Project Report

Extensive Uses of Wood-Gas In Surface Transportation

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"Then in the summer of 1940, a law was passed . . . ordering us to stop all driving whatsoever. Every gallon of gasoline in the country belonged to the government . . . even the fuel in an individual citizen's car. Farmers couldn't get their milk to market, so they dumped what they couldn't use themselves . . . it was chaos for a while . . . a rationing plan was adopted, but there was not enough gasoline obviously. So in time, the country began to make the switch to wood gasification. I drove a 1936 Chevy for a living, and had to make minor timing changes to the engine."

This paragraph was extracted from a report written by a citizen in Europe, during the Second World War.

Acknowledgment

I hereby express my sincere gratitude to the US AID, especially Mrs. S. Samuels of the Guyana Mission, the Guyana Government and the staff at T.A.E.T. (University of Florida), for their guidance and cooperation.

Abstract

This project, entitled "Extensive Uses of Wood-Gas In Surf Transportation," describes the utilization of biomass gasification surface transportation, where all the energy in the gas that leaves gasifier, is utilized.

A system was developed for the petrol-powered river-crafts and roa vehicles to obtain their energy in one of these modes:

(a) Wood-gas

(b) Gasoline

(c) A mixture of wood-gas and gasoline

The fuel mode is obtained by selecting the position of a multi-position electrical switch, which provides the requirement instantly.

In addition to this, the river-craft will have the following facilities:

(a) Cooling or heating of a particular space

(b) Meal handling facilities

(c) Water distillation facilities

All of these auxiliary facilities obtain their energy from the wood-gas generator, without impairing the performance of the engine.

Contents

1 Introduction

Energy, the ability to do work, comes to our attention principally an input for economic development. Modern societies, depend on the production and use of large amounts of energy to achieve their projections.

Guyana, like many other developing countries, has had difficulties the petroleum fuel price escalation.

Unpredictable, diminishing petroleum supplies and increasing costs will encourage the acceptance of suitable alternative technologies. nation can decrease its reliance on petroleum fuels by increasing the use available alternative fuels and conversion technologies, in the transport sector.

Several reasons have caused this sector to be considered. These include the following:

(a) The transport sector has a significant energy need which could be jeopardized by increasing fuel prices and unreliable supplies.

(b) There is access to an alternative supply of fuel, large enough to meet its demand. Eighty percent of Guyana is estimated to be covered by forests.

(c) It is possible to obtain the technological expertise and equipment required to convert biomass to a more usable form.

(d) An estimated 95% of the energy used in surface transportation, is obtained from petroleum. Buses transport the largest percentage of public commuters. The freight distribution system is done mainly by trucks, while river-crafts are also employed in both areas.

People have adopted conventional energy to a wide use of personal and industrial uses. The most significant uses are for cooking, heating, cooling, illumination, transportation, communication and mechanical work.

The utilization of indigenous material to power the surface transport sector must now be adopted by the people. Wood-gasification can continue to supply the convenient 'liquid' fuel that we have come to depend on during the age of low-cost petroleum.

Biomass materials can be converted to a number of useful products, which are needed as energy sources. They can be converted directly by combustion, or to an economically transportable fuel by chemical, thermochemical or biological processes.

Gasification by the thermochemical method is suitable for surface transportation. Two broad approaches to gasification can be distinguished, i.e.:

(a) Gasifiers in which relatively large particles are subjected to inherently slow heating rates and long retention times, yielding gaseous products.

(b) Gasifiers in which rather finely divided material is heated rapidly, and the products are both gaseous and solid (char).

The gases produced through gasification, have a wide range of energy content and corresponding applications. Using gas with an energy content below 200 BTU/SCF may result in some loss of performance in engines or boilers.

Automobiles and river-crafts are primarily transportation devices. Temperature control in the passenger and storage compartments, will always be less important than the primary function of transportation. Therefore, the design considerations of these auxiliary systems, must not impair the smooth operation of the vehicle's prime-mover.

2 Gas Production

Solid fuels, such as biomass, have a limit to direct use in some circumstances, while on the other hand, gaseous fuels are preferred because they are clean burning and easy to distribute.

2.1 The Gasification Process

Gasification of solid fuels is accomplished in high temperature processes, similar to combustion, which converts the fuel to a gas.

Air-gasification is the simplest method, but gives a gas of low energy content, that must be close-coupled to its end-use of heat or mechanical power.

The mechanics of gasification vary widely in different processes, but each particle of biomass must undergo some or all of these stages:

(a) Drying

(b) Evolution of hydrocarbons

(c) Combustion of fixed carbons

In wood gasifiers, these processes proceed continuously in a vessel under controlled conditions. The first stage, drying, occurs at a temperature of 100°C, and locally, the temperature cannot rise until all the water has been driven off. Due to the low thermal conductivity of biomass, and the even lower conductivity of char, larger pieces can be burning on the outside while there is still moisture inside.

The breakdown of biomass material by heat to yield a medium energy gas, oil and char, is called pyrolysis. Biomass gasification produces hydrocarbon gases which are not ignited in the process. Additionally, some of the heat, CO_2 and CO produced by combustion, react as follows:

(a) Heat + wet wood $\longrightarrow$ dry-wood + H_2O

(b) Heat + CO_2 + C $\longrightarrow$ 2CO

(c) Heat + CO + H_2O $\longrightarrow$ CO_2 + H_2

The resulting gas which contains CO, H_2, CO_2, H_2O, CH_4 and other hydrocarbons (as well as N_2 when air is used), flows from the gas generator. This gas has some sensible heat, but most of its energy is carried as latent chemical energy.

Air-gasification of wood can be summarized by the following.

(a) Wood-gas contains sensible heat and latnet chemical energy, when it leaves the gas-generator.

(b) Inside the gas-generator, most of the sensible heat is reconverted to latent energy by evaporating water, reducing CO_2 and H_2O to produce CO and H_2, and volatilizing hydrocarbons from unburned wood.

(c) Products of the different reactions pass out of the gasifier as a gas with a latent energy of 100 to 900 BTU/SCF.

(d) Inorganic ash will remain after the reaction, and must be removed either continuously or in batches.

2.2 Gasifiers

Gasifiers, the reaction units, are in a seemingly bewildering variety. The principal types are as follows:

2.2.1 Air Gasification

(a) Updraft

(b) Downdraft

(c) Fluidized bed

(d) Suspended bed

2.2.2 Oxygen gasification

2.2.3 Hydrogen Gasification

2.2.4 Pyrolysis Gasification

2.2.5 Electrochemical Gasification

Other aspects are also considered, when wood-gasifiers are being examined. These are:

(a) Fuel type and form: chips, pellets, powder, etc.

