ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

School of Mechanical, Chemical and Materials Engineering

CONVERSION OF CARBURETOR FUEL SYSTEM TO THROTTLE BODY INJECTION SYSTEM

A project submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Automotive Technology

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CANDIDATE'S DECLARATION

We hereby declare that the work which is being presented in the project entitled "**Conversion of Carburetor Fuel System to Throttle Body Injection System**" in partial fulfillment of the requirements for the award of the degree of Master of Science in Automotive technology is an authentic record of our own work carried out from February,2016 to june,2016 under the supervision of N.Ramesh Babu, Associate Professor, Department of Mechanical and Vehicle Engineering, Adama Science and Technology University, Ethiopia.

The matter embodied in this project has not been submitted by us for the award of any other degree or diploma. All relevant resources of information used in this project have been duly acknowledged.

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This is to certify that the above statement made by the candidates is correct to the best of my knowledge and belief. This project has been submitted for examination with my approval.

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SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALS ENGINEERING

DEPARTMENT OF MECHANICAL AND VEHICLE ENGINEERING

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ACRONYMS AND ABBREVIATIONS

TBI	Throttle body injection
CFI	Central fuel injection
EGI	Electronic gasoline injection
PGM	Port gasoline modulator
EFI	Electronic fuel injection
PFI	Port fuel injection
CPFIS	Central port fuel injection system
GDI	Gasoline direct injection
MPFI	Multi point fuel injection
SFI	Sequential fuel injection
CRTBI	Common rail throttle body injection
CR	Common rail
TBFI	Throttle body fuel injection
RPM	Revolution per minute
DC	Direct current
ml	Milliliter
SME	Small micro enterprise
BSFC	Brake specific fuel consumption
CC	Cubic capacity

ABSTRACT

Most modern vehicles are fitted with fuel injection systems that allow the engine work more efficiently and usually result in greater power and clean exhaust emission. This system work by forcing pressurized fuel through a tiny nozzle that atomize the fuel, allowing it to burn more quickly when mixed with air. In Ethiopia (Addis Ababa) interest on light duty vehicles as the main choice of transport for workers and give service to the society has increased recently, mainly due to the increasing fuel price. The majority of the light duty vehicles, especially those with cubic capacity less than 1250cc, are equipped with the conventional carburetor system. Small gasoline fuelled engines operating using carburetor system, however, suffers from low operating efficiency, apart from producing hazardous emissions to the environment. In light of this situation, in this project an attempt was made to develop a retrofit fuel injection kit to address such challenges of meeting power requirement of a small cubic capacity prime mover and also in complying with the emissions regulations currently put in place. Throttle body injection helps in improving engine performance by assisting in well mixing of air and fuel and by promoting combustion. Conversion of carburetor fuel system in to TBI system has the following advantages such as improves fuel economy, reduces environmental pollution, improving engine performance. So in general, the society, automotive industries, vehicle owners and the country as a whole get benefitted. In this the electrical circuit of the throttle body fuel injection system was designed by protues software, showing all the electrical components clearly in the layout. The required components like fuel pump, common rail, fuel return line, injectors etc. are collected from the local market. Components were modified as per the requirement and assembled on the board which can be used as a teaching aid for demonstration of the working principle of TBI system. From the test conducted it was found that the kit was working properly. In addition, the engine test was conducted to compare the performance of TBI system with carburetor fuel system.

Keywords: *Throttle body, common rail, fuel pump, fuel return line.*

1. INTRODUCTION

1.1. Background of the study

the most important facilitate technologies being low cost, series production TBI (throttle body Fuel Injection).During the past years, drop in pollution emissions of more than 90% have been demanded of and achieved by the automobile industry

Like a carburetor, it provides the engine with the correct air fuel mixture for a specific operation condition. Single point injection system is called throttle body injection system (TBI) which has the pulsation damper to regulate fuel line pressure by bleeding off excess fuel back to the tank. Before the new model was made the carburetor engine giving service to the society even if they have a problem on their exhaust gases and high speed engine performance [1].

1.1.1. Carburetor

The purpose of the carburetor is to supply and meter the mixture of fuel vapor and air in relation to the load and speed of the engine. Because of engine temperature, speed, and load, perfect carburetion is very hard to obtain. The carburetor supplies a small amount of a very rich fuel mixture when the engine is cold and running at idle. With the throttle plate closed and air from the air cleaner limited by the closed choke plate, engine suction is amplified at the idle-circuit nozzle. This vacuum draws a thick spray of gasoline through the nozzle from the full float bowl, whose fuel line is closed by the float-supported needle valve. More fuel is provided when the gas pedal is depressed for acceleration. The pedal linkage opens the throttle plate and the choke plate to send air rushing through the barrel. The linkage also depresses the accelerator pump, providing added gasoline through the accelerator-circuit nozzle. As air passes through the narrow center of the barrel, called the "venturi", it produces suction that draws spray from the cruising-circuit nozzle. The float-bowl level drops and causes the float to tip and the needle valve to open fuel was pass through the fuel line to the carburetor.

To cause a liquid to flow, there must be a high pressure area (which in this case is atmospheric pressure) and a low pressure area. Low pressure is less than atmospheric pressure. Since the atmospheric pressure is already present, a low pressure area can be created by air or liquid flowing through a venturi. The downward motion of the piston also creates a low pressure area, so air and gasoline are drawn through the carburetor and into the engine by suction created as the piston moves down, creating a partial vacuum in the cylinder. Differences between low pressure within the cylinder and atmospheric pressure outside of the carburetor cause air and fuel to flow into the cylinder from the carburetor [1].

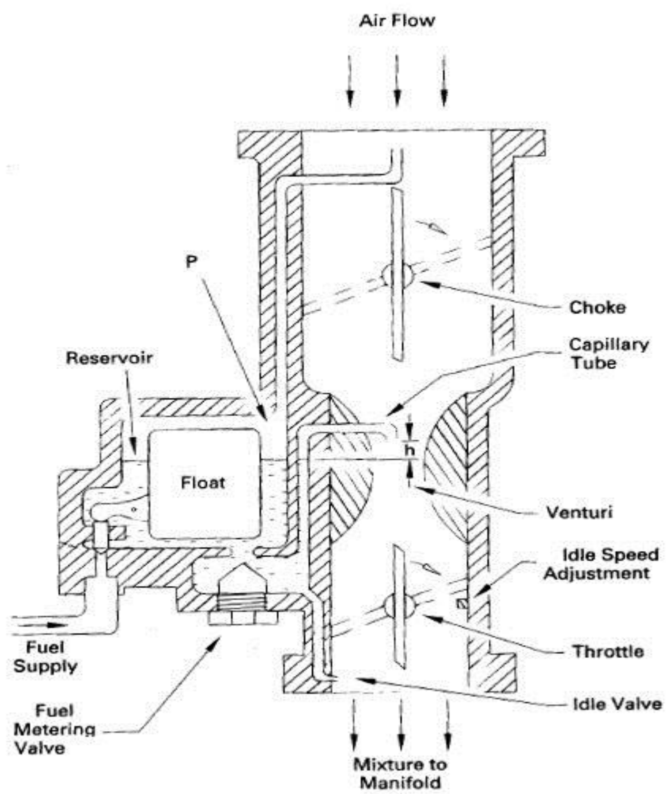

Figure 1: Carburetor systems and their components

As the air enters the tube, it is accelerated to high speed at the venturi tube because of change in the areas. A pressure difference is created between the reservoir and the venture tube By Bernoulli's principle; this causes the fuel to rush in to the venture tube. As the fuel moves down the tube, it breaks up into very small droplets, carried by the high velocity air and in course both gets mixed. The mixture then through the intake manifold is pass through the cylinder by the intake valve at the desired time [12].

1.1.2. Factors affecting carburetor

Carburetor ice is the term for a condition where ice accumulates in the throat of a carburetor. Its most commonly associated with piston-engine light aircraft. The Ninja 250 is susceptible to carburetor ice in certain conditions. Fuel injected engines are practically not susceptible to icing up, although it's theoretically possible to accumulate some ice under extremely adverse conditions. For the Ninja 250, it appears that a range of about 20° F to 50° F (-7° C to +10° C) with visible moisture (fog or rain) can cause carburetor ice. Pod-style air filters may exacerbate the problem, since they can allow more moisture into the carburetors than the stock air box, however the shorter intake tract may yield some benefits when considering strictly atmospheric moisture.

Factors affecting carburetor icing include:

- Ambient Temperature
- Dew point
- Relative Humidity
- Altitude
- Throttle Opening (related to riding style)

For example, it has been shown that noticeable carburetor icing will occur at 450′ ASL approximately 90% of the time when

1. The Ambient temperature is less than 6°C above the dew point
2. The current temperature is below 6°C (43°F), and
3. The relative humidity is high (> 80%), or it is raining, and
4. Riding in city traffic (moderate throttle openings)

Additionally, for the same altitude, it has been noted that if it is snowing big fat snowflakes, carburetor icing will almost certainly occur; whereas little tiny powdery snow flakes indicate that it will probably not occur. Larger snowflakes generally correspond to higher relative humidity [12]. Carburetor ice is a problem because it constricts the carburetor, choking off the engine in a very literal sense. As the ice builds up, it closes off the passage through the carburetor, reducing the fuel/air mixture the engine can get. Under appropriate conditions, carburetor ice can entirely kill the engine. Even before that, it reduces the engine's performance enough to be dangerous in any real-world traffic situation. Carburetor ice is closely analogous to asthma in a living creature.

1.1.3. Fuel Atomization and Vaporization

In order to change gasoline from a liquid into a combustible form, first the liquid fuel enters the carburetor, where it is sprayed into incoming air and atomized i.e. reduced to mist. The resulting air-fuel mixture then moves into the intake manifold, where the mist is changed into vapor. Vaporization takes place only when the fuel is hot enough to boil. Since the intake manifold pressure is much less than atmospheric pressure, the boiling point of gasoline drops when it enters the manifold. Heat from the intake manifold floor combines with heat absorbed from air particles surrounding the fuel particles to begin vaporization. It is also helped by raising the temperature of the intake manifold, since the higher the temperature, the more complete is the vaporization. This heated area in the intake manifold is called a hot spot. When there is poor vaporization, too much liquid fuel reaches the cylinders. Some of this extra fuel is given off as unburned hydrocarbons, and some wash away oil from the cylinder wall causing engine wear. The rest is carried past the piston rings blow by gases. Sometimes there is poor vaporization, which may happen due to several factors as follows.

(i) A too low mixture velocity.

(ii) A cold manifold or low manifold vacuum. (Hi) Cold incoming air.

(iv) Insufficient volatility of fuel.

(v) Poor manifold design.

(vi) Low flow capacity of carburetor [4].

1.2.Statement of the Problem

Ethiopia is suffering with many carbureted vehicles on the road which are less efficient causing higher pollution, consuming more fuel. It is leading to spending of more foreign exchange in importing of more fuel. This project, aims to develop throttle body injection system, which has a capability to control output engine performance based on given operating condition. TBI helps in improving engine performance by assisting in well mixing of air and fuel and by promoting combustion. This project precisely addresses the above-mentioned problem.

1.3. Objectives

1.3.1. General objective

The General objective of this project is to convert carburetor fuel system to throttle body fuel injection system for gasoline vehicles.

1.3.2. Specific objectives

The specific objectives of the project are to:

- Collect the required components necessary for construction of TBI system
- Modify the components as per requirement
- Assemble the components to prepare a prototype on the frame
- Prepare the electrical circuit required
- Demonstrate the functionality of the TBI system.

1.4. Scope of the project

The project is delimited to development of a basic working model of TBI system by modifying the carburetor system using the available components.

1.5.Limitations of the study

Problems encountered while doing this project work are the following:

1. Finding the existing intake manifold and high-pressure injectors was a challenge.
2. Because high-pressure lines are very small, it was a big challenge to modify the connectors by welding.
3. The vehicle used for testing is not in good condition.

1.6. Significance of the project

Conversion of carburetor fuel system in to TBI system has the following significances.

- Improves fuel economy
- Reduces environmental pollution
- Improves engine performance

So in general, the society automotive industries, vehicle owners and the country as a whole get benefitted.

1.7. Project outline

This project is organized into five chapters to completely cover the whole research project activities. The following paragraphs describe each of the following chapters. Chapter 1 background of the project is, in a multi cylinder engine with a carburetor, it is difficult to obtain a uniform mixture in each cylinder. Chapter 2 provides literature review on the principle of throttle body fuel injection. It includes the overview to reduce the exhaust emission by controlling the amount of fuel injection. It also discusses TBI system design with its overall block diagram, and the study on required parameters with critical components in designing and development of TBI. Chapter 3 materials and methods of TBI. Chapter 4 results and discussions. It includes the overview of test and its subsystems. Discussion was done for both theoretical and experimental activities. Chapter 5 conclusion and recommendation of the project. It also provides the recommendation for future study.

