Development of Biogas Conversion Kit for Diesel engine

1. Introduction

A substantial quantity of **wet** as well as **dry** biomass in various forms becomes naturally available in the rural areas. Efficient utilization/ recycling of biomass are a much needed intervention. Appropriate technologies for waste-to-energy conversion of this resource will go a long way in improving rural economy, ecology as well as energy self-sufficiency. Recycling of **moist** biomass such as animal and human excreta, domestic as well as agro-industrial organic waste through **biomethanation** is a highly cherished objective which will have universal applicability in the rural sector. In fact, this conversion process makes available renewable energy in the form of biogas as well as valuable biomanure in the form of slurry. It improves rural sanitation, promotes the adoption of organic farming and the use of animals more viable economically. In fact, even in the urban sector, such a conversion is becoming inevitable in context with large dairy clusters, poultry and other animal farms, sewage treatment plants and even in large hotels, hostels, food processing industries etc. where large amount of organic waste is produced and needs to be recycled in an eco-friendly manner.

It is essential to develop commercially viable technologies and rural entrepreneurship packages using these technologies to effectively harness locally available, renewable energy resources in the rural area to provide basic utilities for the rural population and to augment the entrepreneurial activity by value addition to agricultural and other RI products.

In order to integrate above-mentioned waste-to-energy conversion with widespread commercial activity, it is important to devise appropriate field worthy technologies not only for production but also for commercial **utilization** of biogas at scales suitable for the rural /urban sector.

2. Present Scenario

To facilitate large scale utilization of biogas, it is essential to have a suitable energy conversion device i.e. an **engine** to enable efficient conversion of biogas energy into required mechanical/ electrical forms. Presently biogas is being used at a limited scale in dual-fuel engines which partially (to the extent of 30-40%) utilize the diesel fuel. Hence a strong need to have a 100% biogas operated engines has been clearly identified. Small, stationary type diesel engines in the power range 5-20 hp are being universally used in rural areas for water pumping, gen-sets as well as for variety of agro-industrial processing applications. Bulk of these engines is D.I., vertical, single cylinder, **'Kirloskar'** type design engines operating at 1000-1500 rpm. After a careful assessment of the user needs, entrepreneurship possibilities and the current practice, it was established that the development of a simple kit to convert this spectrum of existing diesel engines into biogas/ producer gas engines will be highly desirable.

The manufacturers who supply gas generator are Cummins gas generator, Kirloskar gas generator Parkash gas generator etc. Cummins gas generators are available in large power range i.e. 125-500 kVA. Kirloskar and Parkash gas generator are available but their cost is very high. They supply the new generators only.

With the spurt in the use of CNG for heavy duty automobiles, the technology for conversion of high power vehicular diesel engines into spark ignition gaseous fuel engines has now come to the market. However, this technology is quite complex and a different strategy for downsizing and simpler technology is needed to carry out the conversion of small horse power rural application stationary diesel engines.

3. Need and Objective

To promote environmental protection, sanitation and use of renewable energy sources, the need for wide-spread 'Waste-to-Energy' conversion of the moist as well as the dry biomass is being felt increasingly. The moist biomass can be converted through bio-methanation and dry biomass through gasification. To facilitate this process in a commercial way, it is essential to efficiently utilize the resulting dilute gaseous fuels viz. biogas and producer gas. In order to obtain mechanical/electrical power from these gaseous fuels, it is required to develop low-cost technology to convert the existing engines into biogas/producer gas engines.

The work on converting the small-sized (3-5 kw range), single cylinder, stationary engines used widely for multiple rural applications into biogas engines was accomplished by IIT, Delhi in collaboration with Dr. G.P. Govil and suitable conversion kits were evolved. These conversion kits are slowly becoming popular with the biogas users who have also expressed the need for making available bigger biogas engines in the power range of 10-20 kw. This will greatly facilitate the commercial utilization of biogas and also promote sustainable rural industrialization.

It was also realized that old reconditioned automotive diesel as well as petrol engines can be gainfully converted to yield low-cost biogas/producer gas engines. This will also enhance the utility of these engines which can no more be used for automotive purpose.

