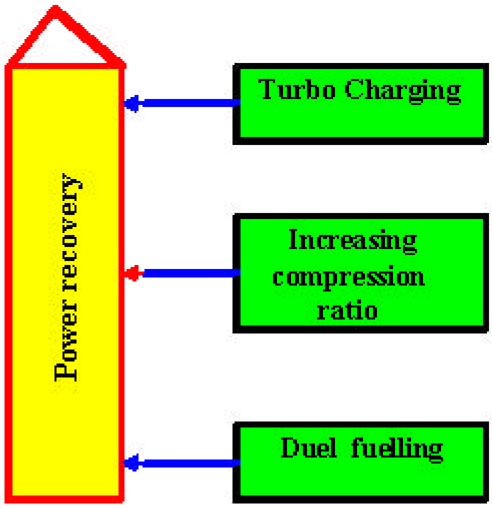
In gasoline engine, air-fuel mixture is sucked during suction stroke and mixture is ignited with a spark at the end of compression stroke. Gasoline engine running on producer gas can operate on producer gas alone without any injection of gasoline. This is certainly convenient in remote rural areas, where gasifier-engine system is used for power or electricity generation. In general, low speed engines with large displacement and combustion place have advantage over today´s comact and high speed engines.

Conversion of gasoline engine to producer gas

Unaltered gasoline engine run with producer gas experiences the power loss of 30-50% depending upon the producer gas quality.

Unaltered gasoline engine run with producer gas sound good from economical point of view. This approach is beneficial, for some application such as irrigation pump, which works at constant load and even at low load also. This approach is not practically workable for tractor or any other automobile which has to work under different loading condition.

In case already installed gasonline engine is converted to producer gas drive, some of the power can be recoverd through supercharging or turbocharging. The turbocharger would be required to deliver the gas-air mixture into existing unalatered engine at differential pressure of 1 atm to achieve equivalent of compression ratio increase from 5 to 10. This compression can be achieved by reciprocating type of pump. The power for pump shall be provided by turbine run on exhaust of engine.



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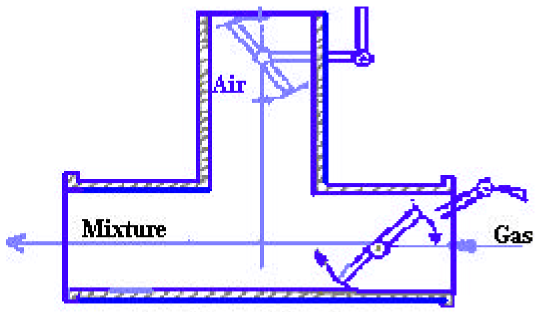
Compression ratio

Power loss in gasoline engine run on producer gas be recovered by increasing the compression ratio. Commercially built gas producers were usually operated at the compression ratio of 6.5 to 7.5. Keeping in mind hydrogen content in producer gas and it´s effect on flame speed, compression ratio as high as 10 is said to be technically and economical feasible. There are other operational problems with higher compression ratio. Engine with higher compression ratio are difficult to start, creates vibrations, increases wear and tear on piston, reducing the life of the system.

Gas-fuel mixture

In the case of engine run on gasoline, gasoline-air mixture is adjusted automatically by carburetor and controlled by accelerator. Finding the correct gas-air ratio in producer gas drive engine is difficult as gas composition changes over a run, sometimes drastically. There are different kinds of valves ranging from simple hand operated valve to fully automatic valve for control of gas-air mixture.



Hand operated valve

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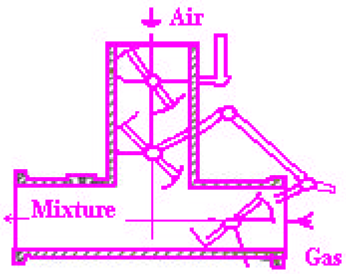
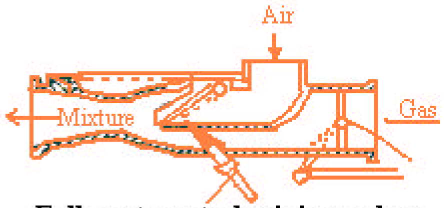