2. LITERATURE REVIEW

2.1. Introduction

The basic goal of the automotive industry is to develop vehicle with high power, low specific fuel consumption, low emission, and low maintenance and better drive comfort. With increasing vehicle pollution, the role of the vehicles in causing air pollution has been increasing significantly day to day. Since the engines with carburetor do not hold the air fuel ratio close to the stoichiometric at different working conditions, catalytic converter cannot be used in these engines. Therefore these engines have high emission values and low efficiency. Throttle body Fuel Injection (TBI) systems instead of fuel system with carburetor have been used since 1980's. In fuel injection systems, induced air can be metered precisely and the fuel is injected in the manifold to air amount. Fuel systems without electronic control it is impossible to fulfill with the increasingly emissions legislation. TBI fuel injection is a type of fuel injection system where the fuel is injected into the throttle body. The throttle body fuel injection system, or TBI as referred to by Ford Company, works using a single injector. The throttle looks like a carburetor without the fuel bowl, the metering jets or the float [1].

2.2. Definition of throttle body

A throttle body is the intake system component in fuel-injected engines that the driver controls with the accelerator. Although the accelerator is commonly known as a "gas pedal," it doesn't actually control the delivery of fuel to the engine. Instead, it actually controls the flow of *air*. In fuel-injected engines, it specifically controls the angle of a butterfly valve inside of a throttle body. In some ways, a throttle body is similar to a carburetor. This is particularly true in vehicles that use single-point fuel injection, where the fuel injector is built into the throttle body.

However, most throttle bodies are only responsible for controlling the flow of air, where carburetors perform that function in addition to mixing the air and fuel before it enters the intake manifold.A typical throttle body consists of a one- or two-piece metal casing that has a large bore passing through the middle of it. This bore is partially or fully blocked by a component known as a throttle plate, which pivots on its axis (i.e. a butterfly valve.) The throttle plate is typically controlled by mechanical throttle linkage, except in cars that are equipped with drive-by-wire technology.

Although the throttle plate is the main way that controls the flow of air through a throttle body, these components sometimes include additional valves or paths for air to flow. One example is a cold start fuel injector, which is a component that allows a fuel to adjust the cold start.Throttle bodies work by providing the driver of a vehicle with a way to control the amount of air that is flowing through the intake system at any given time. Although the accelerator pedal is often referred to as a gas pedal, and phrases such as “step on the gas” are ingrained in our minds, the accelerator actually controls the flow of air into the engine [3].

When you press on the accelerator pedal, one of two things happen. In most cases, mechanical linkage between the pedal and the throttle body pulls on the throttle plate, which causes it to open.One type that isn’t found as often now as it once was single-point injection. These systems are also referred to as “throttle body injection” because there is only one fuel injector, and it’s located inside the throttle body. This combines fuel and air delivery into a single component, similar to the functionality of carburetors.

Single-point fuel injection is referred to by a handful of different names, including throttle body injection (TBI), central fuel injection (CFI), EGI, and PGM-CARB. The throttle bodies in these systems are similar to those used in other, more modern fuel injection systems, aside from the fact that they have built-in fuel injectors.

When a throttle body goes bad, there are a few different common failure points. Although they can fail mechanically, it’s much more common for external parts to go bad. The specific diagnostic procedure depends on the problem that you are experiencing, since there are a number of different components that can fail. This type of fuel injection system consists of only two major castings - the fuel body and the throttle body. The fuel body supplies the fuel while the throttle body has a valve that controls the flow of air.

2.2.1 Installing the Throttle Body

The throttle body regulates the air going into the valves. Universal models are the easiest for conversions. Bolt the throttle body on and hook it up at the throttle linkage. This connected to the accelerator pedal. An idle air controller is needed with the EFI throttle body. This goes into a small passage that pushes extra air past the throttle plates. It opens or closes the passage depending on how much air is needed in the manifold.

2.2.2. Throttle Body Failure

One common issue with throttle bodies is referred to as "coking." This is an issue where rough, black residue builds up on the throttle plate or inside the bore, and it can cause anything from a rough idle to a hard start condition. In many cases, this issue can be fixed by simply cleaning the residue from the throttle plate and bore, although precautions may be necessary. Some throttle bodies are coated with materials that can be stripped away by harsh solvents (i.e. carburetor cleaner), so cleaning a throttle body can actually damage it if you aren't careful.

Figure 2: Coking can lead to idling problem and throttle sticking

2.2.3. Throttle Valve

All gasoline engines have a throttle valve to control the volume of intake air. The amount of fuel and air that goes into the combustion chamber regulates the engine speed and, therefore, engine power. The throttle valve is linked to the accelerator (gas pedal). The throttle valve is a butterfly valve that usually consists of a disc mounted on a spindle. The disc is roughly circular, and it has the same diameter as the main air passage in the throat or "venturi". In a carburetor, the throttle valve is usually located at the bottom of the carburetor, between the jet nozzle and the intake manifold. The throttle spindle is connected to the accelerator in such a manner that when the pedal is depressed, the valve opens. When the pedal is released, the valve closes. Fuel injected engines use throttle valves to regulate engine power, even though the fuel is also regulated through the injectors.

There are advantages and disadvantages in using the throttle body fuel injection system with carburetor system [6].

2.2.3.1. TBI Fuel Injection Advantages

- It is less expensive than carburetor systems.
- It is easier to clean, maintain and service because there are fewer parts.
- It is cheaper to manufacture than a carburetor system and simpler to diagnose.
- It greatly improves the fuel metering compared to a carburetor.

2.2.3.2. TBI Fuel Injection Disadvantages

- The possibility of condensation is much higher since the fuel travels longer from the throttle body to the combustion chamber.
- Since the system needs to be mounted on top of the combustion chamber, you're prevented from modifying the manifold design to improve your car's performance.

2.2.3.3. Carburetor advantage and disadvantage

- It have different operation condition
- Carburetors are also much simpler to install than fuel injection systems
- The carburetor is currently much less expensive than the electronic fuel injection systems.

2.2.3.4. Carburetor disadvantage

- At a very low speed, the mixture supplied by a Simple Carburetor is so weak that it will not ignite properly and for its enrichment, at such conditions some arrangement in the carburetor is required to be made.

- The working of simple carburetor is affected by changes of atmospheric pressure. Carburetors used in aircraft are to be provided with altitude control, as the rich mixture is unnecessarily available, due to less density of air.

- The working of simple carburetor is affected by changes of atmospheric temperature. If the setting is done in winter season, it will be found to give too rich mixture in the summer. This is happened due to less density of air with the rise of temperature to a greater extent than the density of fuel.

- It gives the proper mixture at only one engine speed and load, therefore, suitable only for engines running at constant speed increase or decrease ,the quantity of fuel issuing out will change and not match the velocity of air flowing through the venture and proper mixture is not take place. To overcome this various modifications have to be made in simple carburetor.

- In simple carburetor, the mixture is weakened when the throttle is suddenly opened because of Inertia effect of the fuel which prevents the proper quantity of fuel from flowing immediately [7].

2.3. Fuel system

2.3.1. Fuel delivery system

The fuel delivery system consists of the fuel tank, fuel pump, fuel filters, fuel feed hose, fuel delivery pipe (including fuel injectors) and fuel pressure regulator. There is no fuel return hose. The fuel in the fuel tank is pumped up by the fuel pump and pressurized fuel flows into the injector installed in the fuel delivery pipe .Fuel pressure is regulated by the fuel pressure regulator . As the fuel pressure applied to the fuel injector (the fuel pressure in the fuel delivery pipe) is always kept at absolute fuel pressure of 300 kPa.The fuel relieved by the fuel pressure regulator flows back to the fuel tank.

An internal combustion engine, the fuel injection systems is that which delivers fuel or a fuel air mixture to the cylinders by means of a pressure from a pump. Fuel injection means metering fuel into an internal combustion engine. Fuel injection is also now used in gasoline engines in place of a carburetor. In gasoline engines, the fuel is first mixed with air, and the resulting mixture is delivered to the cylinders.

Metering of the fuel charge may be performed mechanically or electronically. In a diesel engine, the fuel injected directly into the combustion chamber (direct injection) or into a smaller connected auxiliary chamber (indirect injection). In the spark-ignition engine, the fuel is injected into the before it enters the combustion chamber by spraying the fuel into the air stream passing through the throttle body (Throttle Body Injection) or into the air flowing through the port to the intake valve. On automotive spark ignition engines, the carburetor has largely been replaced by a gasoline fuel injection system with either mechanical or electronic control of fuel metering.

2.3.2. Objectives of Fuel Injection

The functional objectives for fuel injection systems can share All share the central task of supplying fuel to the combustion process, but it is a design decision how a particular system will be optimized. There are several competing objectives such as: increase Power output, increase Fuel efficiency, reduced Emissions, increase engine performance, Ability to accommodate alternative fuels, smooth operation, reduced Initial cost and reduced Maintenance.

2.3.3. Benefits of Fuel Injection

The two fundamental improvements are:

1. Reduced response time to rapidly changing inputs, e.g., rapid throttle movements.
2. Deliver an accurate and equal mass of fuel to each cylinder of the engine, dramatically improving the cylinder-to-cylinder distribution of the engine.

1. Port Fuel injection system:

In the port injection arrangement, the injector is placed on the side of the intake manifold. The injector sprays petrol into the air inside the intake manifold. The petrol mixes with the air completely.

This mixture of petrol and air then passes through the intake valve and enters into the cylinders. Port fuel injection (PFI), systems use one injector at each cylinder. They are mounted in the intake manifold near the cylinder head where they can inject a fine, atomized fuel, mist as closest as possible to the intake valve. Since each cylinder has its own injector, fuel distribution is exactly equal. With little or no fuel to wet the manifold walls, there is no need for manifold heat or an early fuel evaporation system. Fuel doesn’t collect in puddles at the base of the manifold. This means that the intake manifold passages can be turned or designed for better low speed-power availability. The port type systems provide a more accurate and more efficient delivery of fuel.

2. Central-port fuel injection system(CPFIS):

General Motors developed an "in-between" technique called central port fuel injection called CPFI. It uses tubes from a central injector to spray fuel at each intake port rather than the central throttle body [10].

2.3.4. Throttle Body Injection

The throttle body injection is the most basic type of fuel injection that can be found on vehicles today. The throttle body injection was the improvement on the carburetor and while it may look different, it is similar in design to the carburetor. The fuel injectors are located in a central housing and the fuel travels with the air throughout the intake manifold on its way to the cylinders. This type of fuel injection is like a computerized carburetor so it will benefit from the precise delivery of the fuel, but there are disadvantages as all of the fuel may not enter the cylinder.

1. Port Fuel Injection

Port fuel or multi point injection is an improvement to the throttle body injection as injectors are placed directly above each intake valve resulting in a more precise fuel delivery. The air and fuel meet at a later stage than the throttle body so condensation of the fuel is reduced. This maybe a complicated compared to the throttle body it offers more power with better fuel economy as more of the fuel can be utilized on each power stroke.

2. Direct Injection

As good as port fuel may sound, engineers have improved on this type of fuel injection and this improvement is known as direct fuel injection or gasoline direct injection (GDI). This type of fuel delivery operates similar to the diesel cycle as the fuel is sprayed directly into the cylinder and mixes with the air. With the use of common rail technology and advanced injectors the fuel is sprayed at a much higher pressure causing the fuel to enter the cylinder as a very fine mist which is ideal for a better ignition of the fuel. This method decreases the surface area around the cylinder where the fuel can come in contact with, before it ignites so a higher percentage (possibly all) of the fuel will be utilized for combustion resulting in more power per stroke.

A direct injected engine can be identified by a clicking sound if you listen to the engine idle with the bonnet open but this clicking sound is not heard from the interior of the car. GDI results in greater fuel economy and power as less fuel may be wasted. Direct Injection maximizes the benefits of forced induction as the fuel will not mix with the heated compressed air before combustion making the direct injection the most efficient of the fuel injection types. Carburetor vs fuel injection is debated as fuel delivery systems [10].

2.3.5. Types of Fuel Injection

Throttle Body injection systems locate the injector(s) within the air intake cavity, or "throttle body". Multi-point systems use one injector per cylinder, and usually locate the injectors at the mouth of the intake port.The fuel injector is an electromechanical device that sprays and atomizes the fuel.

The fuel injector is nothing more than a solenoid through which gasoline is metered.

When electric current is applied to the injector coil, a magnetic field is created, which causes the armature to move upward. This action pulls a spring-loaded ball or "pintle valve" off its seat. Then, fuel under pressure can flow out of the injector nozzle. The shape of the pintle valve causes the fuel to be sprayed in a cone-shaped pattern. When the injector is de-energized, the spring pushes the ball onto its seat, stopping the flow of fuel.