Conversion kit was developed to convert diesel engines to 100% biogas engine in the range of 1.5kVA to 10 kVA and was installed at number of places where it is successfully working with. It had electronic ignition system with manual governing.

It has been seen that where large biogas generation is possible from Goshalas, vegetable/Fish mandi, Dairy cluster there is need for large size engine in the capacity of 5kVA to 20 kVA. Upto 5kVA manual governing was satisfactory but large engine needs automatic governing.

To utilize the larger volume of biogas available in Goshalas, vegetable markets, fish markets etc, the need was felt to improve the kit so that it can be fitted on larger engines. It was decided to develop the kit for larger engine say 20kVA and more. There is need to:

a) Develop an automatic governing system
b) Develop appropriate ignition system
c) Develop Air-Fuel mixture

The present development was carried out with this objective, presently focusing on conversion of an automotive diesel engine into a stationary, constant speed biogas engine.

4. Main Objectives

In the light of the above mentioned need, following objectives were kept in mind for developing a suitable conversion kit;

- To harness the vast availability of Bio-mass in rural parts and to make the Indian villages self-dependent for their energy requirements
- To improve the existing conversion kit for higher range engines.
- To reduce the dependence on scares fossil fuels for shaft power generation.
- As far as possible, efforts should be made to use standard components, easily available in the automotive engine component market.

5. Development Carried Out

The first step is to identify a suitable automotive diesel engine which after conversion would result into a 100% biogas engine producing about 15 kw. In this regard, it may be mentioned that whenever a diesel engine is converted into biogas engine, a de-rating of about 50% takes place while operating at the same speed.

The work involved in this project included the development of suitable technology to convert the compression ignition diesel engine into a spark-ignition biogas engine. It includes a suitable air-biogas mixing, metering and control device in place of the diesel fuel pump system. Then it needs incorporating a suitable ignition system for the multi-cylinder engine. In addition, a suitable governing system for maintaining constancy of speed was also needed.

The conversion kit technologies have been suitably selected /developed and the conversion technique has been evolved so that any such engine can be successfully converted in to an efficient biogas engine.

6. Selection of Appropriate Engine for Conversion

A survey was carried out choose the appropriate engine for conversion. The main players in the field are TATA &. Ashok Leyland who manufacture the large diesel engine/ CNG engine for automotive purposes. Automotive engine run on 3200 rpm at variable load and speed condition while for power generation the generator runs at 1500 rpm under variable load condition .The aim is to provide the conversion kit and to train the entrepreneur to convert the present reconditioned engine with the kit. It was decided to develop the conversion kit for TATA 407 series automotive engine which are prevalent in the market and their spare parts are also available in the market. They can be reconditioned easily. Specifications are given in Appendix I.

In the present case the automotive diesel engine chosen is Tata-407 truck engine and after converting it for constant speed (1500 rpm) biogas operation, it is coupled to a suitable generator forming a biogas genset. Needless to mention that with a minor adjustment, this conversion is also suitable for use with producer gas.

The converted genset has been adequately tested for its continuous field operation and output frequency stability etc.

7. Scientific/Technical basis for Present Development

The scientific principles and the resulting technology involved in the development of the present kit can be understood as follows.

A diesel engine operates on the principle of **compression ignition** of the diesel fuel. It has relatively higher compression ratio **(around 15-22)** and a heterogeneous mode of combustion. This mode of ignition is suited only for less volatile liquid fuels with low self-ignition temperatures. It also uses a fuel injection system which injects the liquid fuel into the engine cylinder at very high pressure towards the end of compression stroke. For gaseous fuels, it is essential to use the spark ignition (S.I.) mode, premix combustion, in which case the air and fuel are homogeneously mixed in an appropriate ratio and then inducted into the engine cylinder. Towards the end of compression, a spark is applied to initiate the ignition of the compressed charge. These engines also need throttling of air-fuel mixture to control the power output.
Normal Spark Ignition Engines which use gasoline fuel are restricted in compression ratio (8-10) because of knocking condition. However, in the case of biogas which contains methane as the fuel element, the self ignition temperature is quite high and much higher compression ratios can be used, which leads to improved efficiency. The conversion of a diesel engine into an equivalent spark ignition engine requires the following modifications/ retrofitting;

