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Golden, Colorado 80401 USA

http://www.biomassenergyfoundation.org

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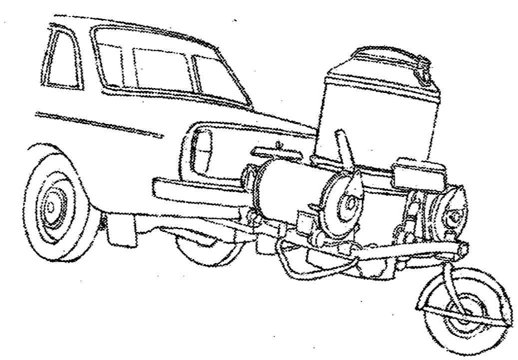
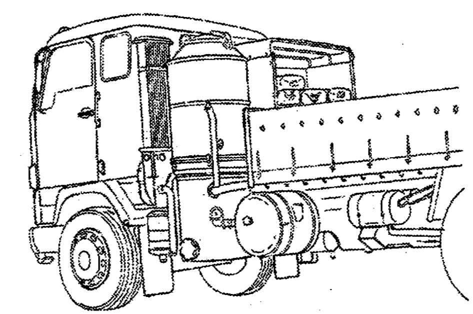
WOODGAS GENERATORS for VEHICLES





by
Nils Nygards

2nd Edition – 2006
Biomass Energy Foundation Press

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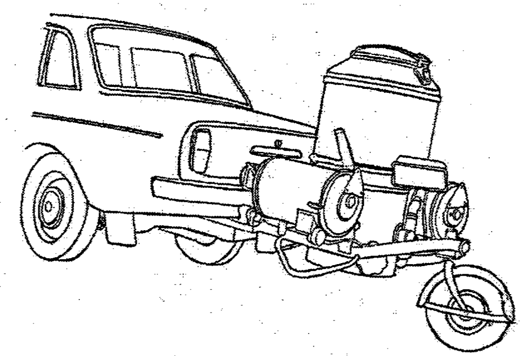

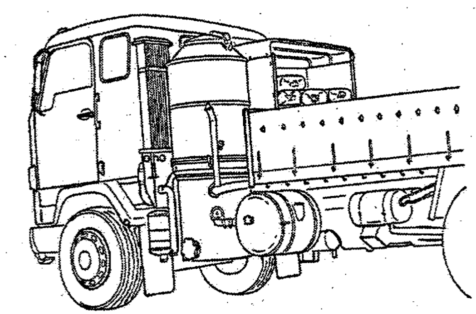

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Preface to 2nd Edition – 2006

The cost of gasoline and natural gas has more than doubled in the last few years. Many project that we have reached the end of the "cheap oil" era and will need to find alternative fuels. Biomass is the ultimate fuel solution after we have used as much fossil fuel as remains and as the planet can stand.

World War II was a trial run for a world without oil. When the Nazis invaded other countries in 1940, they confiscated all gasoline and diesel, leaving civilians to shift for themselves. Many women and children died of starvation in the first few months of the war.

Sweden was uniquely positioned to develop the technology of wood gasification because it did not take part in the war, had no oil, and had large wood reserves. By 1942 the Swedes had converted 67,000 cars, trucks, and buses to WoodGas. After the war they published Gengas, a 340-page history of that era (available in translation from the BEF Press) and they continued working on improving WoodGas generators through the 1970s.

This is our simplest introductory book to the WoodGas era, written in Sweden in 1957 by the Swedish Academy of Engineering to cover their latest developments. While these are interesting "shop notes," there are many other detailed designs available for construction, including several of our books.

The initial translation was made by Nils Nygards. Thanks to John Kerr for redrawing the pictures and to Mike Maus for retyping and helping to edit the text in this second edition. We have added an Epilogue describing the current activity in developing WoodGas primarily for power generation.

Thomas Reed, May 2006

The Biomass Energy Foundation Press

http://www.woodgas.com/bookstore/htm

EPILOGUE

This booklet is an easy introduction to the WWII GenGas era when more than a million cars, trucks, and buses ran on WoodGas when the military took all the gasoline and diesel fuel.

Very few people are aware of this period. Now, as the era of "cheap oil" is ending, we will be considering WoodGas as a replacement. However, liquid fuels still are relatively cheap. But, gasification also is attractive for generating electric power from various forms of biomass. The Biomass Energy Foundation currently is building an 80 kW "minigrid" power system to operate on fruit pits for four Brazilian villages along the Amazon.

Gasification can convert any biomass into a useful gas. One of the best uses would be for making synthetic liquid fuels so that we don't have to operate vehicles directly on WoodGas. Unlikely to happen quickly, this will take time and political effort.