1. Mechanical Fuel Injection

Mechanical fuel injection is the oldest of the fuel injection systems. It uses a throttle linkage and a governor. It is now used mainly on diesel engines. Hydraulic fuel injection is used by some of the imports. Hydraulic pressure is applied to a fuel distributor as a switching device to route fuel to a specific injector. The fuel from the tank is carried under pressure to the fuel injector(s) by an electric fuel pump, which is located in or near the fuel tank. All excess is returned to the fuel tank [9].

2. Electronic Fuel Injection

The principle of electronic fuel injection is very simple. Injectors are opened not by the pressure of the fuel in the delivery lines, but by solenoids operated by an electronic control unit. Since the fuel has no resistance to overcome, other than insignificant friction losses, the pump pressure can be set at very low values, consistent with the limits of obtaining full atomization with the type of injectors used.

The amount of fuel to be injected is determined by the control unit on the basis of information fed into it about the engine's operating conditions. This information will include manifold pressure, accelerator enrichment, cold-start requirements, idling conditions, outside temperature and barometric pressure. The systems work with constant pressure and with "variable timed" or "continuous flow" injection. Compared with mechanical injection systems, the electronic fuel injection has an impressive set of advantages. It has fewer moving parts, no need for ultra-precise machining standards, quieter operation, less power loss, a low electrical requirement, no need for special pump drives, no critical fuel filtration requirements, no surges or pulsations in the fuel line and finally, the clincher for many car makers, lower cost.

2.3.6. Throttle Body Injection versus Multi Port Injection:

2.3.6.1. Comparing the Performance of Carburetors versus TBI and Port Fuel Injection

Throttle Body Injection, is a arrangement that specifies a particular method of metering air and fuel in a marine engine. The throttle body mechanism resembles a carburetor in that it has a throttle plate that opens and closes, admitting more or less air into the engine. But, unlike a carburetor, it has no float bowl, main jets or air bleeds. Instead, single fuel injector nozzles that squirt a continuous stream of gasoline vapor directly into the air flow above the throttle plate.

What about TBI versus port injection Can a helmsman actually tell the difference between the two? The answer depends on boat size. On a small boat, say a 20-footer, a port-injection engine will walk away from a TBI rig. But on a heavier boat, like a cruiser, even with the 40-hp difference, you probably won't actually feel a real seat-of-the-pants difference. Naturally, with all the additional plumbing and computer software, port-injected engines cost more than TBI. Both require specially trained mechanics to troubleshoot the fuel systems. On the other hand, both styles of EFI engines are generally more reliable than carbureted marine engines. Contemporary marine engines, both TBI and multi-port fuel injected, feature sophisticated ignition and engine management system. Microprocessor spark timing monitors the engine's vital signs. Should low-grade fuel because engine knock, the module reacts immediately by retarding ignition timing so the knocking stops. The rev limiter keeps the engine from self-destructing should big water ever pitch pole the bow into a wave and leave the blades freewheeling in thin air. Another benefit of electronic monitoring, if either the cooling or lubrication system should fail, an audible alarm alerts a helmsman before damage occurs.

The fuel injection types according position used in newer cars include:

1. Single-point or throttle body injection (TBI)
2. Port or multi-point fuel injection (MPFI)
3. Sequential fuel injection (SFI)
4. Direct injection

1. Single-point or throttle body injection(TBI)

The earliest and simplest type of fuel injection, single-point simply replaces the carburetor with one or two fuel-injector nozzles in the throttle body, which is the throat of the engine’s air intake manifold. For some automakers, single-point injection was a stepping stone to the more complex multi-point system. Though not as precise as the systems that have followed, TBI meters fuel better than a carburetor and are less expensive and easier to service [9].

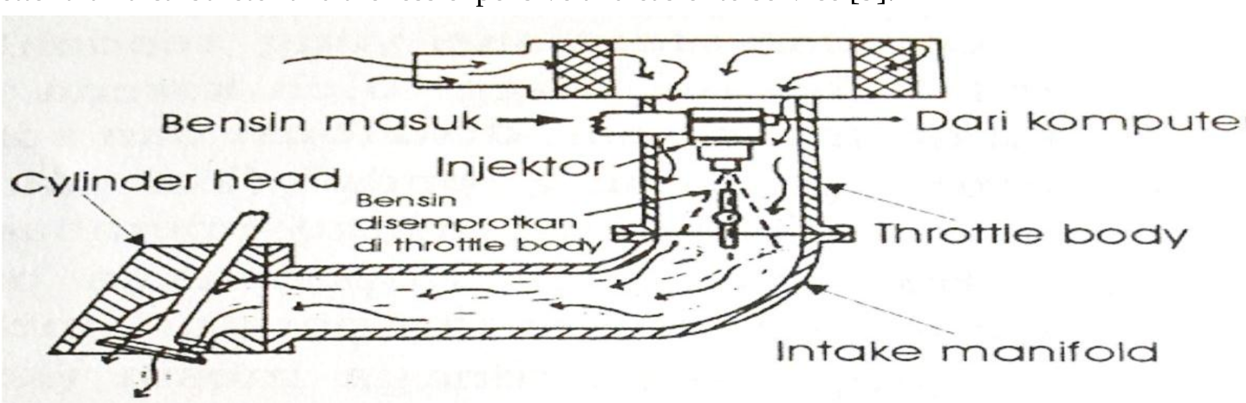

Figure 3: Single-point or throttle body injection during injecting fuel to the hollow

2. **Port or multi-point fuel injection(MPFI)**

Multi-point fuel injection devotes a separate injector nozzle to each cylinder, right outside its intake port, which is why the system is sometimes called port injection. Shooting the fuel vapor this close to the intake port almost ensures that it will be drawn completely into the cylinder. The main advantage is that MPFI meters fuel more precisely than do TBI designs, better achieving the desired air/fuel ratio and improving all related aspects. Also, it virtually eliminates the possibility that fuel will condense or collect in the intake manifold. The intake manifold must be designed to conduct the engine's heat, a measure to vaporize liquid fuel. This is unnecessary on engines equipped with MPFI, so the intake manifold can be formed from lighter-weight material, even plastic. Incremental fuel economy improvements result. Also, where conventional metal intake manifolds must be located atop the engine to conduct heat, those used in MPFI can be placed more creatively, granting engineers design flexibility.

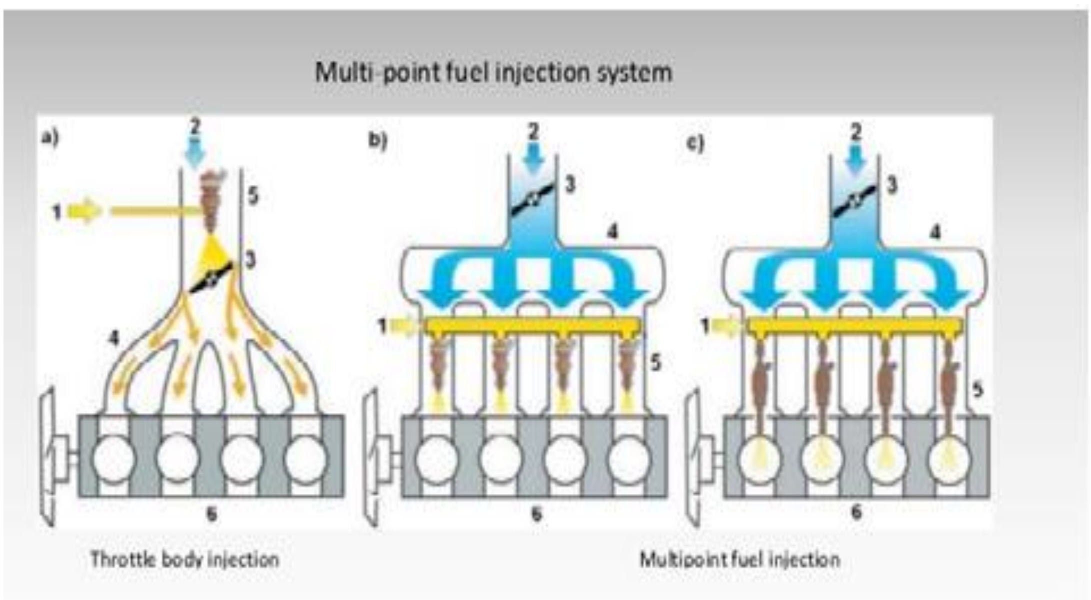

Figure 4: TBI and Port or multi-point fuel injection construction

3. **Sequential fuel injection (SFI)**

Sequential fuel injection, also called sequential port fuel injection (SPFI) or timed injection, is a type of multi-port injection. Though basic MPFI employs multiple injectors, they all spray their fuel in sequential order. As a result, the fuel may "hang around" a port for as long as 150 milliseconds when the engine is idling. This may not seem like much, but it's enough of a shortcoming that engineers addressed it: Sequential fuel injection triggers each injector nozzle independently. Timed like spark plugs, they spray the fuel immediately before or as their intake valve opens. It seems a minor step, but efficiency and emissions improvements come in very small doses.

4. **Direct injection**

Direct injection takes the fuel injection concept about as far as it can go, injecting fuel directly into the combustion chambers, past the valves. More common in diesel engines, direct injection is starting to pop up in gasoline engine designs, sometimes called DIG for direct injection gasoline. Again, fuel metering is even more precise than in the other injection schemes, and the direct injection gives engineers yet another variable to influence precisely how combustion occurs in the cylinders. The science of engine design scrutinizes how the fuel/air mixture swirls around in the cylinders and how the explosion travels from the ignition point. Things such as the shape of cylinders and pistons; port and spark plug locations; timing, duration and intensity of the spark; and number of spark plugs per cylinder (more than one is possible) all affect how evenly and completely fuel combusts in a gasoline engine. Direct injection is another tool in that discipline, one that can be used in low-emissions lean-burn engines.

2.4. Intake Manifold

2.4.1. What is the role and job of the intake manifold

An Intake Manifold, which is also called Inlet Manifold, is a series of tubes attached to several engine parts as well as to the throttle body, if the motor is not fuel injected. This auto part is not just a passageway for the mixture to flow into but it also contributes to a better distribution of the fuel and air. The intake manifold takes the both air and fuel inlet and feeds each of the individual cylinders.

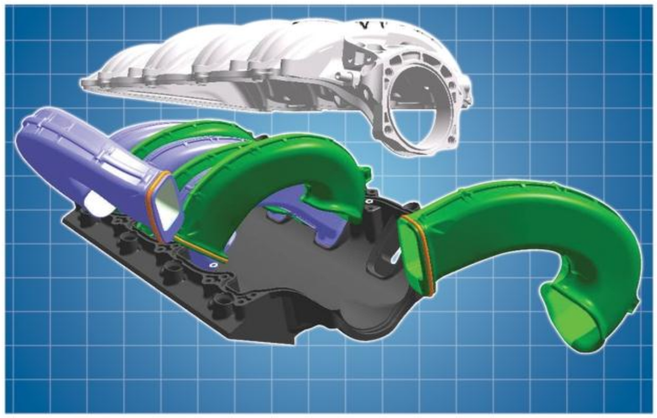

Figure 5: Intake manifolds

It is an area of air and fuel mixed and distributed to all cylindersan intake manifold is more than the plumbing that connects the carburetor or throttle body to the ports in the cylinder head. It is an integral part of the induction system that has to match the airflow characteristics of the cylinder head and camshaft, as well as the displacement and rpm range of the engine. A well-designed manifold that is properly matched to the engine's requirements will make more torque and horsepower than a manifold which is mismatched to the engine.

Stock intake manifolds are often a compilation of compromises. Stock manifolds are typically designed to minimize manufacturing cost, to accommodate emissions fittings, to fit a tight engine compartment with limited hood clearance, and to provide good low to mid-range performance, fuel economy and emissions. Most stock engines spend 95 percent of their running time between idle and 3,000 rpm, with rare bursts above 5,000 rpm. Consequently, if the engine is modified with a hotter camshaft, larger carburetor or throttle body, and/or bigger heads, the stock manifold will usually run out of air above its original design speed and hinder power rather than build power.

2.4.2 Types of intake manifold

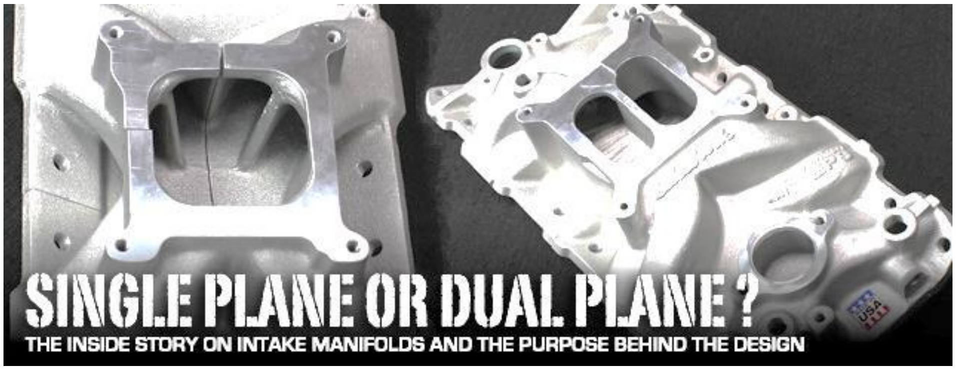

Figure 6: Intake manifolds

It is an area air and fuel mixed and distributed to all cylinders . The ongoing debate over selecting intake manifolds generally divides enthusiast into two location of conventional single plane is for race, and dual plane is for the street.