a) Removal of the fuel injection system (fuel pump and the injector)
b) Incorporation of a suitable spark plug in place of the injector by appropriate modification in the injector hole.
c) Modification in the engine intake system incorporating suitable mechanism for air-fuel mixing and control i.e. a gas carburetor system.
d) Retrofitting with cam shaft/ crank shaft a specially designed ignition system.
e) Modification in the combustion chamber/ compression ratio etc. (if needed)

The overall arrangement of the conversion kit is shown in the schematic layout in figure 1 depicting the above mentioned constituents.

Ignition system

Battery operated electronic ignition system has been used, as it is available in the market and suitable ignition advance has been carried out for biogas operation. It has been connected to camshaft with the help of housing .Fig 5.

Derating of the Engine

Automotive diesel engine used is TATA 497 which will produce 52.5 kW at 3200 rpm in the diesel mode. Since Generator operates at 1500 rpm, so in diesel mode the engine will produce around 30kW at 1500 rpm. Whenever a diesel engine is converted for use of a gaseous fuel, particularly a dilute gaseous fuel such as biogas which contains only 55-60% combustible constituents viz. methane and the rest is CO_2, there occurs necessarily reduction in the maximum power output of the engine. This is called derating. The main reason for this derating is as follows.

The engine in diesel mode takes in only air during the intake stroke while in the converted mode; it has to take in air and gaseous fuel. As a result, substantial part of the cylinder is occupied by the gaseous fuel reducing the air availability per cycle which controls the maximum fuel that can be burnt per cycle, in accordance with the required air fuel ratio. Further, because of difference in calorific values of diesel (about 43 MJ/Kg) and biogas (about 20 MJ/ Kg), the energy available in the charge per cycle is reduced. To some extent, reduction also occurs because of decrease in efficiency due to comparatively slower combustion of biogas. Even though, the air fuel ratio required for biogas is much lesser (around 6:1) as compared with diesel (around 20:1), which is an advantage for power output per cycle for biogas engine on the whole, it is usual to have the engine power derated to 50-55% of the original output as a result of this conversion.

8. Design and Technical Specification including Instruction for Use

The conversion kit mainly consists of the following sub assemblies/ components:

i) Spark plug (Fig.2)
ii) Gas carburetor assembly with governor (Fig.3)
iii) Speed pick up sensor (Fig.4)
iv) Ignition system assembly with H.T Coil (Fig.5)
v) Electronic control unit (Fig.6)
vi) Diaphragm operated gas valve (vaporizer) (Fig.7)
vii) The complete assy is shown in Fig.8

9. Performance

Diesel engine converted to biogas generator has been installed at IIT Delhi. Performance trials were carried out.

10. Cost Estimates

The reconditioned TATA497 engine with 20 kVA alternator will cost approx. 2.5 lakh only. It can vary depending on the cost of the reconditioned engine.

Appendix – I

Specification of Engine

Model	:	TATA 497
Type	:	Water cooled direct injection diesel engine
No. of cylinders	:	4 in line
Bore / Stroke	:	97 mm x 100 mm
Capacity	:	2956 cc
Maximum engine output	:	52.5 kw (71.3 PS) at 3200 rpm as per CMVR TAP 115/116
Maximum torque	:	200 Nm (20.4 mkg) at 1800-2100 rpm as per CMVR TAP 115/116
Compression ratio	:	19:1
Firing order	:	1-3-4-2
Air filter	:	Dry type
Oil filter	:	Full flow paper type
Fuel filter	:	Two stage pre and fine filtration
Fuel injection pump	:	In line type-MICO
Timing	:	with automatic advance
Governor	:	Centrifugal type variable speed
Capacity of cooling system	:	13 liters