For more information on the uses of biomass as a fuel source and on gasification, please visit our Web site at http://www.woodgas.com, or our membership site, http://biomassenergyfoundation.org. You may also want to do a Web search on the term "gasification" and follow some of the links that appear.

We offer for sale, at our bookstore on the Web, a number of books (this one included) that, to our knowledge, are not available anywhere else in the world. These books may open a whole new world of interest for you!

The world more and more needs alternative fuels. You have an opportunity to be part of the solution by using your creativity in exciting ways, starting with this book.

Onward to the future!

Thomas B. Reed, Ph.D.
Biomass Energy Foundation
Golden, Colorado

English Translation of *WoodGas Generators for Vehicles*
by
Nils Nygards

Foreword to Woodgas Generators for Vehicles, English translation of Swedish original.
By Nils Nygards

FOREWORD

In 1978, at the Greenpeace Experimental Farm, we built a woodgas generator from plans dating back to World War II. The unit was mounted on an old (1948) but serviceable Ford 8N tractor having 22 HP rating. It was not long before we discovered why woodgas was quickly abandoned after the war. The system was only marginally reliable, expensive to fabricate, and heavy.

We searched world literature for better ideas and eventually found Swedish engineering data on woodgas updated to the mid 1960's. The Swedes evidently continued to do research on woodgas for 20 years after the war. In this interval they developed the technology to a high level of reliability, while enabling significant cost and weight reductions.

As of this writing (1980) we have designed, built, and tested equipment in accordance with the post-war Swedish experience, installing a woodgas conversion unit on our Ford tractor. It performs well, giving confidence to woodgas as a reasonable fuel alternative to gasoline in motor vehicles, especially in rural areas having convenient access to woodlot thinnings or wastes from sawmills.

This booklet explicitly describes the advanced Swedish system and contains valuable information for those who want to more fully understand operating characteristics of a variety of woodgas powered vehicles.

Jim Bohlen
Greenpeace Experimental Farm
Denman Island, British Columbia
Canada VOR 1TO

1979
Nils Nygards

Woodgas Generators for Vehicles

BACKGROUND

Using generator gas as fuel for combustion engines is nothing new. It was widely and successfully utilized in Europe during the emergency of World War II. When the War was over and cheap oil again was available, the Gengas systems were immediately discarded, in part because they were not as efficient, they were difficult to handle, and certain health risks came with them, especially when they were compared to petroleum.

However, in a time of need, Gengas is indeed a substitute fuel to consider. The fuel crisis, however, must be very serious before a massive change to this fuel would be motivated. The reason for making this information available in America is that it lends some degree of contentment to the public to know that substitutes exist and also that anyone with the curiosity to make and use such fuel can produce such a system with the help of this information.

FUEL RESOURCES

During World War II, wood cubes or wood charcoal generally were used as a base for woodgas. However, to produce one cubic meter of charcoal requires approximately 2½ cubic meters of wood. It is fairly easy to see that this is very wasteful when considering that one cubic meter of wood chips equals one cubic meter of charcoal in travel distances for a vehicle.

Any kind of wood can be used for fuel – the only difference being that hardwood will last longer and, if softwood is used, it will be necessary to stop more often to restock the generator. (For example, approximately 400 liters of pine equals 300 liters of birch.[1]) The moisture content of the wood can be approximately 10%, but not exceeding 20%, to be usable in the gas generator.

For production of wood chips, the following points should be considered:

1. Drying of wood chips to 10% moisture content is problematic.
2. It is easier to chip wet wood than dry wood.
3. Planks are easier to dry than chips.

PRINCIPAL FUNCTION

To produce woodgas for use as a motor fuel, system with the following is required:

Gas Generator
Flare for startup
Gas Cleaner
Radiator for cooling the gas
Mixer

[1] Note that in the United States, wood usually is not measured in liters, but in cords or, less frequently, in pounds.

The equipment manufactured must be tight <u>and</u> have good strength.

Caution must be observed when filling wood chips and starting the system, and also at the end of the driving period when the system is closed down. Also, if any component is opened up to the atmosphere for any reason, care should be taken.

Units cannot be brought into garages unless the garage has sufficient mechanical ventilation.

The fire hazard close to the "generator" is considerable. Care must be taken when filling or adding fuel and when slagging. Fire extinguishers <u>must</u> be carried and, also, in the dry season, a water tank should be at hand.