These well-defined lines of thought have become entrenched in performance engine philosophy, but do you know why? What is the technical rationalization behind this logic? How do engine dynamics such as firing order, back pressure, fuel metering, induction pulses and more come into play when designing intake manifolds? And more important, should you consider these dynamics when selecting an intake?

Figure 7: Intake manifolds

It is the part of TBI used to mixing air and fuel and distributing distributing to cylinder.“It’s not just single-plane manifolds are for racing and dual-planes are for street. We have many customers racing with dual-plane manifolds. In some circle track classes, dual-plane manifolds are the spec manifold. ”A dual-plane manifold has a split opening in the plenum area directly below the carburetor mounting pad. Each side of the opening feeds four cylinders on a V8 engine. Single-plane manifolds have a single intake opening into the plenum and feed all 8 cylinders directly. The larger plenum area is less restrictive and supports a higher power range than a comparable dual-plane manifold, which has a wider power range and works better at low rpm [8].

In recent years, the popularity of stroke kits combined with the availability of larger and larger displacement aftermarket engine blocks has created a whole new generation of monster-sized motors. We’re now seeing small block Chevys with displacements over 427 cubic inches, and big block Chevys with displacements well over 600 cubic inches. Consequently, performance intake manifolds that were designed for small block and big block motors of a decade ago may not have enough plenum area and runner volume to keep up with today’s extreme engines. So intake manifold manufacturers have been redesigning their products to better accommodate the increased breathing requirements of today’s larger displacement stoker motors. The latest “improved” manifolds can often generate an additional 20, 30 or even 50 or more horsepower on many of these larger displacement engines compared to what was possible using an older manifold design. Jim Davis of Professional Products said his company’s engineers redesigned their original “Hurricane” manifold for small block Chevys to handle today’s larger displacements. The new “Super Hurricane” manifold has a larger plenum and runners for engines over 400 cubic inches. Davis also said the company has come out with a new “Hurricane Plus” manifold for small block Chevy engines under 400 cubic inches that has better flow characteristics and delivers 10 to 15 more horsepower over the older design.

Variable-displacement engines are used by a variety of manufacturers today, including Mercedes-Benz, General Motors, Chrysler and Honda, but the idea of deactivating cylinders to improve fuel economy under constant throttle conditions isn’t a new one. In fact, it dates as far back as the early years of the 20th century, when the Sturtevant 38 allowed motorists to shut down as many as three cylinders to save fuel.

Today’s variable-displacement engines operate seamlessly and deliver reliability on par with more conventional designs, thanks to sophisticated engine management systems. That wasn’t the case before electronics technology matured, and Cadillac will forever be known as the company that launched the forward-thinking but trouble-prone L62 V-8-6-4 engine in its 1981 model lineup.

2.5. Electrical fuel pump

The electric fuel pump is mounted at the bottom of the fuel tank, which consists of the armature, magnet, impeller, brush, check valve and relief valve.

2.5.1. Types of electrical fuel pump

1. Intake electrical fuel pump
2. out tank electrical fuel pump

2.5.2. Electrical fuel pump operation

When electrical energy is supplied to the fuel pump, the motor in the pump runs and together with the impeller. This causes a pressure difference to occur on both sides of the impeller as there are many grooves around it. Then the fuel is drawn through the inlet port, and with its pressure increased, it is discharged through the outlet port. The fuel pump has a check valve to keep some pressure in the fuel feed hose even when the fuel pump is stopped. Also, the relief valve is equipped in the fuel pump, which releases pressurized fuel to the fuel tank when the outlet of the fuel pressure has increased up to 64 - 85 psi.

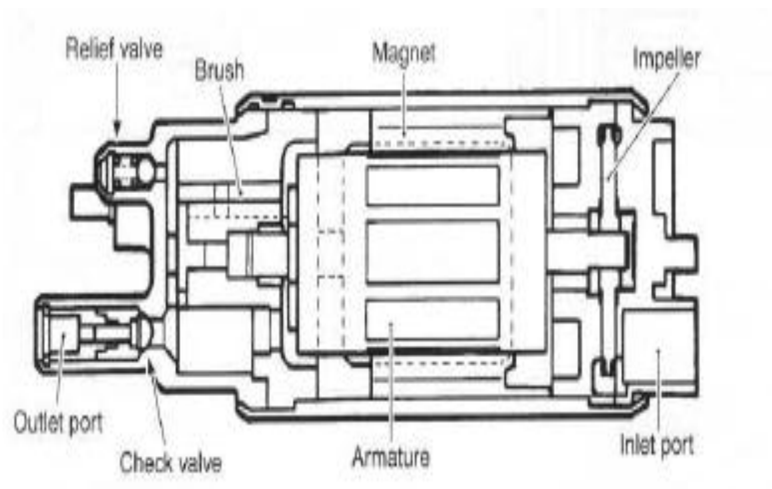

Figure 8: Schematic of an electrical fuel pump

When the impeller is driven by the motor, pressure differential occurs between the front part and the rear part of the blade groove as viewed in angular direction due to fluid friction. This process continuously takes place causing fuel pressure to be built up. The pressurized fuel is then let out from the pump chamber and discharged through the motor section and the check valve [8].

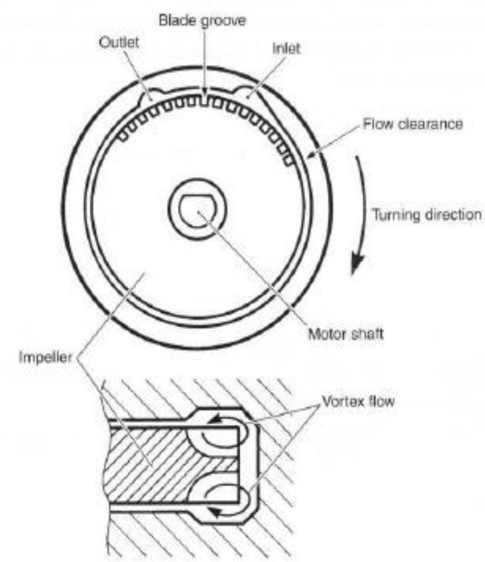

Figure 9: Internal component of the electrical fuel pump

2.6. Common Rail throttle body Injection (CRTBI)

In common, rail systems, a high-pressure pump stores a reservoir of fuel at high pressure up to and above 2,000 bars (psi). The term "common rail" refers to the fact that a common fuel rail supplies all of the fuel injectors, which is nothing more than a pressure accumulator where the fuel is stored at high pressure. This accumulator supplies multiple fuel injectors with high-pressure fuel. This simplifies the purpose of the high-pressure pump in that it only has to maintain a commanded pressure at a target (either mechanically or electronically controlled). When the fuel injectors are electrically activated, a hydraulic valve (consisting of a nozzle and plunger) is mechanically or hydraulically opened and fuel is sprayed into the cylinders at the desired pressure. Since the fuel pressure energy is stored remotely and the injectors are electrically actuated, the injection pressure at the start and end of injection is very near the pressure in the accumulator (rail), thus producing a square injection rate. If the accumulator, pump and plumbing are sized properly, the injection pressure and rate will be the same for each of the multiple injection events.

CRTBI stands for Common Rail throttle body Injection meaning, throttle body injection of the fuel into the cylinders of a gasoline engine via a single, common line, called the common rail which is connected to one injector. Whereas ordinary gasoline throttle body fuel-injection systems have to build up pressure anew for each and every injection cycle, the new common rail (line) engines maintain constant pressure regardless of the injection sequence. This pressure then remains permanently available throughout the fuel line. In this technique allows fuel to be injected as needed, saving fuel and lowering emissions.

2.6.1. Operating Principle

Solenoid or piezoelectric valves make possible fine electronic control over the fuel injection time and quantity, and the higher pressure that the common rail technology makes available provides better fuel atomization. In order to lower engine noise, the engine's electronic control unit can inject a small amount of gasoline just before the main injection event ("pilot" injection), thus reducing its explosiveness and vibration, as well as optimizing injection timing and quantity for variations in fuel quality, cold starting and so on. Some advanced common rail fuel systems perform as many as five injections per stroke.

Common rail engines require very short (< 10 second) or no heating-up time at all , dependent on ambient temperature, and produce lower engine noise and emissions than older systems. Gasoline engines have historically used various forms of fuel injection. Two common types include the unit injection system and the distributor/inline pump systems (See gasoline engine and unit injector for more information). The common rail is a fuel rail where fuel pressure can build much higher than the pressure that was used in previous engines and the fuel is sent directly to the cylinders through the use of electrical injectors which are situated directly above each cylinder. Common rails are used to improve the operation of both the gasoline and diesel engines. They are used in throttle body injection gasoline engines and have provided several improvements over previous types of fuel injected engines [5].

Figure 10: Photo of Common Rail with injector

2.7. Fuel pressure regulator

The fuel pressure regulator consists of the spring and valve. It keeps absolute fuel pressure of 43 psi to be applied to the injector at all times .When the fuel pressure rises more than 43 psi, the fuel pushes the valve in the regulator open and excess fuel returns to the fuel tank on 3K Toyota.

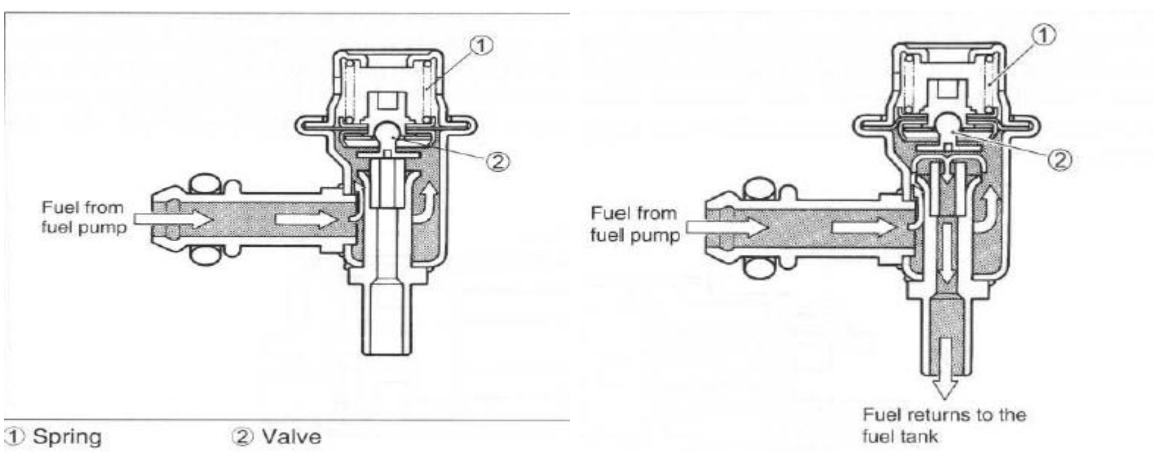

Figure 11:Operations of pressure regulator during opening and closing fuel return line

2.8. Function of Injector

The purpose of an injector is to spray the fuel in atomized or mist form so that it burns completely & uniformly. The Fuel Injection Pump (FIP) supplies pressurized gasoline fuel thru' high pressure lines to the inlet port on each injector. The conventional or first generation injectors are mechanical type and opened on hydro-mechanical pressure. Inside the conventional injector, a spring holds the needle valve in 'closed' position until the specified injection pressure is applied through high pressure fuel line. The TBI injector has resistance of 14.5Ω and injection angle was 23°

The purpose of the fuel injection system is to precisely inject a metered amount of fuel at the correct time. Based on the ON or OFF by the switch by the driver, the injector will decide to turn ON injector and OFF. Fuel injection is a system for mixing fuel with air in an internal combustion engine. The functional objectives for fuel injection systems vary but all of them share the central task of supplying fuel to the combustion process [6].

There are several competing objectives such as:-

- Power output;
- Fuel efficiency;
- Emissions performance;
- Reliability;
- smooth operation;
- initial cost;
- Maintenance cost.

2.8.1. Types of gasoline electronic fuel injector according to their operation

A. Gasoline direct injection[GDI]

B. Port injection

  i. Timed

  ii. Continuous

C. Manifold injection

2.8.2. Types of Gasoline Electronic Fuel Injectors according to their construction

- Mechanical (K-Jetronic)
- Electromechanical fuel injection system (KE Jetronic)

- Electronic fuel injection ,K and KE- Jetronic [13].