(b) Ash type: dry ash or slag

(c) Pressure: suction, low-pressure or high-pressure

The simplest way to produce gas is by air-gasification, where air is used to oxidize the biomass and generate heat for the reactions. This process has the most immediate use with mobile or stationary engines, and those built for engine operation, generally operate under a slightly negative pressure, due to the intake stroke of the engine.

Updraft Gasifier

The simplest air-gasifier is the updraft (counterflow) type where air is introduced to the biomass through the bottom of the furnace. Rather high temperatures are generated initially where the air first contacts the char. The combustion gases immediately enters a zone of excess wood and char, where CO_2 or H_2O is reduced to CO and H_2 from the excess carbon.

As the gases rise to lower temperature zones, Fig. 1, they meet the descending biomass and pyrolyze the mass at temperatures of 200°C to 500°C. Continuing to rise, the gas contacts wet incoming biomass and dries it. The counter-flow of gas and biomass exchanges heat so that the gas exits at a lower temperature.

This type of gasifier has several disadvantages. A wide variety of chemicals, tars and oils are produced in the pyrolysis zone, and if allowed, will condense in cooler regions. For this reason, the gas is usually used in close-coupled modes in which the tars and oils will burn and contribute to the final energy content of the gas.

Downdraft Gasifier

The downdraft gasifier (co-flow), shown in Fig. 2, eliminates the tars and oils in the gas as produced in the updraft type.

Air is introduced through a set of nozzles, and the products of combustion are drawn downward through a bed of hot charcoal, extending towards the grate. This causes the oils and vapours in the higher regions to be cracked

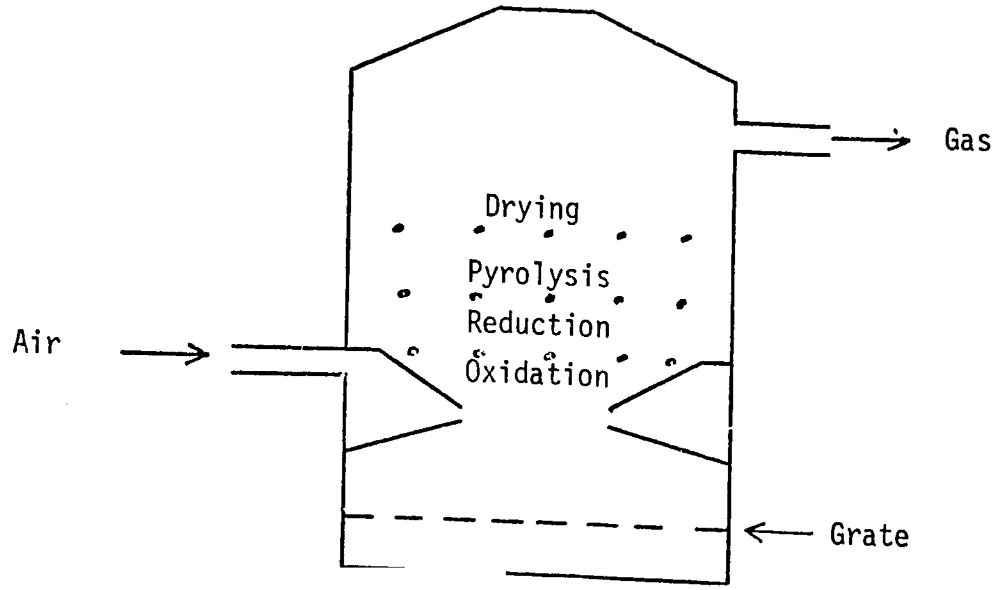


Fig. 1 Updraft Gasifier

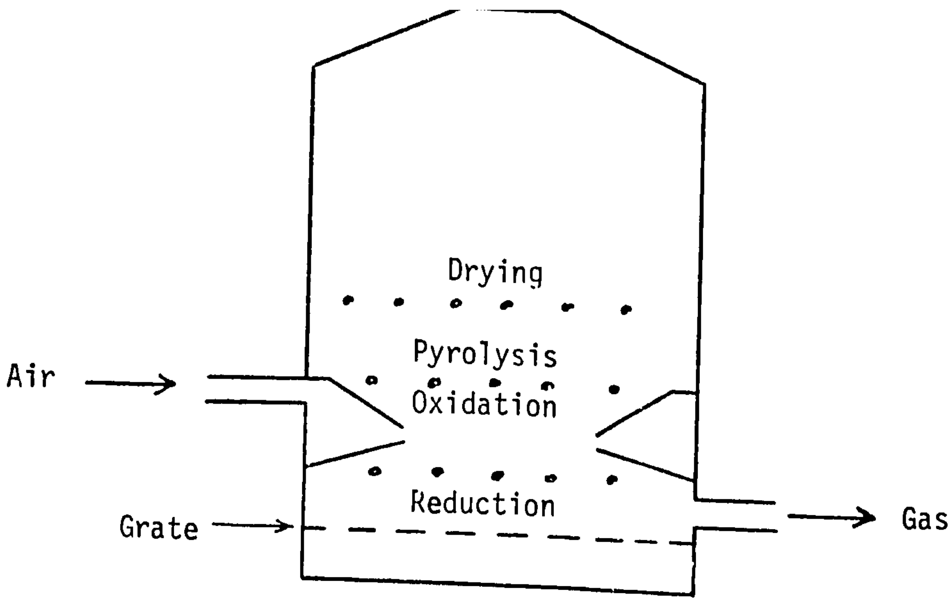


Fig. 2 Downdraft Gasifier

into gases.

The tars and oils are reduced to less than 10% of the value produced in updraft gasifiers, making the gas suitable for supplying energy to prime-movers or as heat sources.

Gasifier Parameters

The optimum operation of a gasifier depends on the construction, and the physical and chemical characteristics of the fuel used. These include:

(a) Provision for the condensation and removal of excess moisture.

(b) Proper shaping and sizing of the fuel stock to prevent bridging.

(c) Proper dimensioning of the combustion and reduction zones to produce high quality gas. If the combustion zone's diameter is too small, the gas production will be limited. If it is too large, the tar content of the gas will be increased.

(d) Ash removal systems must be facilitated, but the loss of char should be minimized.

3 Gas Refining and Uses

Gas produced from air-gasification of wood in the downdraft gasifier, consists of the following components:

(a) Carbon monoxide

(b) Hydrogen (gas)

(c) Carbon dioxide

(d) Methane

(e) Nitrogen

(f) Water

(g) Ash

(h) Soot

Some of these components are noncombustible, and their elimination required for producing the highest possible BTU value/unit volume of g Large concentrations of solids in the gas will cause operational probl and accelerate engine wear. These undesirables, such as solids, moist and heat, will be removed by the following systems. Removal of the heat allow the gas to have a higher latent heating value/unit volume will utilized for useful purposes.