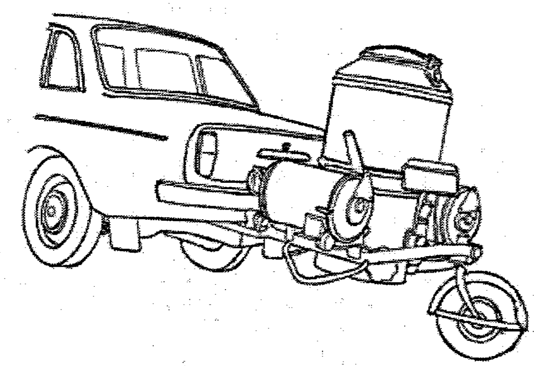
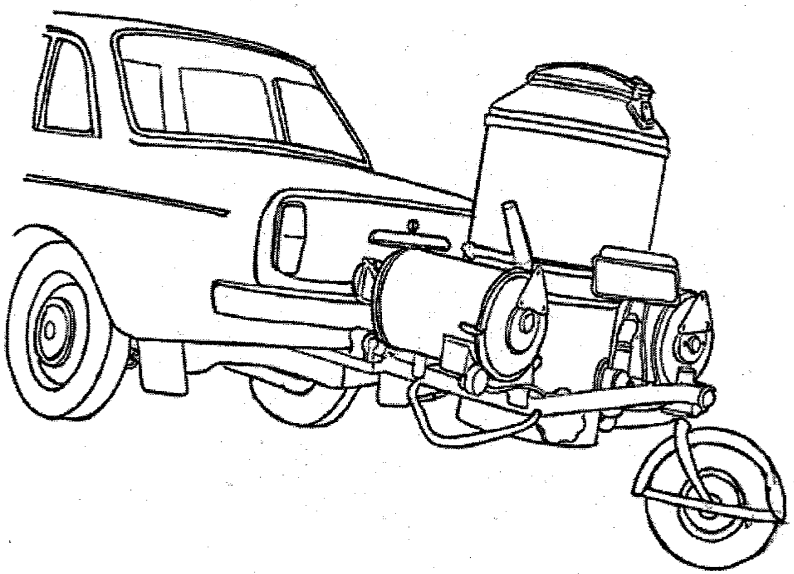


Figure XVI: Passenger car with wood gas generator



BUSES

Figure XVI shows a trailer containing the Gengas aggregate and also having room for fuel storage. (It is shown on an automobile, but this also could be adapted to fit a bus.)

A more difficult way is to adapt the component at the rear end of the vehicle. However, the weight distribution then becomes heavy in the rear and it also can be hard to find supportive structures to attach to.

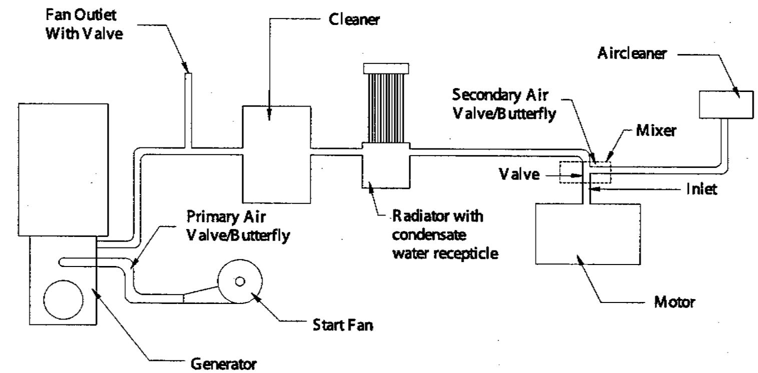
The trailer is desirable from the servicing point of view, but in poor road conditions the trailer may have some drawbacks.

SAFETY POINTS

Considering the risk of poisoning to the driver and/or passengers, or to people close to the equipment, and also considering the inherent fire hazard, it is important that the making of, mounting of, and caring for the GenGas aggregate is done with all care and knowledge. The GenGas contains carbon monoxide (CO) which is without both smell and taste. Inhalation of CO can be fatal even in small dosages. Therefore, **do not EVER use this system in an enclosed space.**

The gas is generated in the generator from which it goes to the cleaner where chardust and other particles are eliminated. Next, the gas is fed through the radiator where it is cooled and any moisture condenses and falls out. Then, the cooled gas goes to the mixer where secondary air is added before entering the engine. (See Figure I)

Figure I: Schematic of Woodgas Generator



PRODUCTION OF WOODGAS

The gas comes from partial combustion of wood chips in the generator. Because of limited access to air, the combustion of the wood is not complete. However, gasification of the fuel material occurs without further combustion of the produced gas.[2]

Figure II (following page) shows how gas is produced in a downdraft gas generator.