Figure 12: Photo of high-pressure injectors

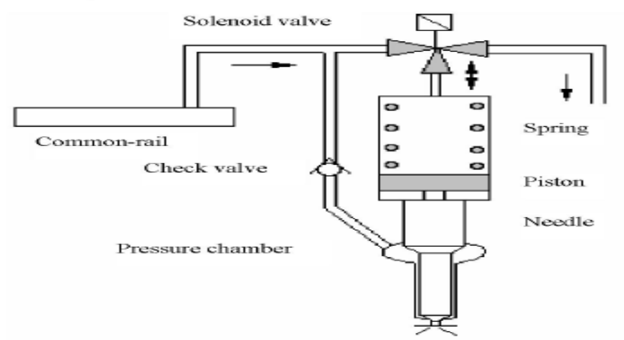

Figure 13: Circuit diagram of injection system

2.8.3. Fuel tank

The fuel tank contains a fuel gauge sending unit, a filler tube and a fuel pump. In most tanks, there is also a fine mesh screen "sock" attached to the pickup tube. This is used to filter out large particles, which could easily clog the fuel lines, fuel pump and fuel filter. Since the advent of emission controls, tanks are equipped with a control system to prevent fuel vapor from being discharged into the atmosphere. A vent line in the tank is connected to an activated carbon or charcoal filled canister in the engine compartment. Vapors from the tank are stored in this canister, until they can be purged later for combustion in the engine. When you fill up at a gas station the gas travels down the filler tube and into the tank. In the tank there is a sending unit which tells the gas gauge how much gas is in the tank. In recent years the gas tank has become a little more complicated, as it now often houses the fuel pump and has more emissions controls to prevent vapors leaking into the air.

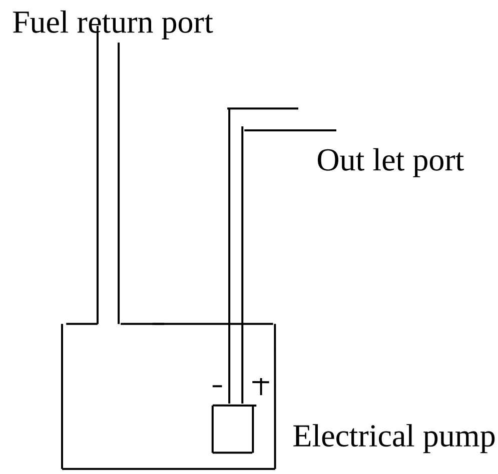

Figure 14: Circuit diagram of fuel tank

2.9. Fuel filters

In addition to the mesh screen attached to the pickup tube, all fuel systems have at least one other filter located somewhere between the fuel tank and the fuel metering components. On some models, the filter is part of the fuel pump itself, on others, it is located in the fuel line, and still others locate the filter at the carburetor or throttle body inlet.

2.9.1. Types of fuel filter Inline and spin-on filters

Inline and spin-on filters are located between the fuel pump and fuel metering components. They connected to fuel lines either by clamps, banjo bolts, flare fittings or quick-disconnect fittings. Most are "throw-away" units with a paper element encased in housing. Some have a clear plastic housing that allows you to view the amount of dirt trapped in the filter. Some filters consist of a replaceable pleated paper cartridge installed in permanent filter housing.

2.10. Emissions

2.10.1. Introduction

Los Angeles, in 1947, was the first place to call attention to atmospheric pollution problems, which in 1952, Dr. Arie J. Haagen-Smit blamed the rise on the automobile, which was backed by his research. In a complete combustion process, for every kg of hydrocarbon fuel burnt, 1.3 kg of H_2O and 3.1 kg of CO_2 is produced. The undesirable exhaust emissions, NO_x, HC, CO, CO_2, polyaromatics, soots, lead salts, nitro-olefines, and aldehydes ketones, are produced in very small quantities. And of these toxins, only NO_x, HC, and CO are produced in large enough quantities to cause environmental problems.CO2 caused concerns because it was suspected of allowing ultra-violet rays to penetrate the atmosphere. CO causes problems by being absorbed into red corpuscles of the blood, preventing the absorption of oxygen. Lastly, Nitric acids and nitrogen dioxide along with HC caused smog [13].

2.10.2. Emissions from Carbureted and Timed Port Fuel Injected or continuous injected engine/TBI/

A comparison was made between the exhaust emissions characteristics of a popular make car when equipped with the stock carburetor and when equipped with a timed-port or continuous fuel injection system. A brief optimization study was made to adjust the spark timing and fuel flow characteristics to minimize emissions. Performance and economy were compared between the fuel injected and carbureted versions. Emission measurements of CO, C02, and hydrocarbon were made in road tests by proportional sampling and through the California Cycle by continuous non dispersive infrared instrumentation.

TBI was study compared the emissions from a passenger car equipped with timed port or continuous fuel injection to those from the same car equipped with standard carburetor. Performance and economy were evaluated with a manual transmission vehicle to permit repeatable steady-state operating conditions on a chassis dynamometer over the full range of speed and load between 15 and.65 miles per hour at five-mph increments. After a break-in period of three weeks, in which approximately 1600 miles were accumulated, the vehicle with a standard carburetor was tuned to factory specifications and road tested to establish parameters from which a road-load developed power curve could be derived for the chassis dynamometer and to establish the acceleration characteristics of the carbureted engine.

2.10.3. Absolute manifold pressure and engine speed were used to fix engine power output

Engine temperatures were allowed to stabilize at each test condition before data were collected. Performance and. economy data were also obtained for the test vehicle equipped with the injector set at manufacturer's recommended conditions, and with an emission- optimized injector. Emission data were obtained for the manual-transmission vehicle used in the performance and economy tests, and a similar vehicle equipped with automatic transmission.

The fuel injection system used for these tests is a timed or continuous, port injection system with speed-density control. Fuel flow from the injector nozzles is intermittent and timed to a fixed part of the engine cycle so that fuel delivery occurs only during a portion of the intake stroke when the air velocity is high. The fuel nozzles are located in the branches of the engine intake manifold adjacent to each cylinder-head intake passage. The nozzles are of the closed, constant-pressure type and operate at approximately 500 psi. The amount of fuel delivered is directly proportional to both manifold pressure and engine speed. The position of the metering element is established by a diaphragm controller that senses engine vacuum.

A deceleration fuel cut-off is provided so that no fuel is injected when manifold vacuum exceeds 22 inches. An electric fuel pump supplies fuel to the metering pump at about 10 psi. The pump system includes a vapor diverter and return line to the tank. The throttle body of a standard Rochester carburetor is used to control air flow [12].

3. MATERIALS AND METHODS

This chapter gives the details about the materials used for the construction of the TBI system and the systematic methodology followed to achieve the set objectives.

3.1. List of Materials

The list of materials used for construction and implementation of TBI system is given in table 1.

Table 1: Material for construction of TBI system

No	Item	Unit	Qty
1.	Ignition switch	Pcs	1
2.	One step Switch	Pcs	3
3.	Electrical fuel pump	Pcs	1
4.	Wire flexible 1.5mm yellow, black and blue	Roll	1
5.	Relay 12V	Pcs	8
6.	Intake manifold	Pcs	1
7.	Common rail with injector	Pcs	2
8.	Cold start injector	Pcs	1
9.	Throttle body or carburetor	Pcs	1
10.	Nut and bolts 10 Ømm,12Ømm	Pcs	30
11.	Battery Rock 60A	Pcs	1
12.	Chipped 120mx200m	Pcs	1
13.	Play wood 80mx4m	Pcs	1
14.	Angle iron 4mmØ and 8m	Meter	6
15.	Screw	Pcs	30
16.	Clomp	Pcs	30
17.	Male and female connector	Pcs	50

18.	Indicator lamp 30w	Pcs	3
19.	Hose 8mm	Meter	2
20.	LTZ Square pipeØ1.25mx200m1.25mm	Meter	6
21.	Ink white	Gallon	1
22.	Ink black	Gallon	1
23.	Gasket maker	Pcs	1

3.2.Methods

A systematic methodology was followed, starting from literature review to achieve the objectives of this project.

The steps involved are as follows:

1. Reviewing the literature related to carburetor fuel system and throttle body fuel injection system.
2. Preparing electrical circuit required for operation of TBI system.
3. Preparation of layout of TBI system
4. Selection of materials used for construction of throttle body fuel injection.
5. Construction of the real model of TBI system
6. Demonstration of the functionality of TBI system.

3.3. Literature review

A thorough literature review was done related to the construction detail and performance of various types of throttle bodies and throttle body injection systems. Various components included in throttle body injection kit were studied carefully. The knowledge required for the construction of TBI was acquired. That's changing, in part due to the availability of many fuel injection options. Builders of custom street roads and “rest mod” vehicles are generally divided into two camps with regard to the engine’s fuel system. They either want to retain an old school carburetor approach or upgrade to throttle body fuel injection (TBFI). Today’s offerings allow a choice between a system that features a central plenum with a single “dry” throttle body (design approach but with added performance and custom appearance) or one that utilizes a carburetor-style intake manifold that accepts either a dry throttle body and single point injectors installed in the runners, or a “wet” TBI throttle body with built-in injectors to somewhat copy a carburetor setup. In simple terms, we have either throttle body injection (TBI), where the injectors are mounted in the throttle body assembly, providing a central point air/fuel delivery atop the intake manifold, or multipoint fuel injection (MPFI), where one fuel injector is dedicated per cylinder, with each injector providing fuel closer to each combustion chamber, at the output end of each intake runner.

Aftermarket performance throttle bodies are currently available in a variety of configurations, to replace an existing throttle body on a light duty engine or a throttle body that amounts to a one barrel-style intake manifold. A throttle body that incorporates one or more fuel injectors provides both fuel and air and can be referred to as a wet throttle body. A throttle body that serves only to regulate intake air is usually referred to as a dry throttle body. A variety of styles and sizes of dry throttle bodies are designed to mount in the same manner as a one barrel carburetor and incorporate one fuel injector per cylinder, with the injectors mounted in locations on the throttle body below the throttle valve. This approach provides an option of a carburetor appearance with the advantage of mechanical controlled the air but fuel injected is the same at all operation condition except at idle.

In addition to single-carburetor intake manifolds that accept a single throttle body, multiple-injector setups are also available with multiple throttle bodies, providing the appearance of a multiple “downdraft” carburetor theme, with injector rails located at the center of the engine valley, in-between the two rows of velocity-stack-equipped throttle bodies. From a performance perspective, the options are varied to suit individual taste. In terms of today’s performance aftermarket offerings, a wet-style throttle body type injection setup can offer both simplicity and disguise. At the other end of the spectrum, multipoint injection systems are available that feature a throttle body (strictly for air intake/control) mounted atop an intake manifold that features dedicated injector bungs at the end of the runners (one injector per cylinder).

3.4. Lay out of mechanical components TBI system

Lay out of TBI system is shown in the figure 15 below. All the components like fuel tank, common rail fuel return line, injector, fuel pump, pressure regulator etc. are shown in their appropriate position in the lay out.

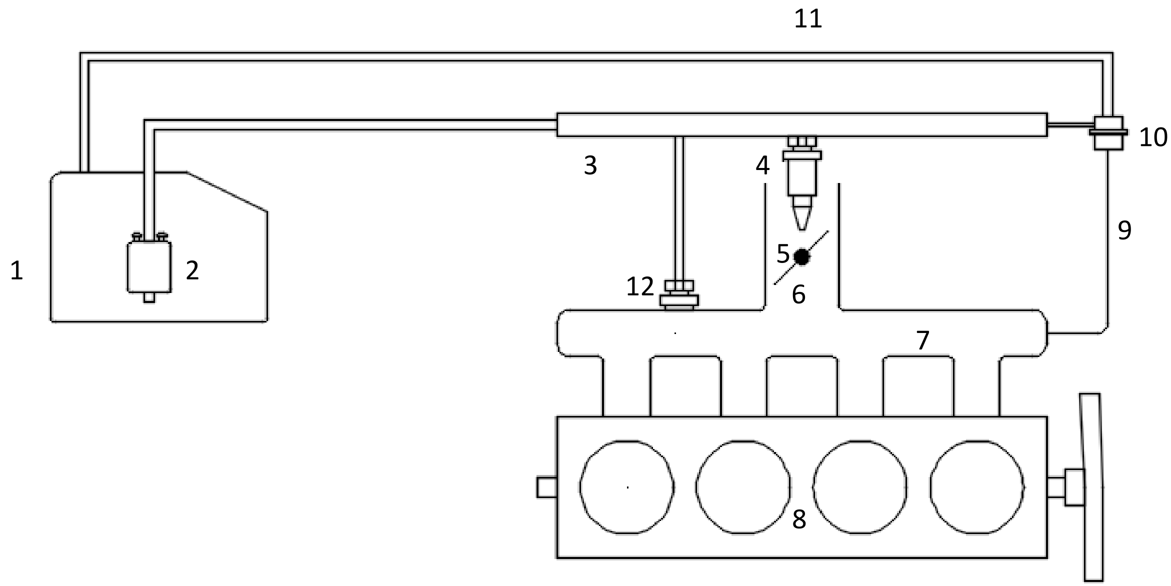

Figure 15: Schematic diagram of TBI

Where

1.Fuel Tank2. Electrical Fuel Pump3. Common Rail 4. Main Injector 5. Throttle Valve 6. Throttle Body 7. Intake Manifold 8. Engine 9. Vacuum Hose 10. Pressure Regulator 11.Fuel Return Line 12. Cold Start Injector with Pressure Line

3.5. Development of electrical circuit

Electrical circuit required with all necessary components for the operation of fuel pump, injector is shown in figure 16 below. The circuit was prepared using proteus software.