Additionally, it is conveniently arranged for the driver to be able change from gasoline to wood-gas or a mixture of the two fuels, by t operation of a simple selector switch.

Fig. 3 shows the entire utilization of the sensible and latent heati values of the gasifier's output.

3.1 The Wood-Gas/Gasoline Fuel System

The design of this fuel system aims at allowing the operator of th petrol engine to be able to use wood-gas, gasoline or a mixture of th fuels, as required. The controls are electrically operated, and two differ ent electrical circuits with different types of components are made t control four solenoids.

Fig. 4 shows the layout of the modified fuel system with the fou

Gasoline/Mobile Wood-Gas Utilization System

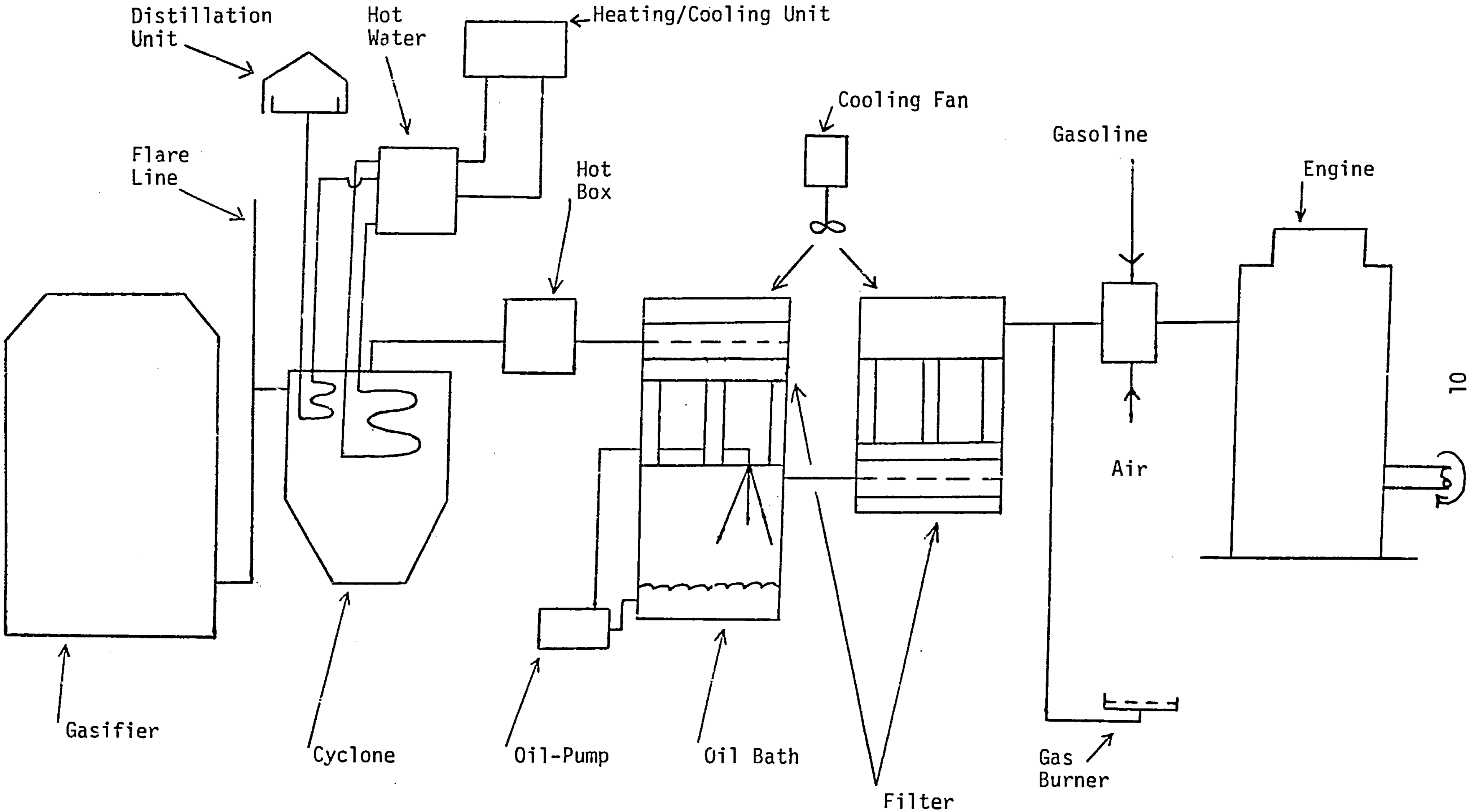


Fig. 3

solenoids that are either fully opened or closed.

Solenoid A - controls the flow of gasoline to the carburetor.

Solenoid B - controls the flow of air to the carburetor.

Solenoid C - controls the flow of air to the wood-gas mixing box.

Solenoid D - controls the flow of wood-gas to the mixing box.

Figs. 5 and 6 are the two different electrical circuits that con the operation of the solenoids.

In Fig. 5 a multi-contact switch is utilized. If the selecto positioned to use wood-gas, current will flow through contacts 1 and thereby energizing solenoids C and D, and allowing air and wood-gas to into the engine. Both quantities are regulated by butterfly valves conn ted to the throttle.

When gasoline is selected, contacts 3 and 4 are closed, causing so noids A and B to be energized. This allows gasoline and air to flow towa the carburetor and into the engine.