Air is supplied through the jets. In front of the jets, the combustion zone is established. The heat from this zone dries and converts the wood chips to charcoal. A large part of the remaining moisture in the wood chips is evaporated above the air inlet; the water vapor rising upward, where it cools and is condensed on the wall of the fuel storage tank's conical void. The condensate, which contains water and other undesirable substances, then goes to a storage tank where it can be drained off.[3]

In the combustion zone, a reaction is happening: Carbon (C) is reacting with air; producing carbon dioxide (CO_2) and carbon monoxide (CO). Any remaining water is vaporized.

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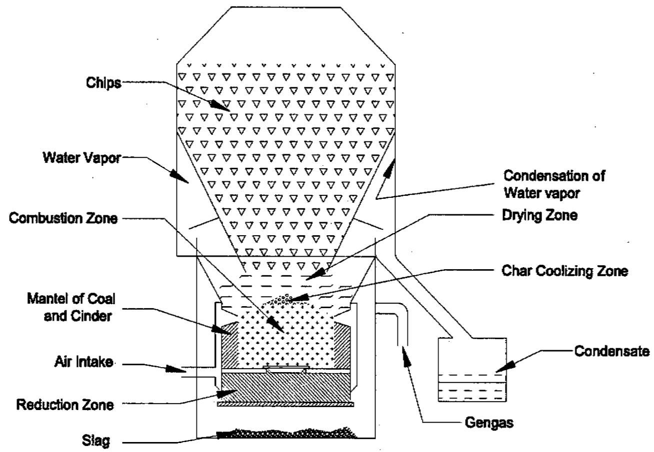
[2] More recent research, conducted at the Biomass Energy Foundation, has shown that nearly any biomass fuel will work just fine as a producer of woodgas. In other words, wood chips are not a unique fuel.

[3] This drying function was not used in most generators.

Figure II: Sequence of process in a generator using wood chips



The reduction zone, where small glowing coal chips are held, is under the combustion zone. Gas passing through this zone is reduced through contact with the glowing coal chips according to the following reactions:

Carbon dioxide (CO_2) is reduced to carbon monoxide (CO).
Water vapor (H_2O) is reduced to carbon monoxide and hydrogen (H_2).
The generated woodgas (from wood with 12-20% moisture) now has the approximate contents:

Combustible Element	**Volume(%)**
Carbon monoxide (CO)	17-22
Hydrogen (H_2)	16-20
Methane (CH_4)	2-3
Tars	0.2-0.4

Non-Combustible Element	**Volume(%)**
Carbon dioxide (CO_2)	10-15
Nitrogen (N_2)	45-50

GAS GENERATOR

The design of the gas generator is dependent on whether the fuel is wood cubes or wood chips.[4]

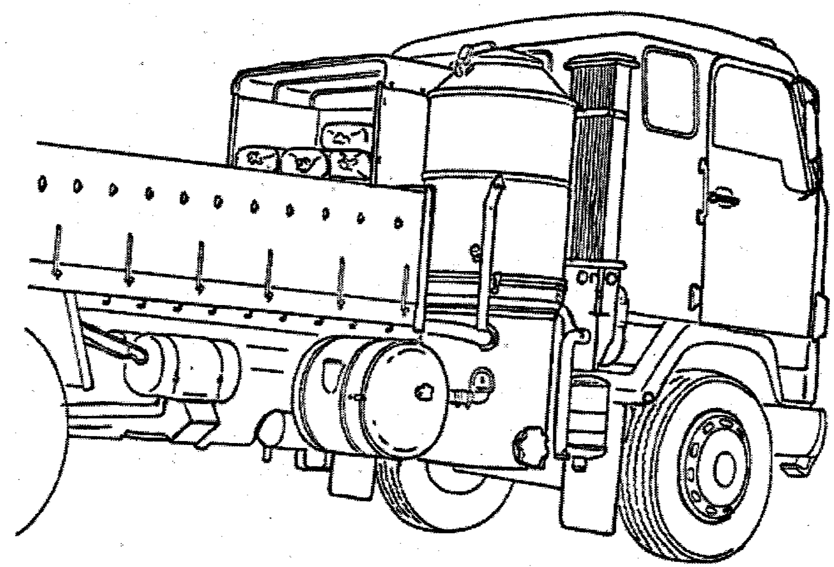
Figure III shows a generator with wood chips as the primary fuel. Generally, it is not practical to use wood chips in a generator designed for wood cubes. Problems with (wood) chips tend

[4] See Note 1. Later research indicates other biomass fuels also will work here.