Semi automatic valve



Fully automated mixing valve

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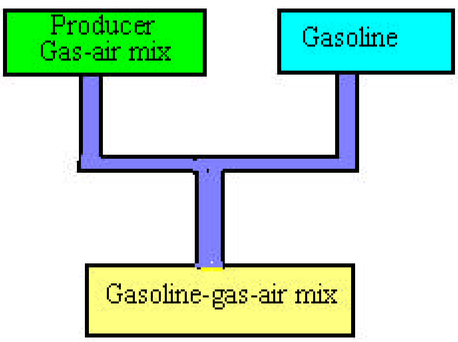
Due fuelling

One of the most widely used and convernient method to increase the power output of engine is duel fuelling. Dual fuelling is good compromise between gasoline savings, conveninece and ease of operations. In dual fuelling, gas-air mixture is injected with small amounts of gasoline. Degree of dual fuelling depends upon the engine load and independence one need in use of producer gas. Three commonly used dual fuelling methods are :



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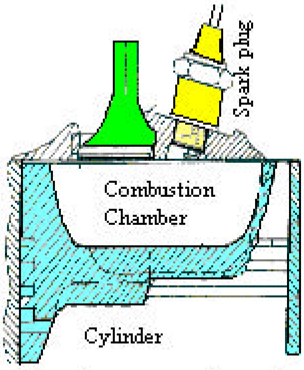
- Dual fuelling on continuous basis, meaning small amounts of gasoline with gas-air mixture

- Starting the engine on gasoline and then switching over to producer gas drive

- Dual fuelling when additional power is needed to overcome the load, for instance, on hills

Conversion of diesel engine to producer gas

Diesel engines are compression ignition engines with compression ratio of 16-24 depending on whether they are direct combustion chamber, pre-combustion chamber, four strokes or two strokes. Fuel is ignited by high gas air temperature. As diesel engine cannot be operated on producer gas alone, it need to be operated on dual fuel or converted completely into spark ignition engine.



Complete conversion of diesel engine to gas drive

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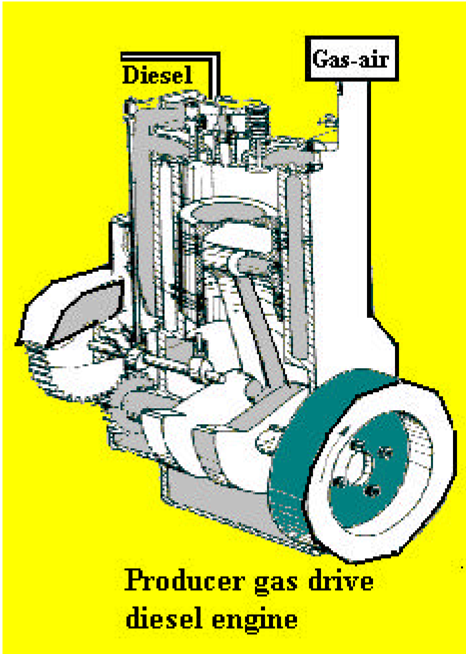

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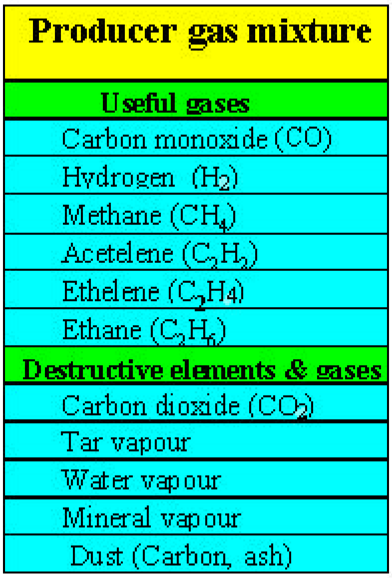
Complete rebuilding of entire engine is expensive and time consuming job. Power drop in diesel engine converted to spark ignition is not as sever as gasoline engine running on producer gas. In case of dual fuelling, modification is confined to a special induction manifold and gas-air mixer as converted in gasoline engines. The pilot injection of diesel amounted to 10 -25% of original consumption. For economical reason, it is best to inject the amount of diesel necessary for smooth operation of engine