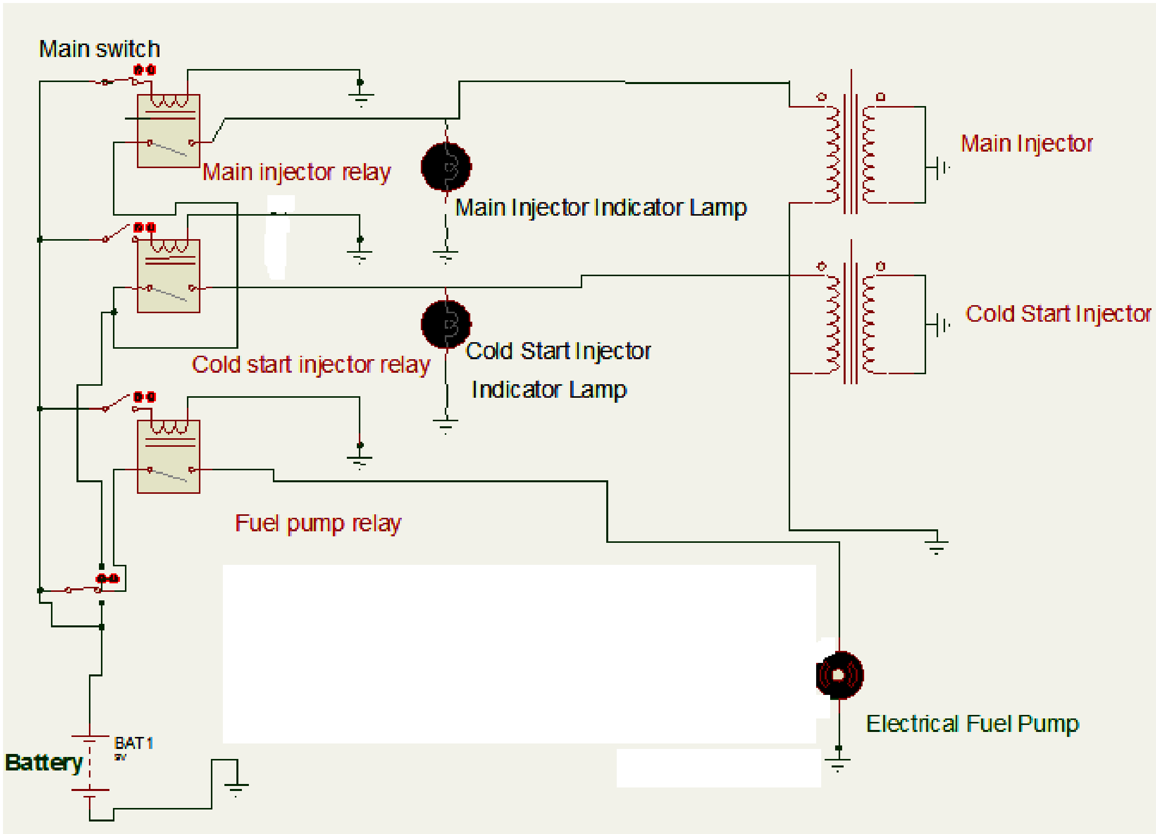

Figure 16: Electrical circuit of TBI

Construction and assembling the throttle body fuel injections electro mechanical on the prepared form. Based on the circuit above the components which are used to make the throttle body fuel injection such as throttle body fuel injection attached on the intake manifold to adding the gasket maker to control the leakage , by drilling the throttle body or carburetor to installed the main injector by 55º for the purpose of increased fuel evaporation , at the same time by drilling the intake manifold to fixe cold start injector near to lower part of the throttle body valve , to insert the electrical fuel pump to the fuel take and insulted the terminal of electrical fuel pump to keep short circuit in the electrical fuel pump the outlet hose connected to the common rail to deliver high pressure fuel for both main injector and cold start injector , from the common rail one hose connect to the fuel take on the side of pressure regulator and the other end of the pressure regulator pip connected to the intake manifold side to sense the vacuum and pressure created in the engine side.

3.6. Collection of required material

3.6.1. Throttle Body

Throttle body is a device which is to be bolted on the top of the intake manifold. The butterfly valve inside the throttle body controls the flow of the air fuel mixture. The main injector has to be fixed on the top of the throttle body. In the project a double barrel carburetor which is available in the shop was used. The secondary barrel was closed to control the air fuel ration passing through the throttle valve.

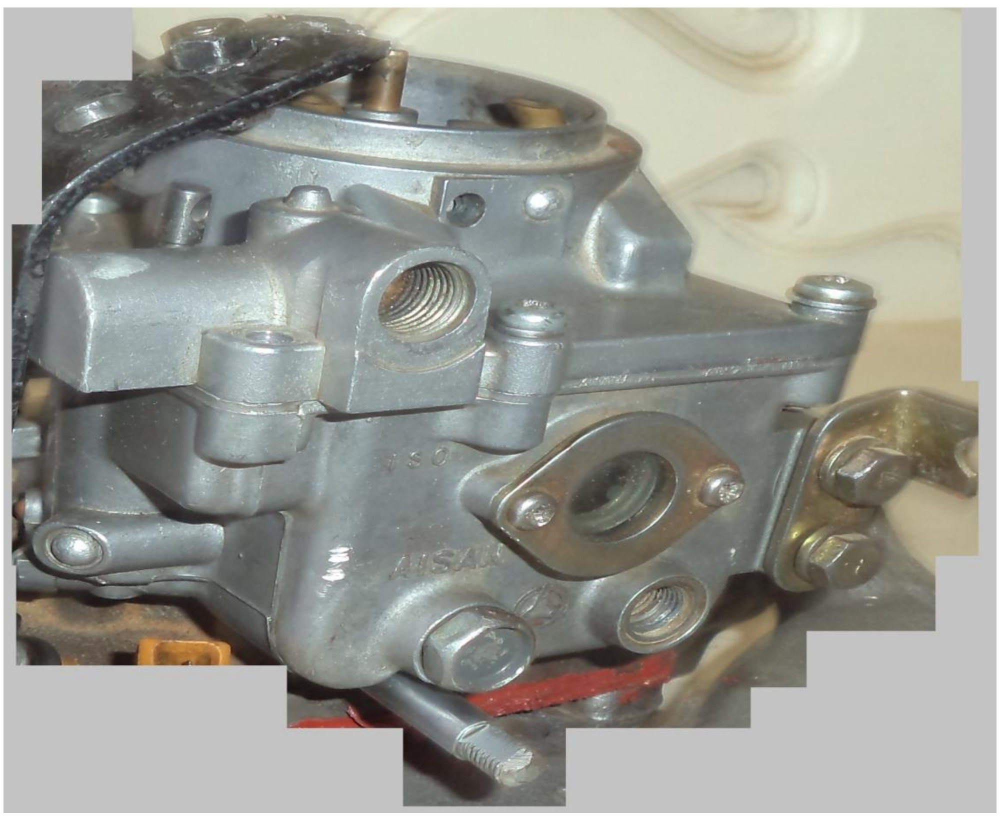

Figure 17: Throttle body with better fly valve

3.6.1. Common Rail

Common rail stores high-pressure fuel as required to operate the injector during different operating conditions. A Rectangular common rail which holds high volume of fuel was used in this project because it have more surface area than cylindrical. TBI systems operate under much higher line pressure than a carbureted system generally in the 40- to 60-psi range, as compared to 6 to 8 psi for carburetion.

3.6.1.1. Modification of Common rail

The available common rail has 4 outlets, but for this project the number of required outlet only two, one for main injector and another for cold start injector. So the common rail was modified by closing two outlets using oxy acetylene welding leaving two outlets. One outlet is used for main injector and other outlet is connected to cold start injector using high pressure tube.

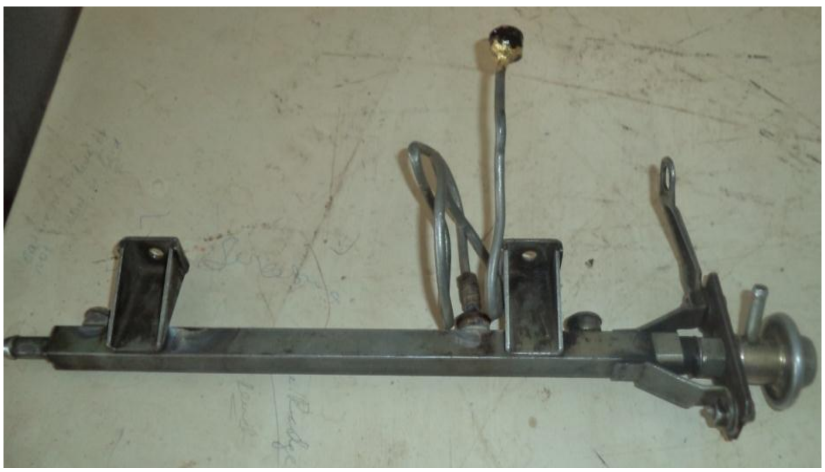

Figure 18: Photo of modified common rail

3.7. Fuel Injectors

Fuel injectors are electronically controlled valves that spray fuel into the combustion mix on demand. Two outlets are used in this project. One is main injector and the other is cold start injector.

3.7.1. Main injector

The function of main injector is to inject fuel during different engine operating conditions to make the engine run with good condition. The main injector injects the fuel at high pressure in to throttle body. Due to high pressure injection, the fuel gets atomized easily and gets mixed with air which improves the engine performance. The main injector is to be inserted in to throttle body at an angle of 55^{o} for better fuel mixing with air.

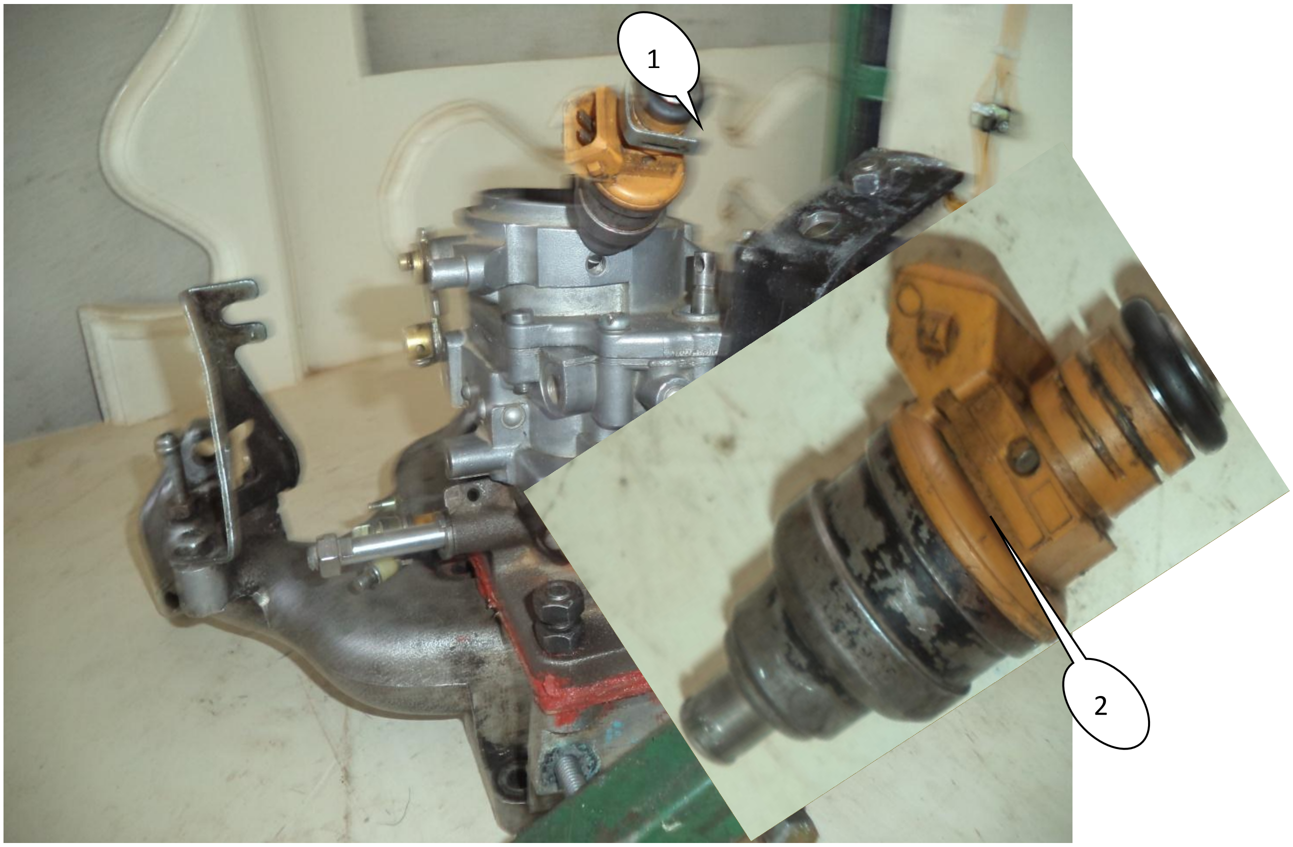

Figure 19: Photo of main injector installed at the top of the throttle body

Where

1. Main injector
2. Cold start injector

3.7.2. Cold start injector

The cold start injector was installed on the intake manifold near to the bottom of the throttle valve to have equal distribution of fuel to all cylinders. The cold start injector is only used during cold time start the engine.