TRUCKS

Flatbed trucks, as Figure XV indicates, are most suitable for adaptation to the Gengas unit. A space behind the cab is utilized where room also is available for the wood chip bags. It also can easily be seen how the weight distribution is ideal in this case. (See Figure XV)

Figure XV: Truck with wood gas generator



PASSENGER AUTOMOBILES

The same points as for buses prevail for passenger automobiles. The trailer in this case is preferable. A pivoting single wheel with permanent attachment at the rear bumper and side stabilizers is used.

Graphically, this is shown in Figure XVI on the next page.

POINTS CONCERNING GENERATOR CONVERSIONS

Changes in the vehicles for use of Gengas include adding components and finding suitable space for them. Also, certain changes must be made to the engine.

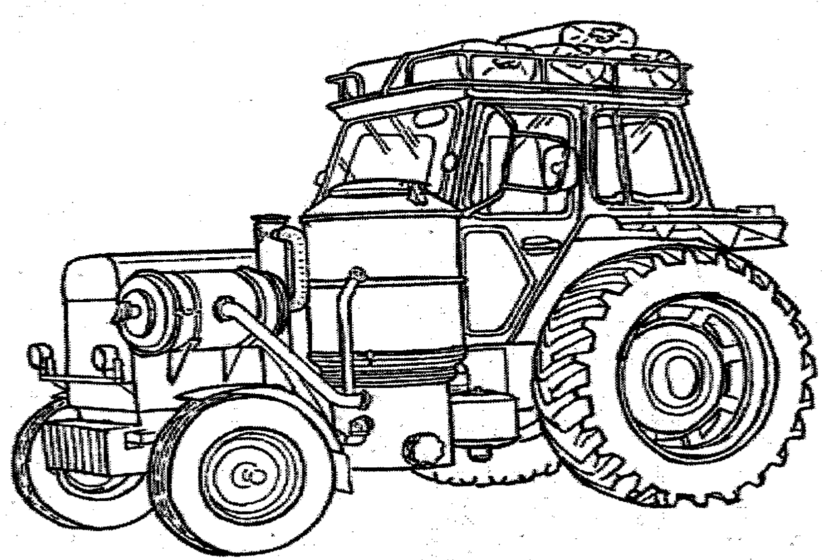
It is most important that components be mounted with skill and care, especially in view of the fire hazard and poison risks.

In planning the manufacture of components for Gengas units, special attention should be paid to the need for the unit to be available both as a unit and as separate components that can be adapted to different vehicles. (In other words, one who plans to use this alternative fuel source should be able to buy all the parts separately rather than only as a prefabricated unit.)

FARM TRACTORS

Because of limited space available on farm tractors, and also because of the different implements used in the chores it does, it is difficult to adapt the woodgas generator to a farm tractor. However, an individual mounting is usually suitable and the bulky parts (are) placed on the left side of the vehicle. Also it must be kept in mind that the view not be obstructed for safety in road traffic. (See Figure XIV)

Figure XIV: Tractor with wood gas generator



to include an excessive compaction of the coal bed in the reduction zone and an irregular downward feeding of the wood chips.

The excessive compaction of the coal bed in the reduction zone has been overcome by making the grate movable, either manually or automatically. (See Figure IV) Irregular downfeed of the (wood) chips is overcome by the special design of the fuel storage container.

A generator designed for (wood) chips can, however, also be used principally for wood cubes. However, to get a better result, the fuel storage container mantle should be modified as shown in Figure V.