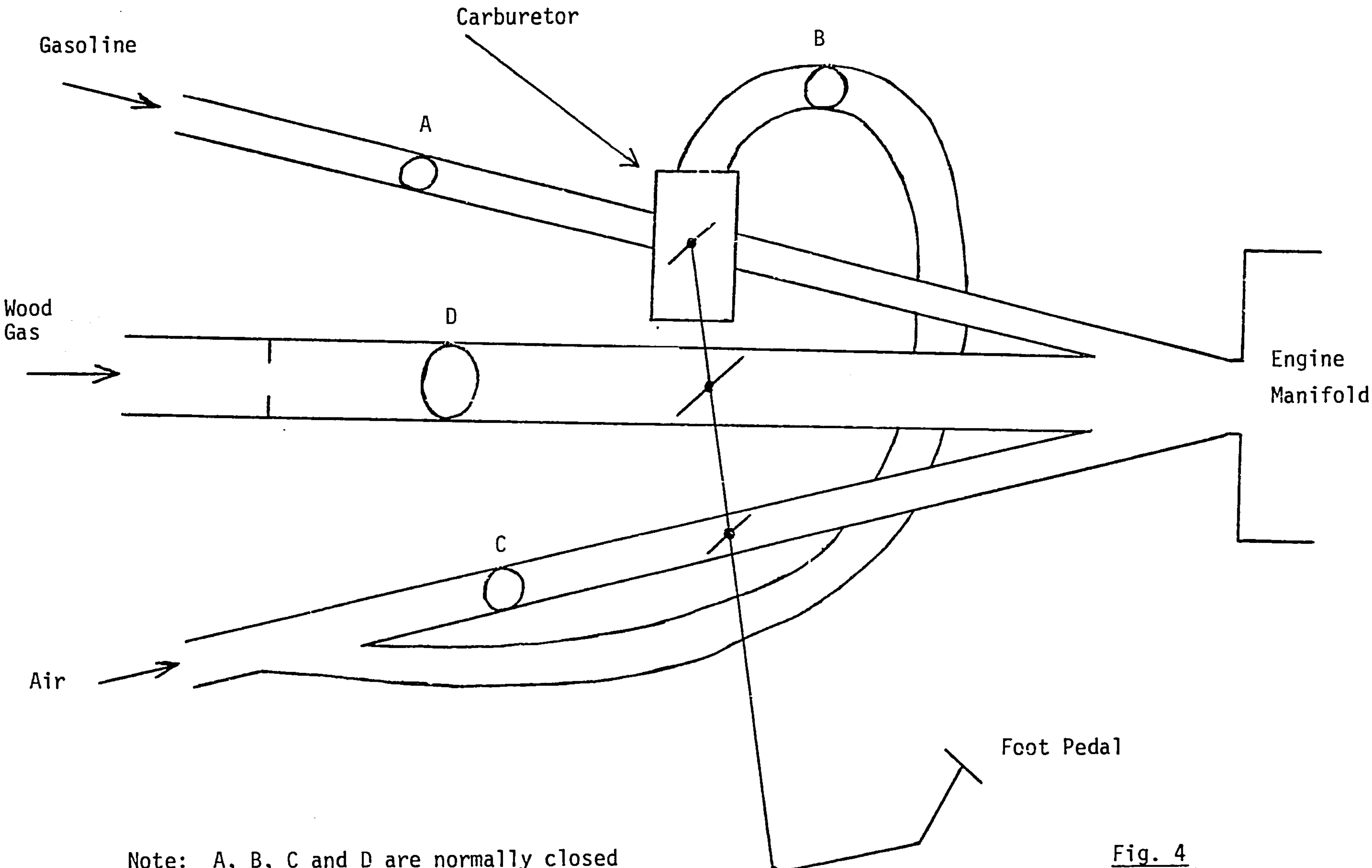
A mixture of the fuels is accomplished firstly by placing the switch the correct position. This causes contacts 5, 6, 7 and 8 to be clos resulting in all four solenoids being energized and a mixture of the fu flowing into the engine.

The alternative electrical circuit for the fuel selection contro Fig. 6, consists mainly of three relays and a simple three-position select switch.

When the selector is positioned to wood-gas, Relay 3 is energized, a current flows to solenoids C and D. Under this condition, wood-gas and a are allowed to flow into the engine.

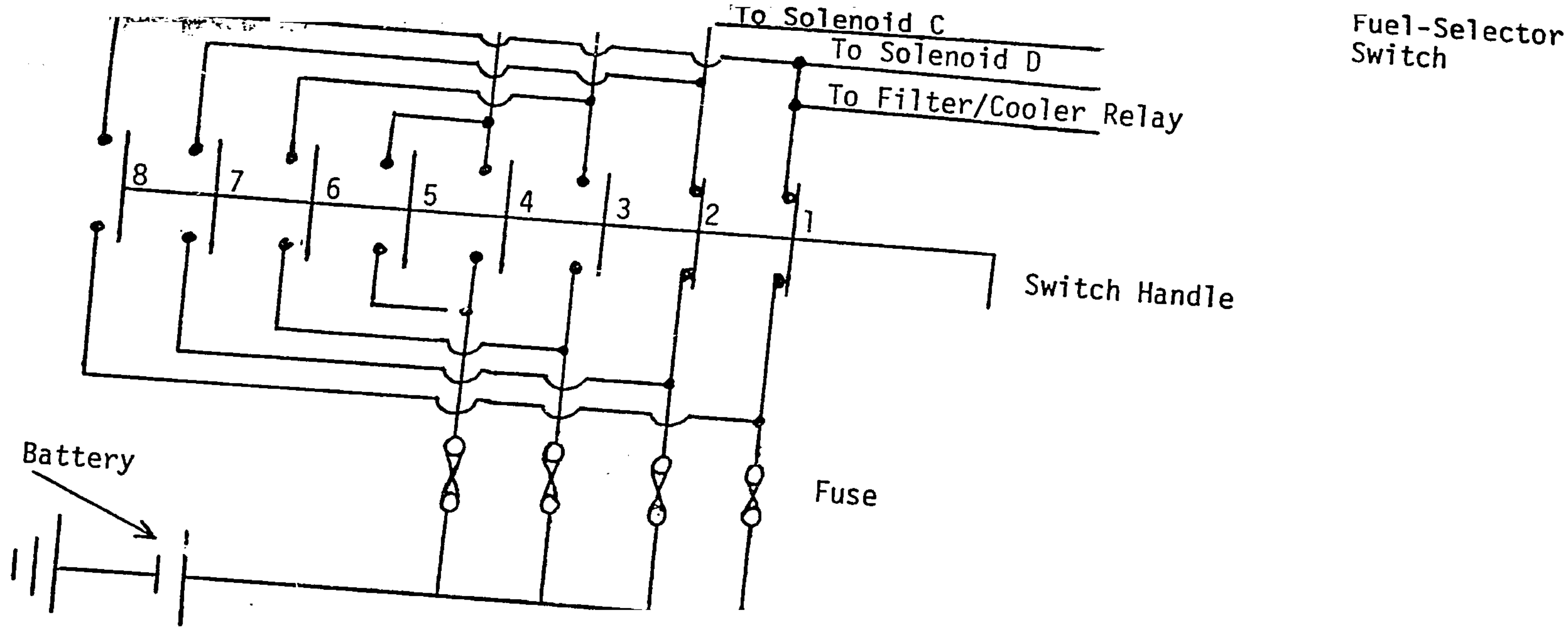
With the selector on gasoline, Relay 2 is energized, causing solenoi

Wood-Gas/Gasoline Fuel System



Note: A, B, C and D are normally closed solenoids

Fig. 4



Switch Position	CLOSED Contacts								Energized Solenoids				Solenoid Condition	
	1	2	3	4	5	6	7	8	A	B	C	D	Open	Closed
Wood-Gas	X	X									X	X	C & D	A & B
Gasoline			X	X					X	X			A & B	C & D
Wood-Gas & Gasoline					X	X	X	X	X	X	X	X	A,B,C D	nil