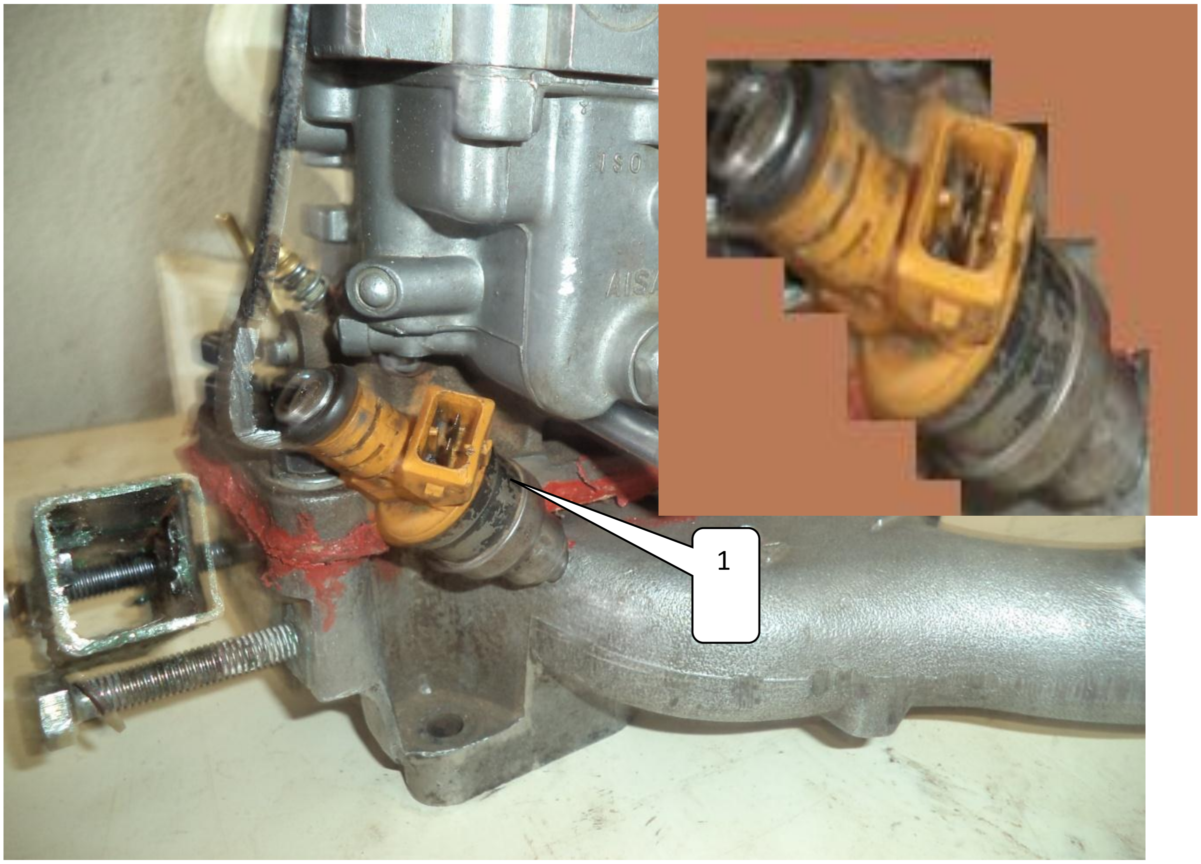

Figure 20: Photo of cold start injector installed on the intake manifold below the throttle body

Where

1. Cold start injector

3.7.3. Choosing injector size

The injector requirements can be determined based on engine horsepower and brake specific fuel consumption (BSFC). The BSFC is the amount of the fuel consumed per unit power output.

Injector size is approached in a somewhat similar manner to that of selecting a carburetor size; bigger isn't always better. If too large an injector is selected, fuel will be wasted and hurt throttle response. Low-impedance injectors are available up to 160 lbs./hr. Injectors alone don't make power; the system must be tuned with the most efficient sized injector for the application. Aftermarket performance systems will provide the appropriate size injector for specific application. Since injector range will vary depending on the anticipated horsepower, it's important to select the proper system part number to match the requirement (or the manufacturer is to be contacted for recommendation). The injector size diameter is 0.86mm. In the throttle body injector were operated sours of battery voltage by energizing injector coil to open and inject high pressurized 138 psi to the throttle body and intake manifold. Choosing injector based on the engine model. The specification use engine given in below table 4

Table 2: The specification of engine

Engine model	3k
Model	ke20l
Piston displacement	1166cc or 72.2cu in
Types of injection	carburetor fuel system
Brake power	1-3-4-2,
Ignition timing order	46kw

3.8. Fuel pump and filter

TBI systems require high fuel pressure and low volume. The high pressure is maintained in the lines and fuel rails. When the injector(s) are signaled to open, the constant pressure is already there to be dispersed. System pumps vary. In general, the operating pressure for typical applications will likely run in the 30-90-psi range (some systems, again, depending on the application. A special TBI fuel pressure regulator is also required, as well as a high-pressure in-line fuel filter. TBI also requires a fuel return line.

The fuel filters used must be high-pressure rated (100 psi burst strength minimum). Any in line filter cannot be used. The fuel filter which is designed for high pressure application only can be used in line electrical fuel pump.

3.9. Fuel Return Line

Any TBI system requires a return line. Only an approved steel line, is to be used not an existing vapor canister line. The return line should enter the fuel tank at the filler neck (below the flapper valve, if so equipped) or at the sending unit flange. A return line size of at least 3/8 in. I.D is to be used proper care has to be exercised while connecting fuel return line to the fuel tank.

3.10. Automobile relays

A relay is a magnetically operated switch. The function of a relay is to switch heavy current on or off by means of a much smaller control current. It connects and disconnects the battery, automatic switching of electrical circuits, etc. The ignition switch controls the relay by regulating amount of current pass to it.

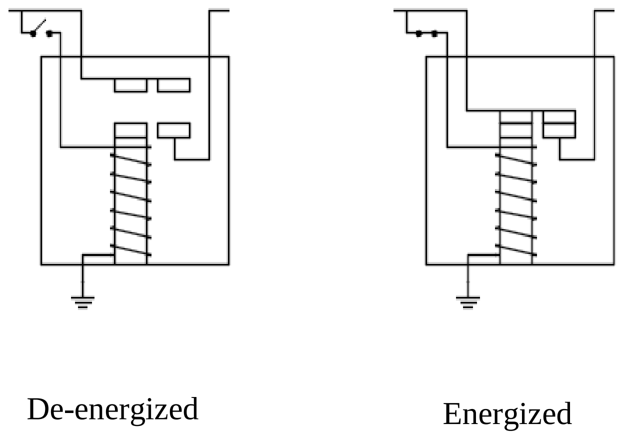

Figure 21: Relay when it de-energized and energize

Explained below is the use of relays as applied in a headlight circuit. If a relay were not used in a headlight circuit, it would lead to a number of inconveniences:

TBI system relays use normally open 12V/30A. Relay terminal 30 and 85 get power from battery it energizes the coil side terminal 86, terminal 87 connects indicator lamp and injectors.

The above stated was the mechanical component assembling order so for operation the electrical circuit of the throttle body fuel injection have to connected as plan of circuit intended, based on 12v battery connected to the ignition switch by 1.5 thickness wire after to that independently the battery directly connected to the three relays on the side of switch side the other terminal of the relay was electric supply gin power from the battery when the operator to on the ignition switch and the other independent switch , the relay load side or terminal (87) connected to the injector which is fixed on the throttle body for mina injector and terminal (86) connected to the ground , between the main injector and relay fixing the indicator lamp in parallel way to the main injector .

At that time injector start to inject metered fuel. For the second relay terminal (85) was connected to switch side and terminal (30) gin power directly from battery and terminal (86) make ground the other terminal (87) was connected to the cold start injector, between the cold start injector and the relay it have also the indicator lamp in parallel form). Cold start injector is connected to ignition switch to the alternator neutral terminal that controls cold start time and to reduce battery power.

The last relay which is used to electrical; fuel pump terminal (85) connected to ignition switch and terminal (30) gain power direct from battery ,terminal (86) ground to the body and terminal (87) connected to electrical fuel pump side.

3.11. Ignition switch

The ignition switch is used to control the current flow to the circuit as a whole and connect the battery with the circuit.

3.12. Battery

Battery is advice used to store energy in the form of chemical energy for long period. The battery what we use is 12V DC. This is used to supply the power for operating various components. A 12 DC battery is used in this work.

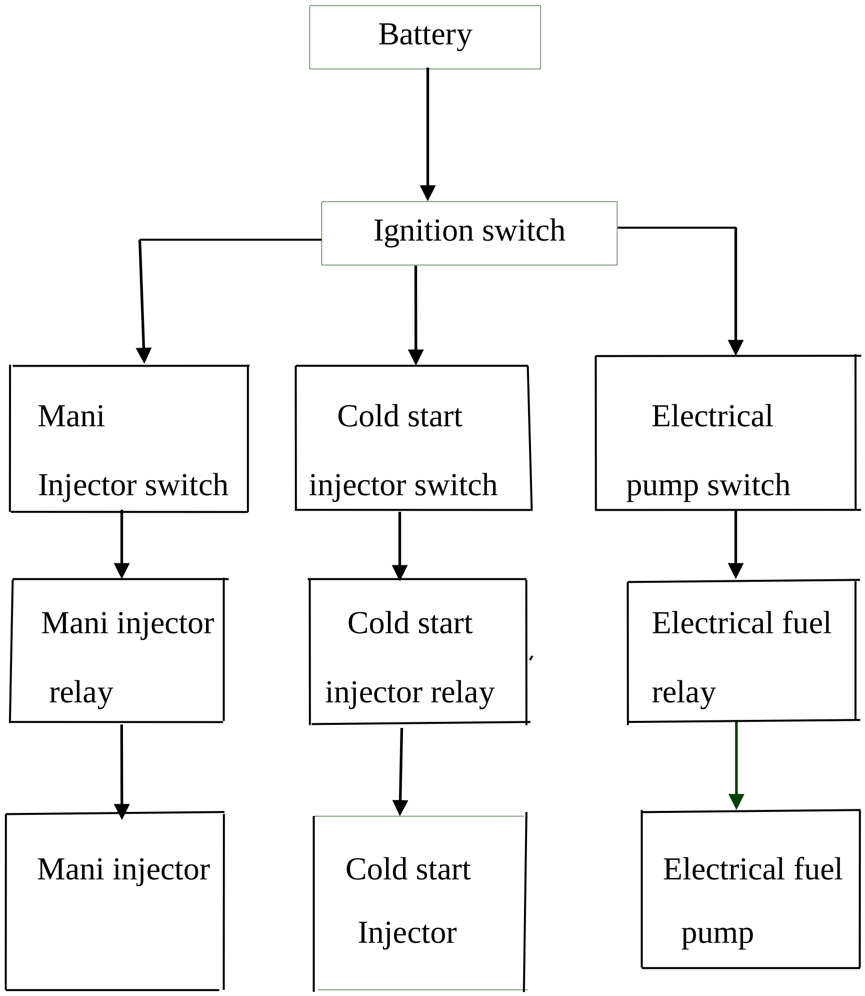

Figure 22: Electrical components of TBI

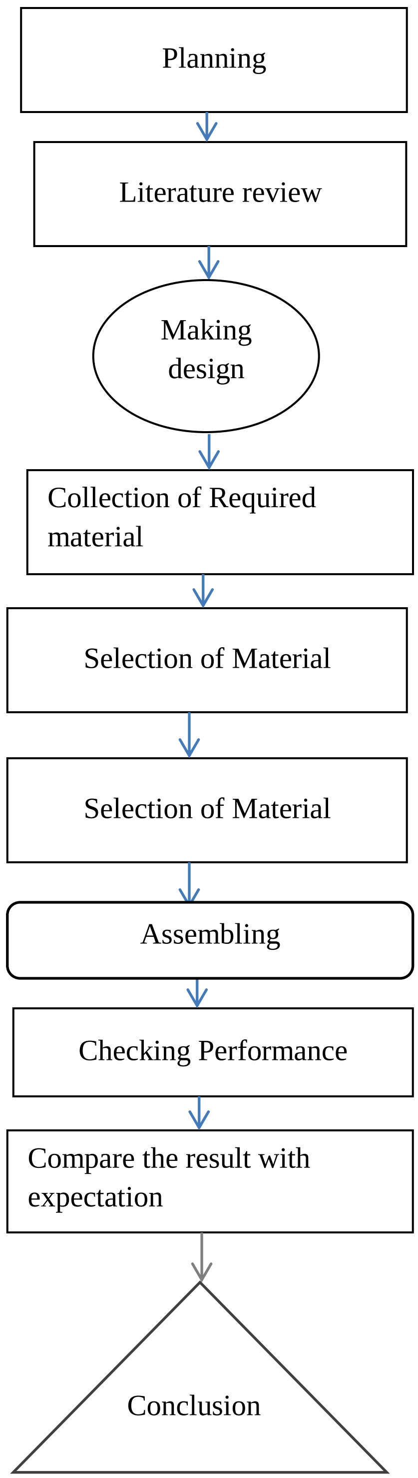

Figure 23: Flow chart of the steps followed in the development of electric circuit