Figure III: Generator that uses wood chips

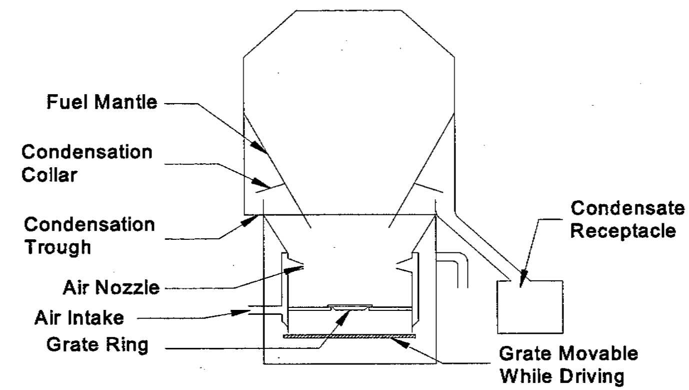


Figure IV: Movable grate to overcome compaction in the charcoal bed

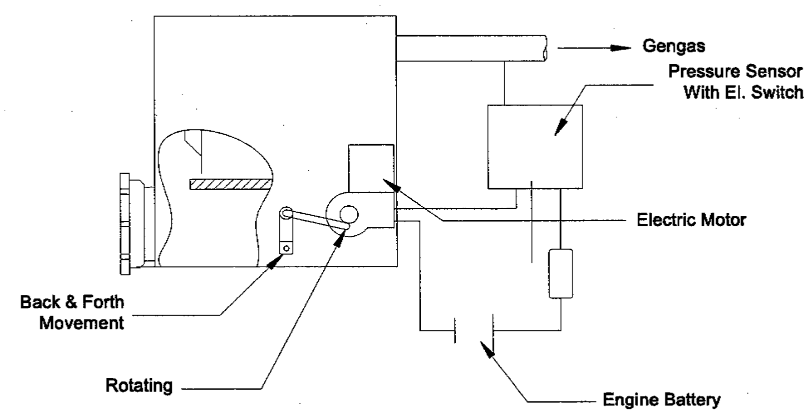
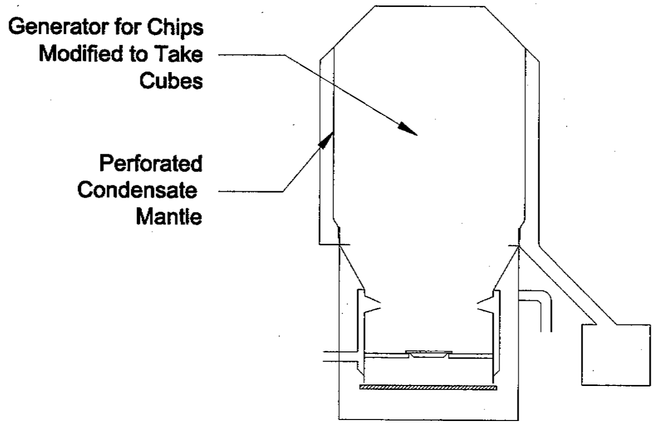


Figure V: Generator for chips after modifications to take cubes:



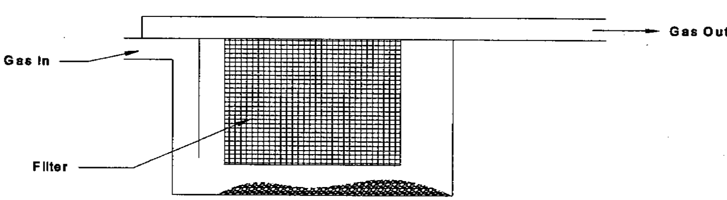
GAS CLEANER

The gas coming from the generator contains minor amounts of coal chips and tars. Therefore, the gas must be passed through a high-efficiency filter.[5]

The high heat resistance of the filter material allows high-temperature gas to pass through. This is important because if water vapor is allowed to condense, the wet filter would restrict the flow of gas, making the engine less powerful.

Figures VI and VII show different filter housings.

Figure VI: Gas cleaner with stationary filter



[5] This can be a Fiberglas® filter, or any other filtration device that will remove the particulate matter from the gas.

In super-charged diesel engines now common in trucks with load capacities of more than six tons, the power factor is lowered because of elimination of the turbo compressor. The power factor in this case must be considered lowered to approximately 40-50% of pure diesel operation.

FUEL CONSUMPTION

Fuel consumption varies greatly, depending on the kind and quality of wood, and how the generator is loaded. Heavier wood requires less frequent refills. The wood should not be rotten. The size of the chips has a bearing on the gas current through the generator. The loading of the generator depends on many factors: cylinder volume of the engine, RPM, whether it is Gengas only or a diesel-Gengas operation (called "rebuilding" mode), and adjustment of the secondary air butterfly (valve) in the gas mixer. The moisture content of the wood is important: low moisture=low fuel consumption.

Example I

- Diesel truck with direct fuel injection
- Cylinder volume 10l
- Motor converted to diesel-Gengas operation
- Travel on medium-good highway
- Load of 6000 kg (13,228 pounds)
- Medium speed: 50 km/hr (31.07 mph)
- Fuel Consumption: 5.0 lit/10 km (1.6 gallon/6.2 miles); Pine or Spruce with approximately 12% moisture. Ignition diesel oil: approx. 0.8 liters/10km (0.25 gallons per 6.2 miles)

Example II

- Tractor with direct fuel injection diesel motor
- Cylinder volume 6l
- Motor converted to diesel-Gengas
- Driving in medium farm load chore
- Fuel Consumption: 150 liters (47.6 gallons) of birchwood chips/hour. Wood has a moisture content of approximately 12%. Ignition diesel oil consumption of approximately 2 liters/hour (0.63 gallons/hour).