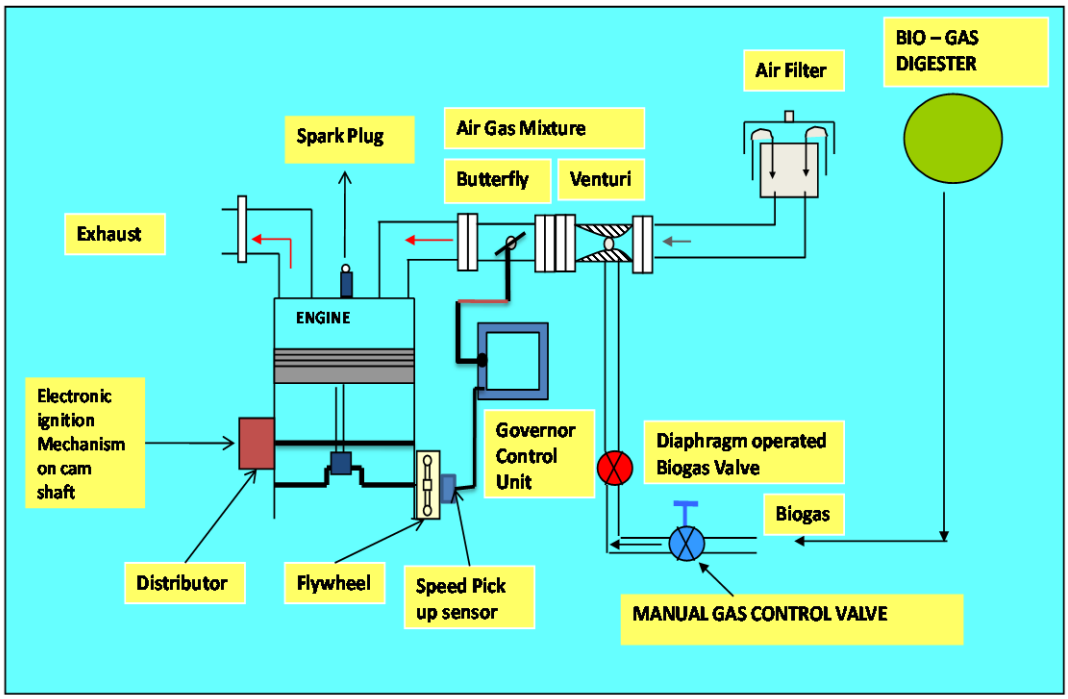

Fig. 1: Schematic diagram for conversion to biogas engine

Fig. 2: Engine with spark plug in head of engine

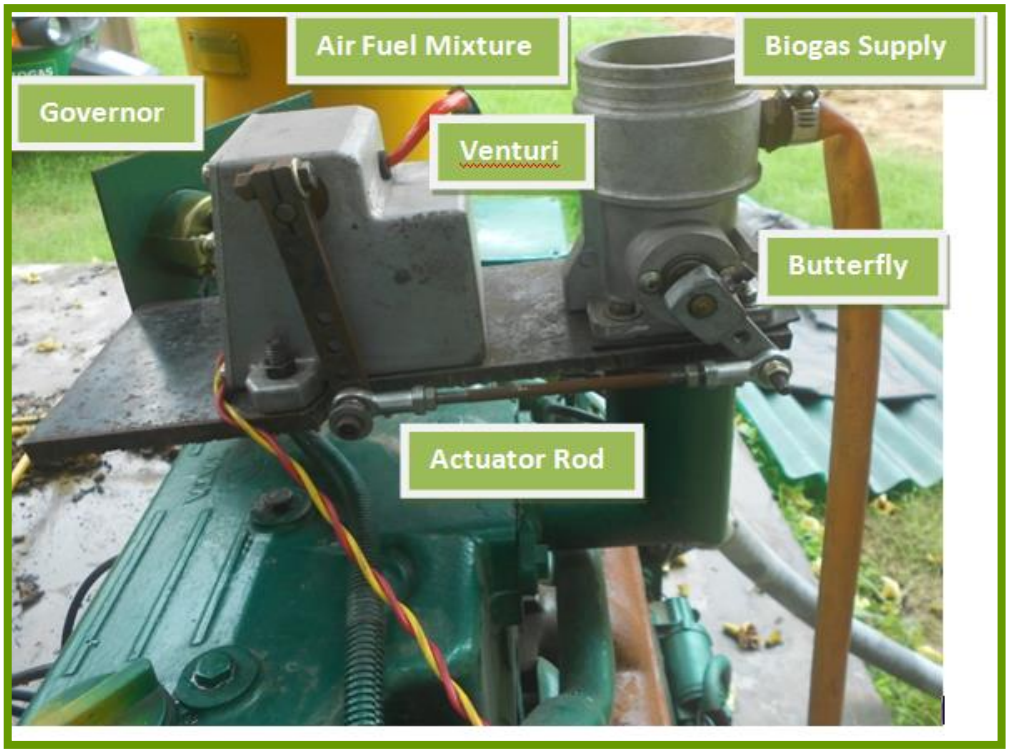

Fig. 3: Governor controlling the butterfly

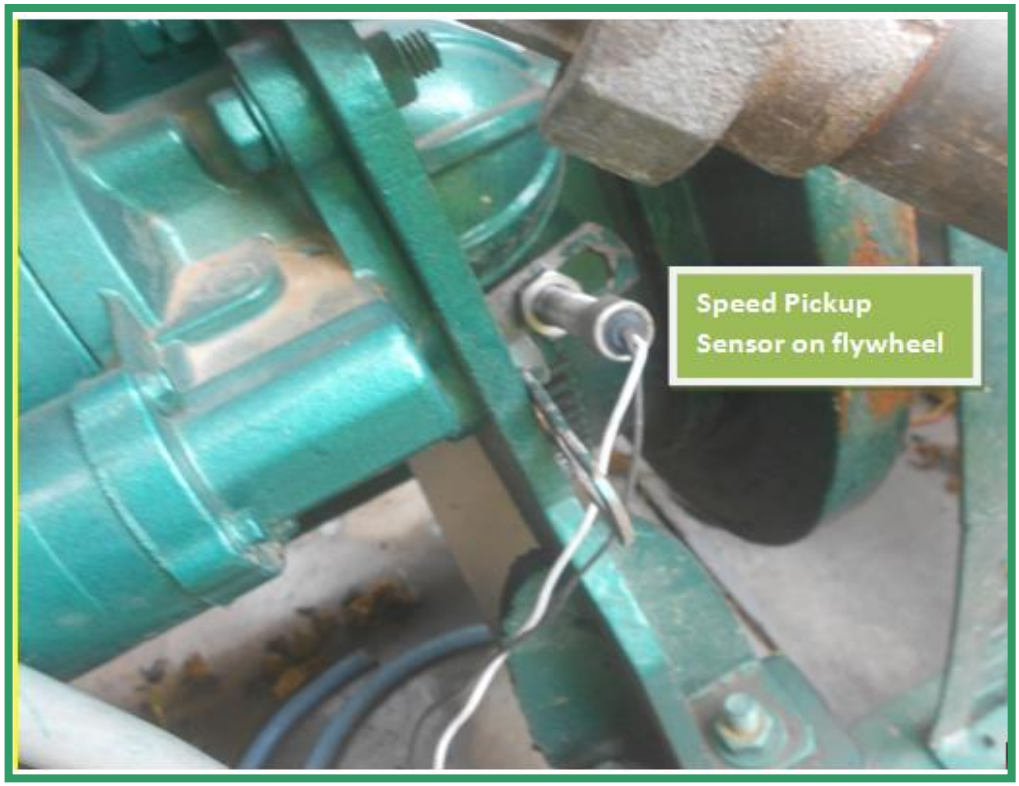