Fig. 5 **Fuel Electrical System**

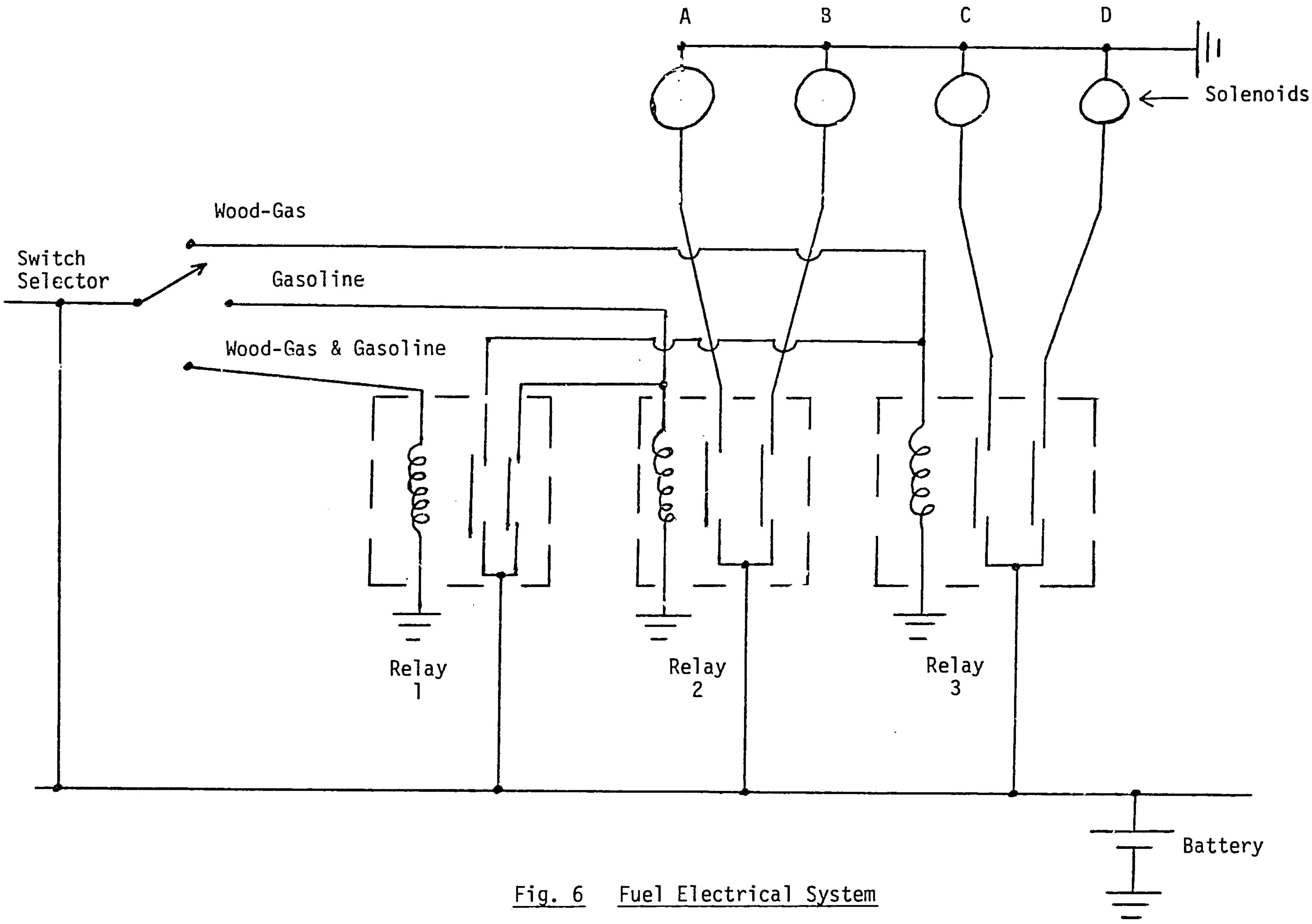


Fig. 6 Fuel Electrical System

A and B to be operative. Air and gasoline are now allowed to f
carburetor.

If a mixture of wood-gas and gasoline is selected, Relay
energized. This causes current to flow into the operating coils o
and Relay 3, making them energized. Under this condition, gasoli
gas and air are allowed to flow into the engine.

3.2 The Gas Preparation System

Gas produced in the wood-gas generator, is hot, and contains
ties. Accomplishing the removal of the impurities and lowering th
erature of the gas will make it denser and more suitable for our use

Fig. 3 shows the complete generation and utilization system.
the hot gas flows into an insulated cyclone where there are two
coils that are connected to a hot water tank. This high temperature
is used for heating or cooling of a particular space. (See space he
cooling system.)

The smaller set of coils supply water/steam to the water distil
unit. (See Water-Distillation System).

In the cyclone, heat is absorbed by the water coils and solid part
of the gas separated. The gas then flows into the hot-box, where it re
some of its sensible heat to the contents of the hot-box.

Finally, the gas passes through a filter/cooler/oil-bath unit be
being used as a fuel source. Fig. 7 shows the gas preparation system.
electrical control diagram of this system is only operational when the w
gas control solenoid (D) is energized. The operating coil of a relay