Example III

- Passenger automobile with gasoline engine
- Cylinder volume 2l
- Motor converted to sole Gengas
- Driving on medium-good highway
- Load: 100 kg (220.46 pounds)
- Medium speed: 65 km/hour (40.39 mph)
- Fuel Consumption: approximately 15 liters/10 km (4.0 gallons/6.2 miles) Spruce or pine, moisture content approximately 12%

The intake pipe is provided with a gas mixer. To ignite the Gengas – air mixture, a certain amount of diesel oil is needed (that is, ignition oil). To assure ignition and an essential cooling of the injectors requires a fuel amount that typically is 20% of that required when the engine in an all-diesel operation is idling.

For the injection pump to give the same amount in the whole range of different RPM's, a simple adjustment to the injection pump is required. In certain instances, it requires a change in the pump itself.

Either vacuum or centrifugal regulators are used for RPM regulation of diesel-motors in fuel oil operation. In diesel-Gengas operation, however, RPM is regulated by a butterfly (valve) in the motor's inlet system. In instances where more exact demands on RPM are called for, the butterfly (valve) can be aided by a separate RPM regulator, as for example in tractors.

With the change to diesel-Gengas operation, the injection angle generally must be set earlier than with sole diesel operation to acquire the greatest power. The reason for this is the same as for carburetor-equipped engines: Gengas has a slower combustion speed and this must be accounted for.

For the setting of the fuel-injection angle, a compromise often must be made between the highest power and an engine that runs knock-free.

The earlier referred-to compression ratio of 10:1 in carbureted engines can be considerably exceeded in diesel-Gengas operation. Compression ratios of up to 16:1 often can be used without causing engine knocking.

EFFICIENCY AND POWER RELATIONS TO FUEL CONSUMPTION

The motor's efficiency and power greatly depend on the fuel's heat value. The effective heat value for Gengas from wood is 1200-1400 $Kcal/Nm^3$.

The heat value for the air-Gengas mixture is approximately 30% lower than for gasoline-air. The motor's power is reduced to the same extent for gasoline (low-compression) engines.

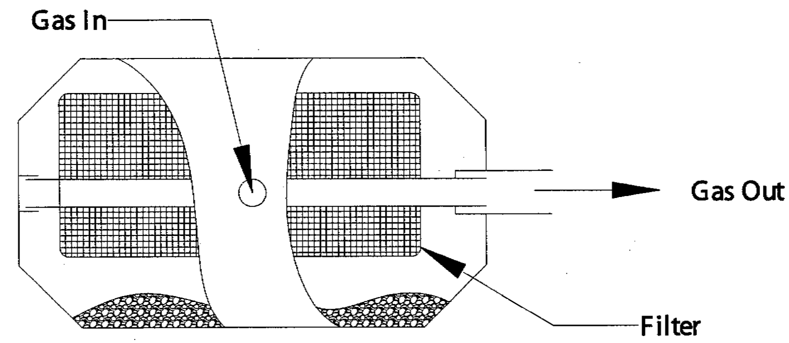
The fuel supply to the engine is lower in Gengas than liquid fuel operation. This partly is because of the relatively high temperature of the air-Gengas mixture and partly because of the lower pressure of the "Gengas' when it is sucked into the motor. This lower pressure is caused by the resistance in the generator, cleaner, and cooler.

The lower heat value of the Gengas, the lower saturation grade in the explosion chamber, and the slower combustion speed all combine to produce a loss of engine power of 40-50% in full Gengas operation of gasoline combustion engines.

In diesel-Gengas operation, the lost power will not be as great because the diesel engine will get a boost from the oil used for ignition purposes.

These factors: compression relation, ignition timing, injection angle, etc., make it impossible to give an exact loss of power. The power loss depends on the range of RPM. Generally, the higher the RPM, the more power is lost. Roughly, however, the power reduction with diesel-Gengas operation can be estimated at 20-30% of pure diesel operation.

Figure VII: Gas cleaner with movable filter (If necessary, this filter can be turned by hand.)

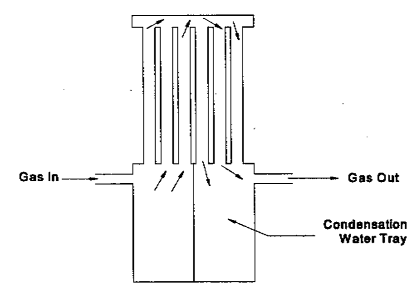


GAS COOLER

High-temperature gas has low weight by volume. It is necessary to cool the gas before it enters the engine, thereby providing a more compact fuel for the motor.