Fig. 4: Speed pickup sensor-signal to Governor

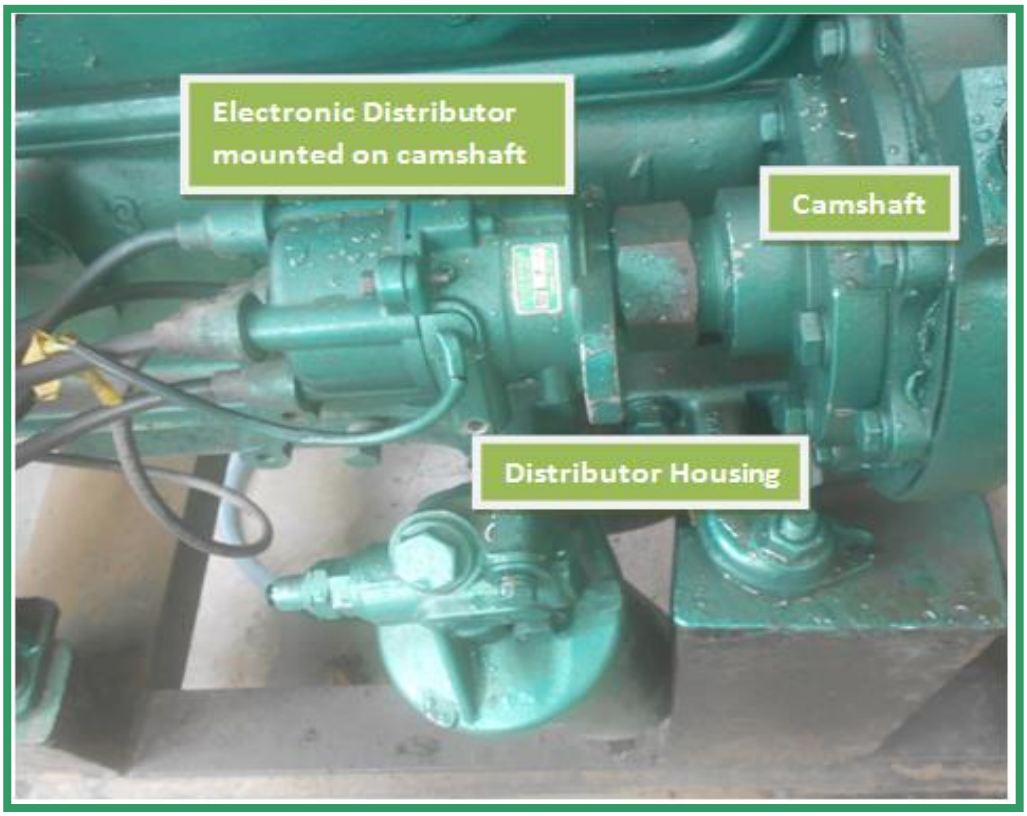

Fig. 5: Electronic ignition system mounted on cam shaft

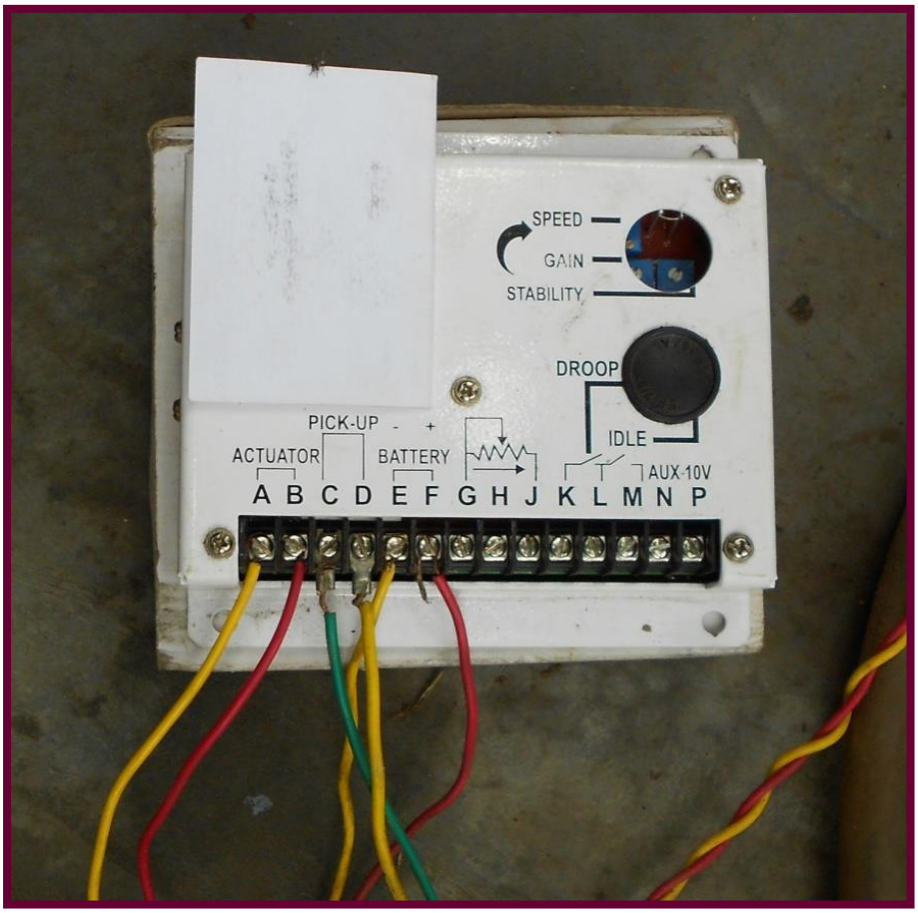

Fig. 6: Electronic Governor control unit

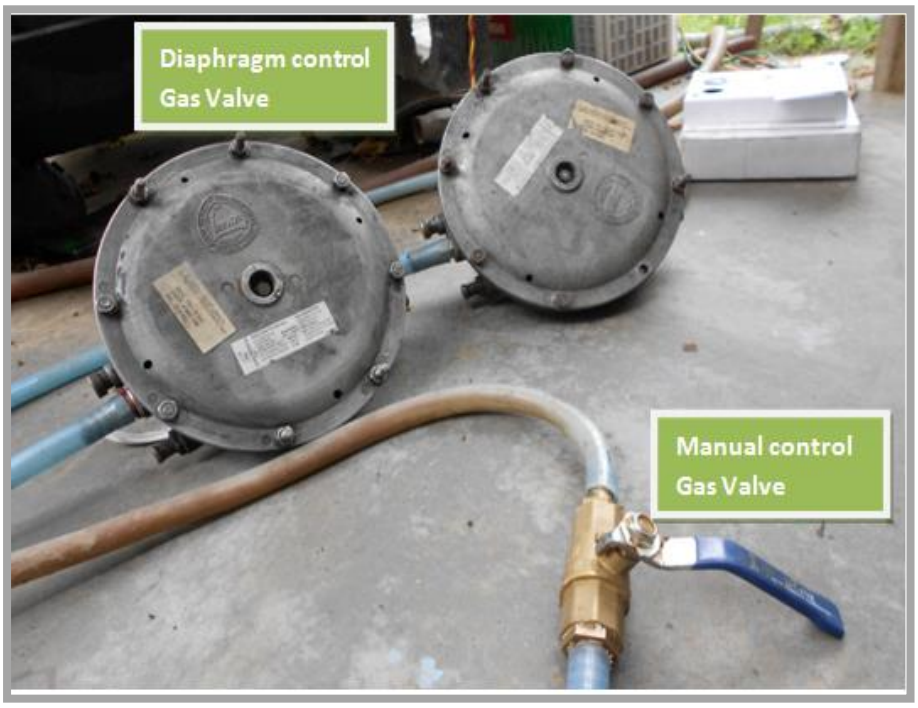