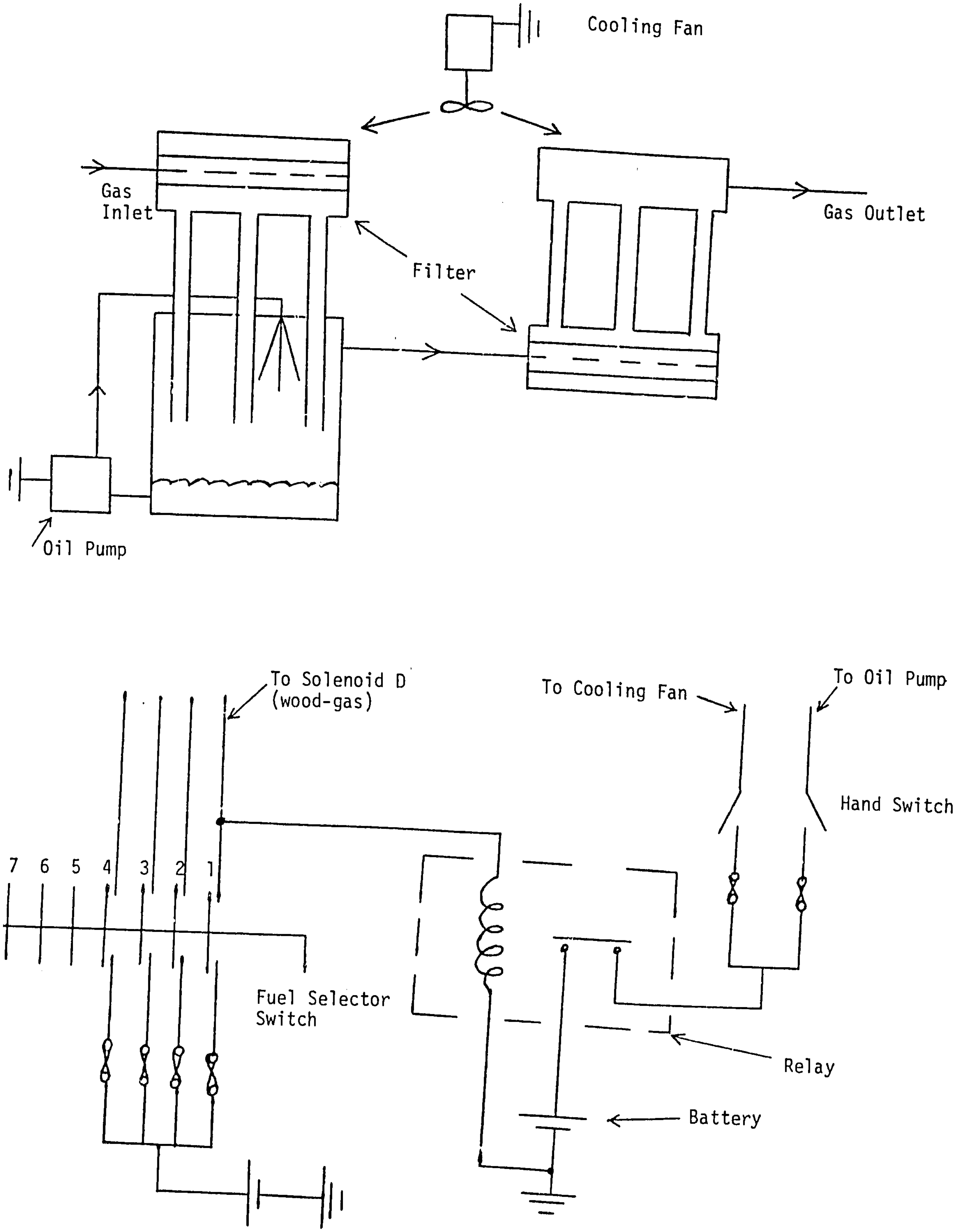


Fig. 7

Oil-Bath/Cooler Electrical System

connected to solenoid D and operates whenever D does. A contact relay causes current to flow to the oil-pump and cooling-fan motor single pole switches are placed in the circuit to allow for in control of the pump or fan, which can only operate when the wood-gas is being utilized. If these two switches are left in the ON positi oil-pump and fan will operate automatically as the wood-gas system is on.

3.3 The Space Heating/Cooling/Fan System

Surface transportation units are of major importance in any nation the heating or cooling of a definite space adds comfort. This temper control service is accomplished by utilizing the sensible heat of the gas, while not impairing the power of the engine.

The space utilized in a vehicle or river-craft by the air tempera control and refrigeration systems removes this amount of volume from production of revenue. Therefore, specially shaped lightweight compon must be used.

Fig. 8 shows the basic absorption cooling system that will be us The working fluid is a solution of refrigerant and an absorbent, where h from the wood-gas is added to the solution in the generator. As a resu the refrigerant is vaporized and a mixture of weak refrigerant concentrat is left behind. The heat is then removed from the vapor, which becom liquified in the condenser. The liquid refrigerant is then available f expansion from the high pressure position of the system, to the low pressu evaporator. At this point, vaporization of the refrigerant occurs a