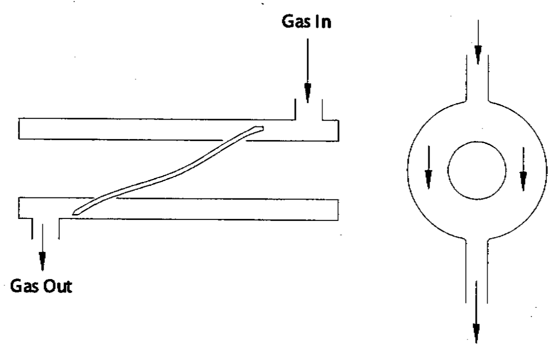
The hot Gengas also contains water vapor, phenols, and wood acids. These substances condense to liquids and fall out at the gas cooler. The cooler must therefore be equipped with a condensation tray that can be drained after use.[6] The radiator must be made so that it can be cleaned readily internally. Two different coolers are shown in figures VIII and IX:

Figure VIII: Conventional Cooler



[6] This could be a self-draining tray, or it could be similar to the tray under a modern refrigerator, which uses the heat from the unit to evaporate condensates.

Figure IX: New-type Cooler

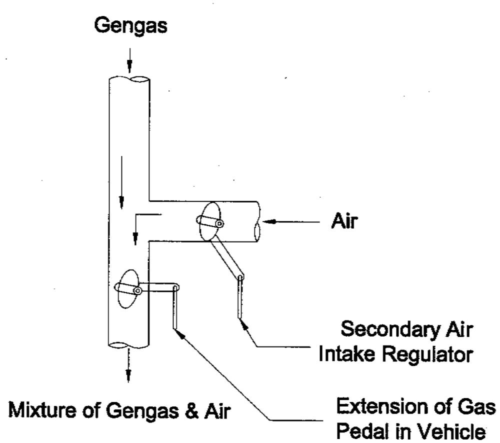


GAS MIXERS

The gas now is ready to enter the engine. However, it first must be mixed with a proper amount of combustion air. This happens in the gas mixer that normally is attached to the engine's gas port. To regulate the amount of air, it is best to have a manual regulator in the cab. An automatic blender would be very costly and complicated.

Figure X shows one type of mixer.

Figure X: Gas mixer



ADAPTATION TO DIFFERENT TYPES OF ENGINES

Engines that have carburetors besides electric ignition systems normally can be converted to Gengas without major changes. The changes normally include fuel systems, intake pipes, ignition adjustments, spark plugs, and compression ratios.

The engine's carburetor is replaced with a modified gas mixer.

The Gengas should be kept as cool as possible to accomplish better filling grade of the cylinders.

The Gengas has a lower combustion speed and the ignition must be set earlier than for conventional fuels to get better power.

The combustion temperature is increased with Gengas operation and the sparkplugs should have a higher heat rating (cool spark plugs) than with liquid fuel.

The Gengas has good knocking resistance. The octane rating for woodgas is approximately 100. Therefore, interference-free combustion can be had with compression ratios up to approximately 10:1. Deviance from this depends on different engine designs.

For motors with compression ratios considerably lower than 10:1, increasing the ratio may give considerable increase in power and efficiency.

A compression increase, however, causes an increased load that can increase the engine's wear if the top pressure for which the engine is designed is exceeded. The motor manufacturer could advise on this. (We suggest consulting with the motor manufacturer.)

Conversion of diesel motors to Gengas can be done in two different ways:

1. Complete generalized gas conversion, that is: spark plugs without additive liquid fuels.
2. Diesel-gas conversion with compression ignition, i.e., Gengas as main fuel, but diesel oil for ignition.

The first of the above choices is ignored in this instance as the change to be made to the motor is too considerable to be at all practical.

The second alternative, however, in which the compression ignition is kept, will make the changes much simpler and cheaper.

This method involves Gengas being supplied to the engine's air inlets, mixed with air, and sucked into the engine. The diesel oil is injected as usual at the end of the compression sequence. The compression heat ignites the diesel oil, which in turn ignites the mixture of Gengas and air.

For the Gengas to be ignited in this instance, a very small amount of diesel oil is required as ignition oil. Also, there is no need for increase in the amount with increased RPM. Consumption of diesel fuel therefore (in diesel – Gengas operation) is reduced to approximately 20% of fuel used in all-diesel operation.

The essential modifications to the engine in diesel – Gengas operation concern the intake pipe fuel system, RPM regulation, injection angle, and compression relation.