Fig. 7: Diaphragm control gas valve

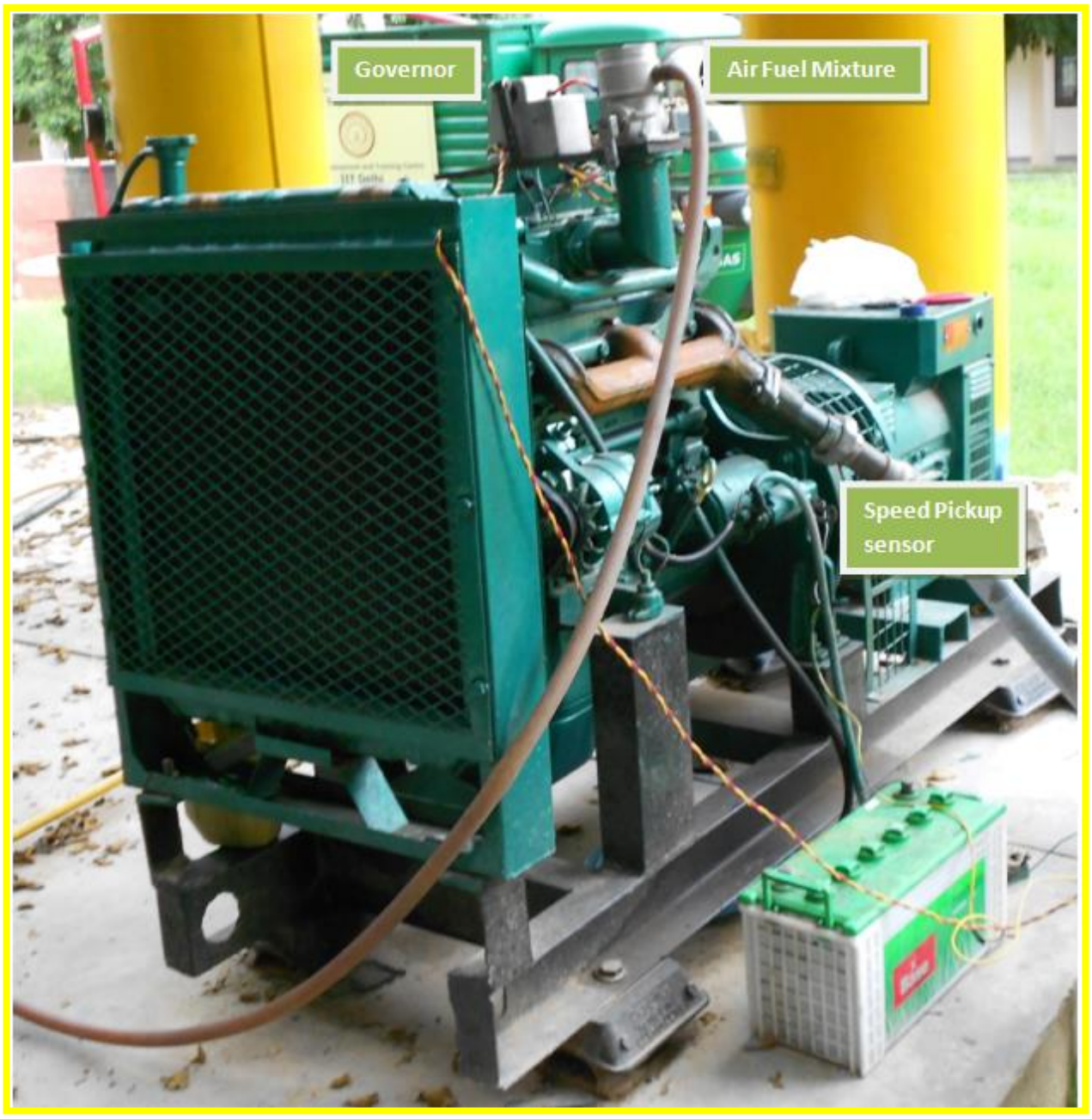

Fig. 8: 100% Biogas generator with electronic governing, electronic ignition system and air fuel mixture

11. Salient Specifications

In the present case Tata - 407 automotive diesel engine has been converted to run on 100% biogas at 1500 rpm and it produces a maximum of 15 kw. The fuel consumption is approximately $1m^3$ of biogas per kwh output. This implies that using an 85 m^3 capacity biogas plant one can obtain 10kw power continuously for 8 hours per day. With the conversion kit developed, any old automotive diesel engine (within the range of 10-20 kw of biogas output) can be easily converted.

General View of Biogas Genset converted from Diesel Engine

Air Fuel Mixing with Electronic Governor Mechanism

Distributors with H.T Coil