Conditioning of Producer Gas

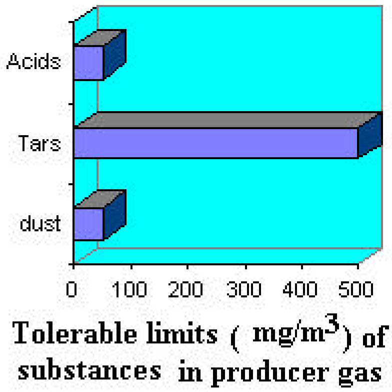


Producer gas mixture
Useful gases
Carbon monoxide (CO)
Hydrogen (H_2)
Methane (CH_4)
Acetelene (C_2H_2)
Ethelene (C_2H4)
Ethane (C_2H_6)
Destructive elements & gases
Carbon dioxide (CO_2)
Tar vapour
Water vapour
Mineral vapour
Dust (Carbon, ash)

Producer gas leaves the gasifier as the mixture of combustible and non-cobustible gases alongwith tar vapour, water vapour, dust, mineral vapour. Sulphur compounds such as hydrogen sulphide (H_2S) and nitrogen compounds (NH_3 , HCN) in producer gas are undesirable as their condensates are corrosive and pollutants in exhuast gases. The generation of H_2S is of little importance in gasification of biomass as long as sulphur content does not exceed 0.5%. The amount of NH_3 and HCN in the gas depends on the nitrogen content of the fuel. Fuel with nitrogen content less than 2 % is safe for gasification. Silicon oxide (SiO_2) and iron oxide (Fe_2O_3) in dust are important because of their abrasive nature.

Image

For trouble free operation, engine must be supplied with producer gas that is sufficiently free from tars, dust and acids. The cleaning of gas is necessary to avoid wear and tear in engine. Dust concentration in the gas depends upon the type of gasifier, intensity of load and type of fuel. As load increases, dust concentration in producer gas also increases. The removal of tar from gas producer is one of the more difficult problems in gas cleaning.



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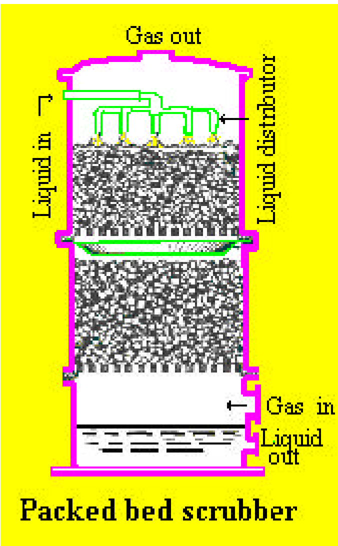
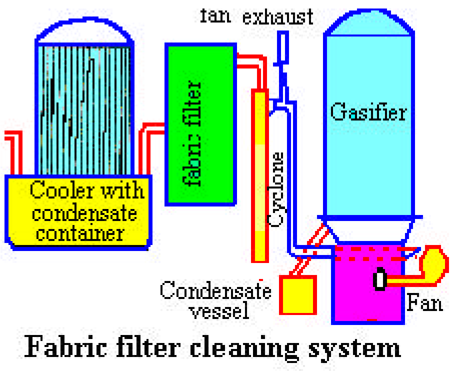


Gas cleaning and cooling for gasifier system is accomplished by a cyclone, a gas cooler with some scrubbing action and a packed bed filter. Gas cooling increases density of gas in order to maximize the amount of gas entering the engine cylinder. Wet scrubbers are used to remove gaseous pollutants and solid particles while cooling the gas at same time. There exists different kinds of scrubbers for small scale producer engine system. A Packing bed scrubber consists of packing, liquid, support grates and distributors plates. Packing can be made from wide range of commercial and home made materials-steel, wool, wood chips, coke, gravel etc. Gas is passed through bottom and removed at top.