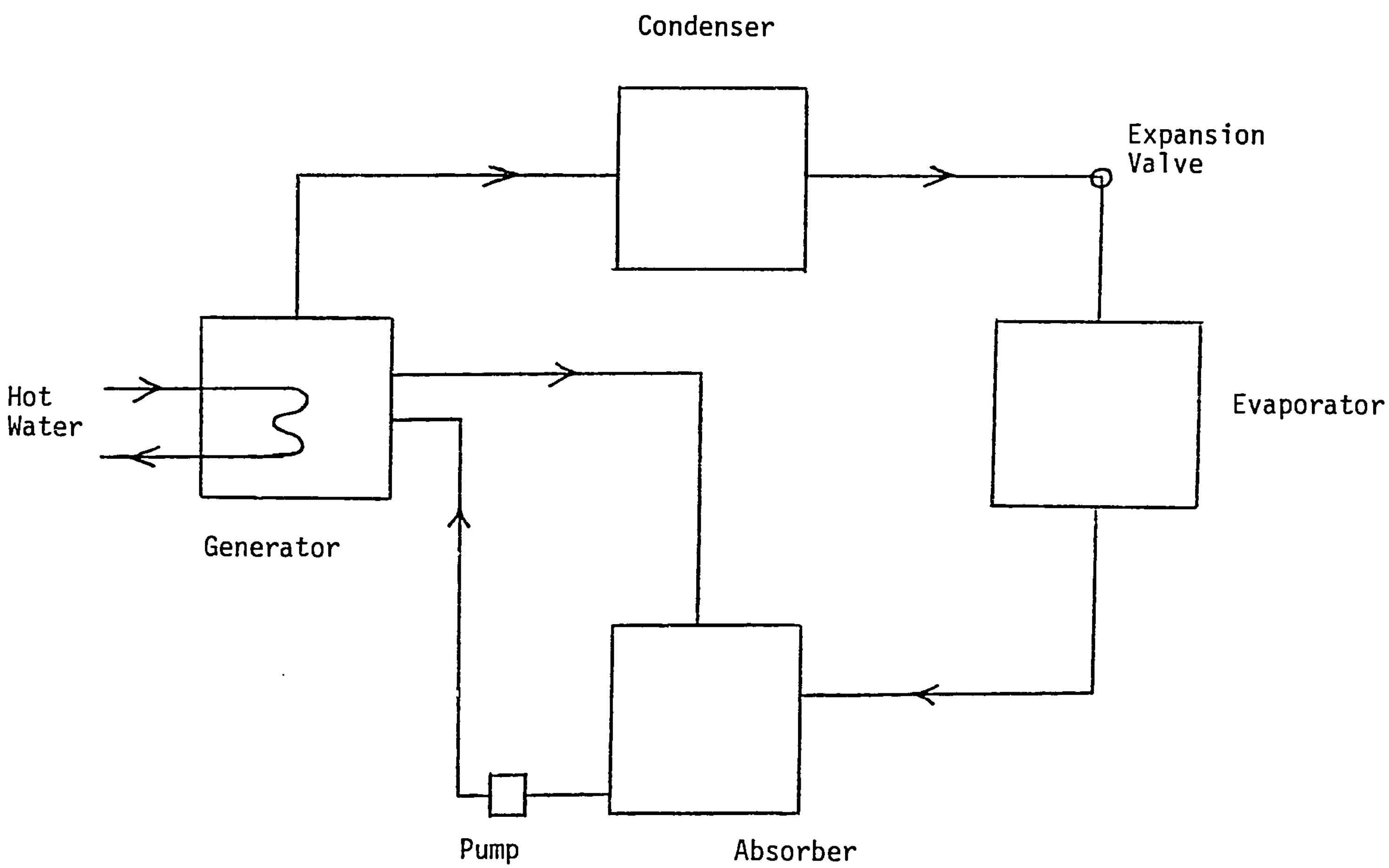
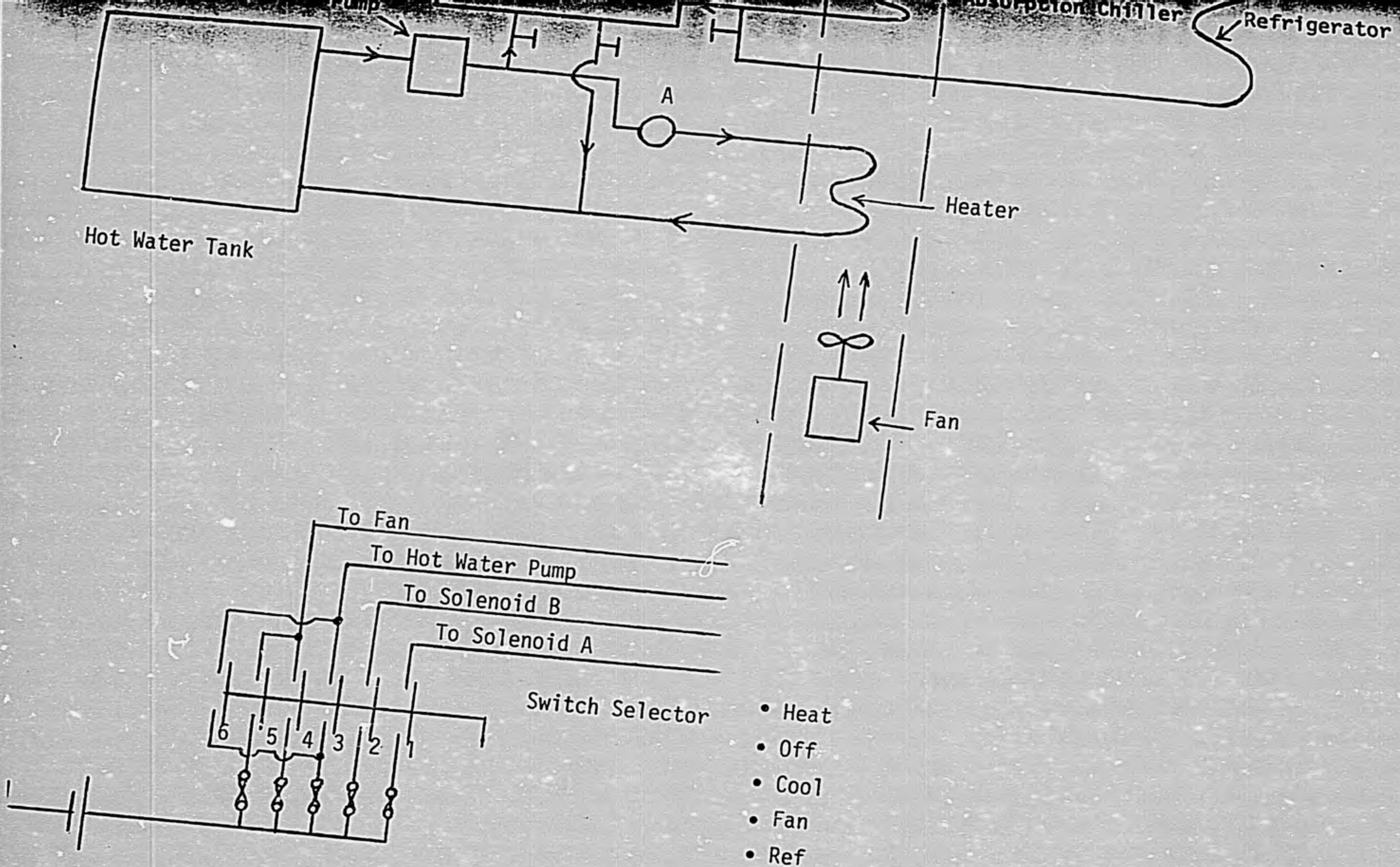


Fig. 8 Absorption Cooling System



Heat-Cool-Fan System

Fig. 9

Switch Position	Closed Contacts						Solenoid Condition		Motor Condition		Energized Solenoids	
	1	2	3	4	5	6	Open	Closed	Pump	Fan	A	B
Heat	X		X	X			A	B	run	run	X	
Off												
Cool		X	X	X			B	A	run	run		X
Fan					X				off	run		
Ref.						X			run	off		

<u>Heat-Cool-Fan-Refrigeration Electrical System</u>

cooling is achieved. The vaporized refrigerant is then recombined in the absorber to form the mixture from which it was initially obtained.

Applying this method of cooling at varying loads will be no problem generally, because control is easily accomplished by a control of the hot water flow.

For passenger vehicles, the cooling load is made up of the following:

(a) Passenger body heat

(b) Ventillation and infiltration

(c) Heat transmission through insulation, if any

(d) Heat generated from machinery

Systems required for naval use, i.e. on the river-crafts, should have more interest in cold-storage facilities. This is considered to be more like the large domestic refrigerator to be used by the crew, and not an all-refrigerated container ship. Perishable foods go aboard fresh, smoked, salted and frozen. For some of these, refrigeration is an absolute necessity.

Space is costly aboard ships, and many compartments at different temperature cannot be provided practically. Some factors that will influence the design of the system are:

(a) It must function under conditions of roll and pitch.

(b) Construction materials should be anti-corrosive.

(c) It must function under high impact shock conditions and vibration.

(d) It must allow speedy handling of the perishables with minimum exposure to the atmosphere.

The electrical diagram which controls the cooling/heating system, Fig 9, consists mainly of a multi-contact switch and two solenoids. When 'fan' is selected, contact 5 will be closed, and the fan alone will operate without the effect of hot water.