Image

Fabric filter is considered to be one of the suitable filters for vehicle application. It is placed immediately after cyclone . In filter with glass-fibre cloth, it is possible to withstand a gas temperature upto 300°C. The performance of filter depends on type of gasifier, fuel moisture content and how vehicle is driven. It is recommended that gas flow rate through filter box shall not exceed 65 m3/h. Pressure loss over filter is affected by load and amount of dust in the producer gas.



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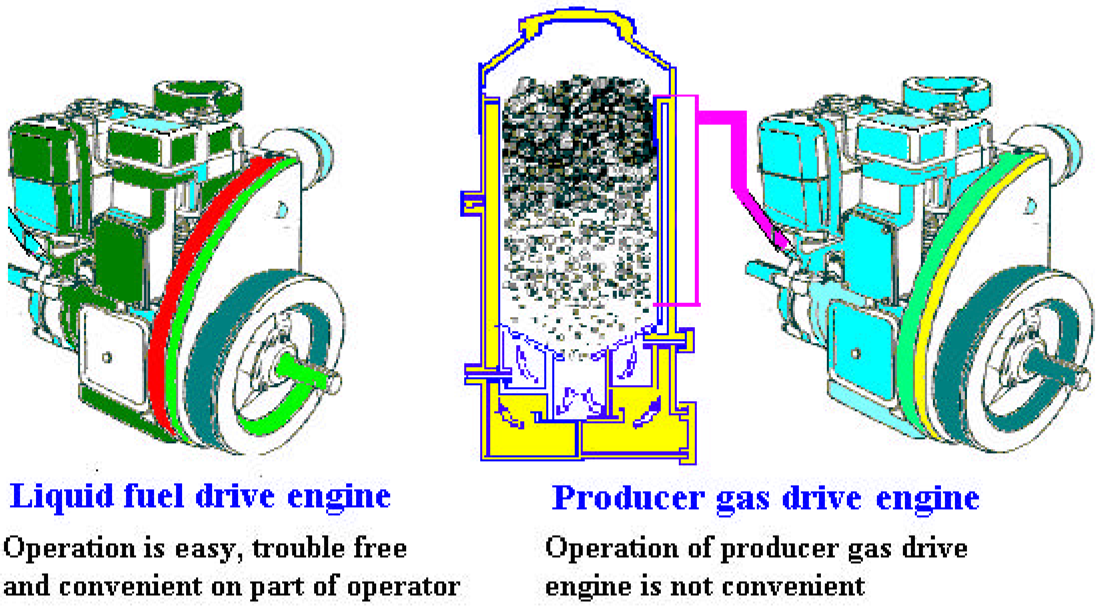
Troubles with Gasification System

Gasification is quite complex and sensitive process. There exists high level of disagreement about gasification among engineers, researchers, and manufacturers. Many manufacturers claim that their unit can be operated on all kinds of biomass. But it is quite questionable fact as phyiscal and chemical properties varies fuel to fuel.



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Operation of diesel or gasoline engine is simple. Engine starts immediately and there is no trouble within the run. Handling of liquid fuel is also easy task. Anybody expecting something similar will be disappointed with operation of gasifier. It requires atleast half an hour or more to start the system. Fuel is bulky and frequent refuelling is often required for continuous running of the system. Handling residues such as ash, tarry condensates is time consuming and dirty work. Driving with producer gas feuled vehicles requires much more and frequent attention than gasoline or diesel fueled vehlicles

Getting the producer gas is not difficult, but obtaining in the proper state is the challenging task. Gasoline and diesel have quite homogenous property. The physical and chemical properties of producer gas such as energy content, gas composition and impurities vary time to time. All the gasifiers have fairly strict requirements for fuel size, moisture and ash content. Inadequate fuel preparation is an important cause of technical problems with gasifiers.

Gasifier is too often thought of as simple device that can generate a combustible gas from any biomass fuel. A hundred years of reseach has clearly shown that key to successful gasification is gasifier specifically designed for a particular type of fuel.Those interested in this technology must remember that it requires hard work and tolerence. Although technology is inconvenient, it is economical at many places and may lead to self-reliance in fuel crisis.

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The detail list of research papers, books and other related literatures on gasification is given below. The list is arranged alphabetically by authors name.

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