When the selector is placed in the 'heat' position, contacts 1, 3 and 4 are closed. This causes the hot water pump, solenoid A and the fan to be energized, causing hot air to be blown into the particular space. Solenoids A and B are normally in their closed positions.

Placing the switch in the 'cool' position, causes contact 2 to be closed and energizes solenoid B. At the same time, contacts 3 and 4 are closed to allow the hot water pump and fan to be run. The hot water now flows into the generator of an absorption chiller and back to the source.

In order for the refrigeration system alone to be working, the hot water pump alone is necessary. When placed at "Ref", the refrigeration system will operate. It can be seen that at position 'Heat', 'Cool' and 'Ref', the hot water pump is operative and under this condition, the evaporator of the refrigerator is supplied with refrigerant by two hand operated valves.

3.4 The Meal-Handling System

The provision of a meal handling system was done specifically for the large river boats. These vessels ply the rivers for long hours while accomplishing their task of surface transportation.

This facility consists of an ordinary gas burner, which uses some of the refined gas produced by the wood-gas generator (Fig. 3), and a hot-box. The hot-box is an ordinary cylindrical container that is installed between the cyclone and the filter/cooler unit. Using the hot-box, Fig. 10, will

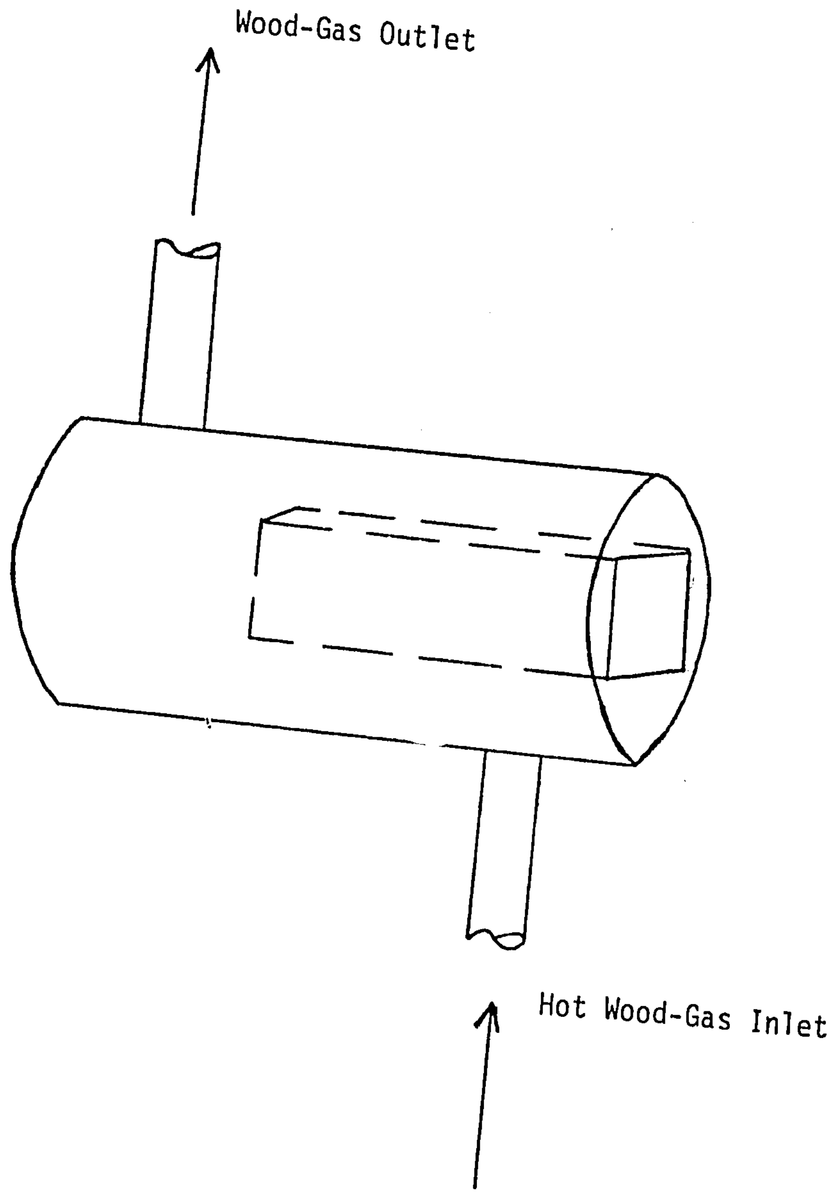


Fig. 10 Hot-Box

facilitate the presence of warm meals when the gasifier is in use. The inner chamber is air sealed, and the heat of the hot gas is transferred to the food containers by radiation and conduction.

Presently, meals are pre-cooked and taken to the vessels, or are prepared on the vessel by using LPG or electrical cookers that are connected to the vessel's generator.

3.5 The Water Distillation System

Distilled water is a commodity that is always in demand, and it can be produced in this system at no cost, while cooling the gas at the same time.

River boats do encounter rough weather, but this facility can be utilized in semi-rough weather or while being moored with the gasifier in operation. Hot water from the hot water tank, Fig. 3, is passed through a 'super-heater' coil and is allowed to flow into a broad bodied container that is covered by a plastic V-shaped roof.

The hot water/steam mixture in the wide-bodied container will allow evaporation, and the condensate will run off the sloping sides, .nto the collector.

4 General Observation

The establishment of a system which reduces or eliminates the use of petroleum fuels in the surface transport sector, must be considered as one that cannot be overemphasized in its importance.

As this system shows, it incorporates many uses of the wood-gas that immediately leaves the gasifier. Also, there is no objectionable noise or vibration produced by the gasifier and the other systems that depend on it.

The complete unit can be used on the river boats, but cooking and water distillation can be eliminated when the system is used on land vehicles.

River boats in Guyana operate for many hours during the day, and most of them do not have heating or cooling facilities, or if they do, the original source of energy is petroleum. Meals are either pre-cooked and taken to the vessel, or are prepared on the vessel by using LPG or electrical cookers that are connected to the vessel's generator. This system allows the meal to be prepared on the vessel, and also keeps it warm while the gasifier is being operated.

The water distillation unit can only be used when the river is relatively calm or while the vessel is moored. This ensures a regular supply of distilled water for the batteries and a possibility of earning revenue.

The components of the system must be built to meet the configuration of the available space. Equipment weight is more a problem because the trend is towards a lighter vehicle which reduces the power required for faster acceleration. Corrision resistant material or coatings must be applied where possible because the equipment will be subjected to weather conditions. Also, provision must be designed into the equipment to allow easy and quick maintenance.

Wood-gas systems are units to be proud of, and in reality there is a slight reduction in the power of the engine. But, this is compensated for when considering the cost and availability of wood or any other suitable biomass material.