3.13. Construction of the TBI system

3.13.1. Installation

Phase I:

1. Preparing of the board for assembling the components and displaying. Connection of the electrical circuit and components.
2. A board of size 84 cm × 54cm was manufactured and painted.
3. A frame of good strength was manufactured for the installation of the board
4. A Layout of electrical circuit was prepared for the installation of the board
5. As per the layout at the required locations the necessary holes were drilled on the board to fix components like ignition switch, throttle body, inlet and outlet of fuel system.
6. Relay were fixed to the board using screws
7. Switches are connected, which are to be used to on and off the fuel injection.
8. Indicator lamp of different colors was connected one in parallel with injector.

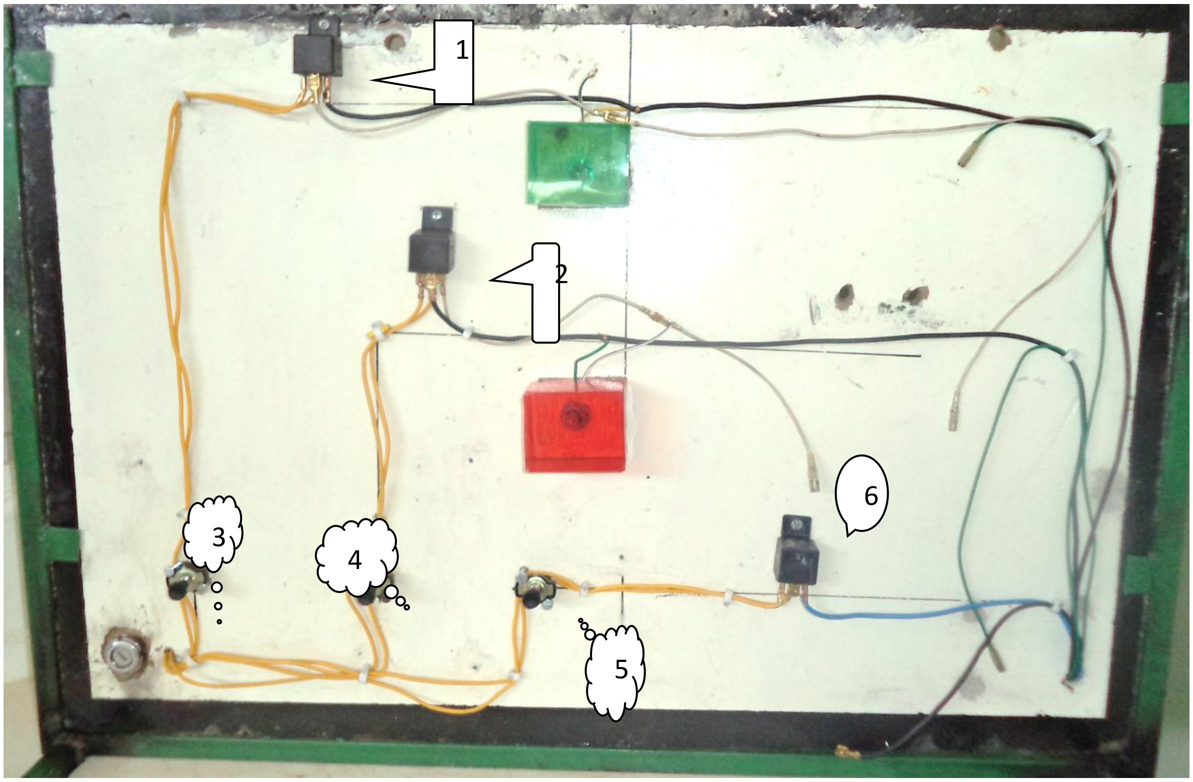

Figure 24: Installation electrical circuit photo for the model

Where

1. Main injector relay	4.Cold start injector switch
2. Cold start relay	5. Electrical fuel pump switch
3. Mani injector switch	

Phase II:

Steps used to install the mechanical parts of throttle body injection on the board.

1. The carburetor, intake manifold, common rail, injectors, gasket maker, and nuts and bolts were collected.
2. The common rail was modified by closing two outlets and welding high pressure line for connecting cold start injector which is to be installed at the bottom of the throttle body. Second high pressure line used for main injector.
3. Throttle body was fixed to the manifold using gasket to avoid leakage.
4. Two holes were drilled one on the top of the throttle body the other on intake manifold near the bottom of the throttle body.

5. Main injectors was fixed on the top of the throttle body and cold start injector was fixed in the intake manifold hole drilled at the bottom of the throttle body.
6. The modified common rail was fixed to the board at the required position by applying epoxy.
7. Throttle body along with injectors was fixed to the board.
8. Injectors were connected to the common rail.
9. Inlet and outlet lines of common rail were connected. Inlet to the pump and outlet to the fuel tank.

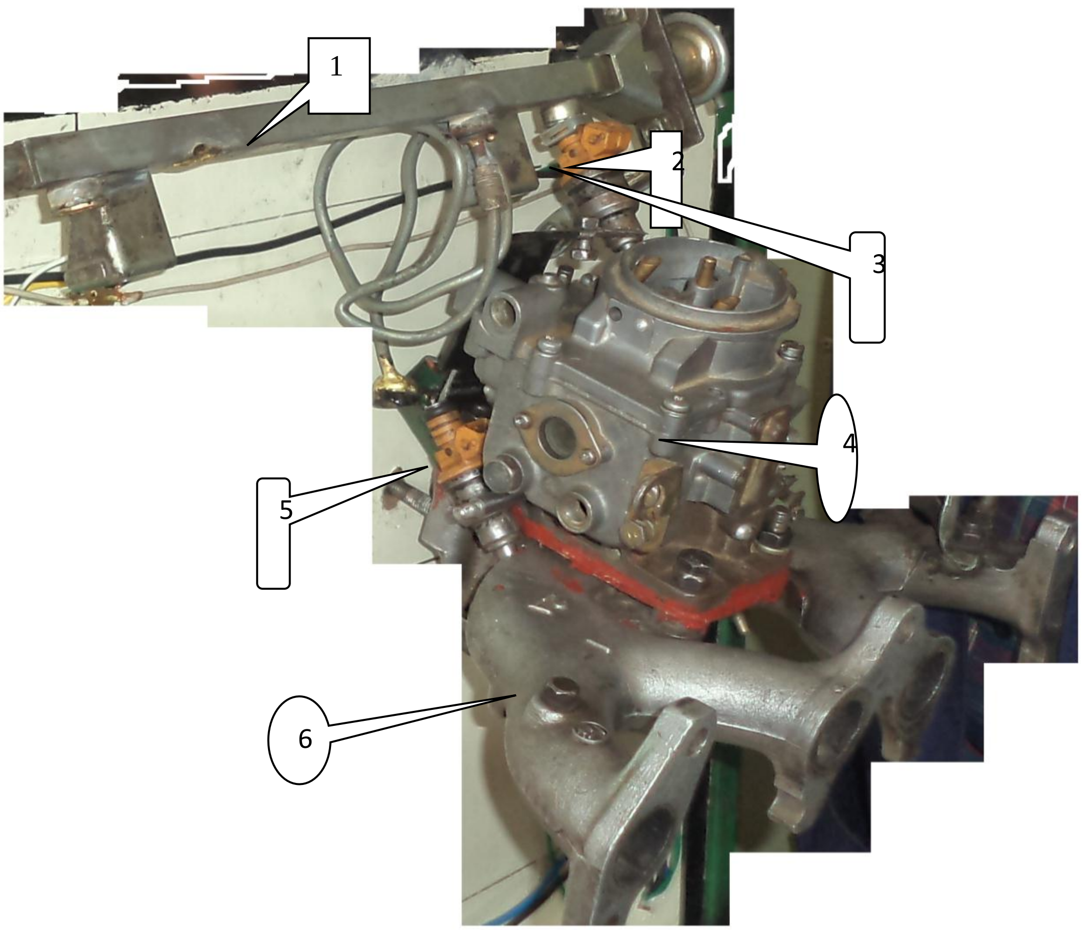

Figure 25: Mechanical parts of the TBI

Where

1.Common rail 2. Pressure regulate 3. Main injector

4. Throttle body 5.Cold start injector, 6.Intake manifold.

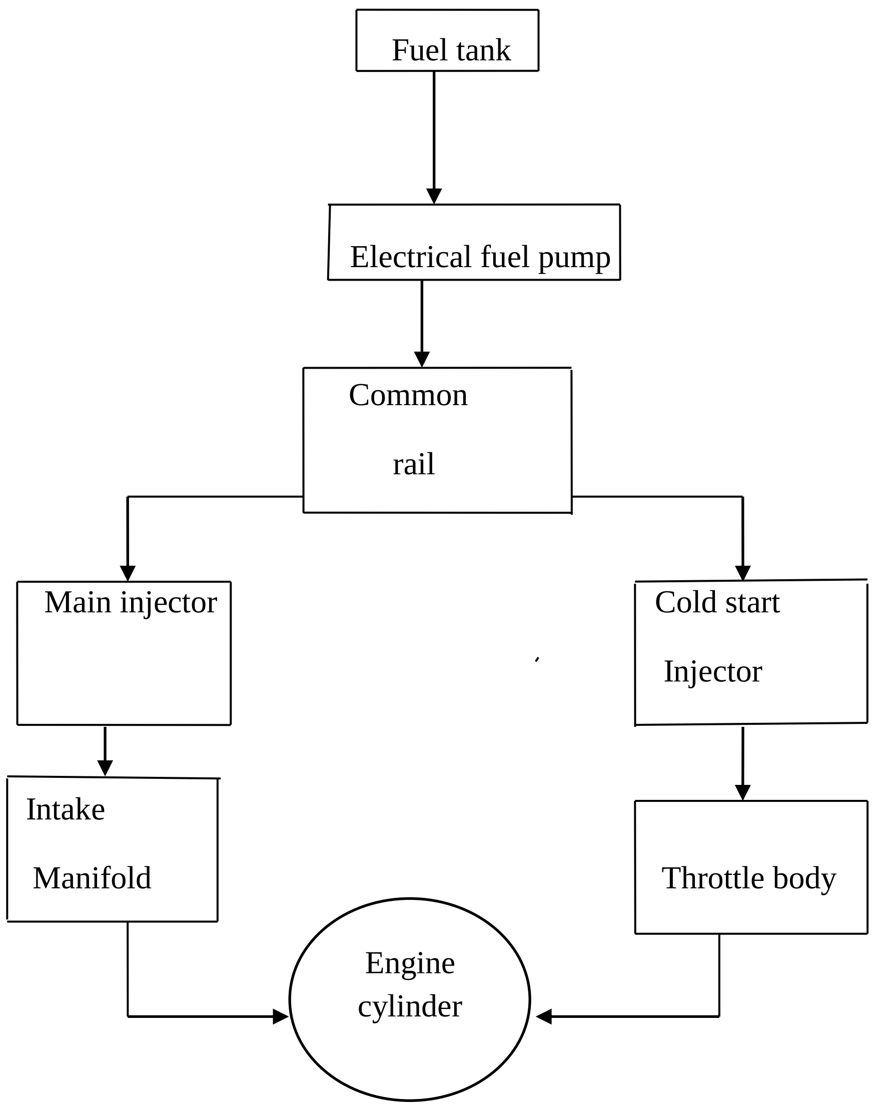

Figure 26: Schematic diagram of the mechanical components of TBI

Phase III:

Steps to connect the mechanical part with the electrical part of the throttle body fuel injection

1. Injector and fuel pump , were connected to the electrical circuit
2. Finally circuit is connected to the battery.
3. Working procedures of mechanical Components of TBI

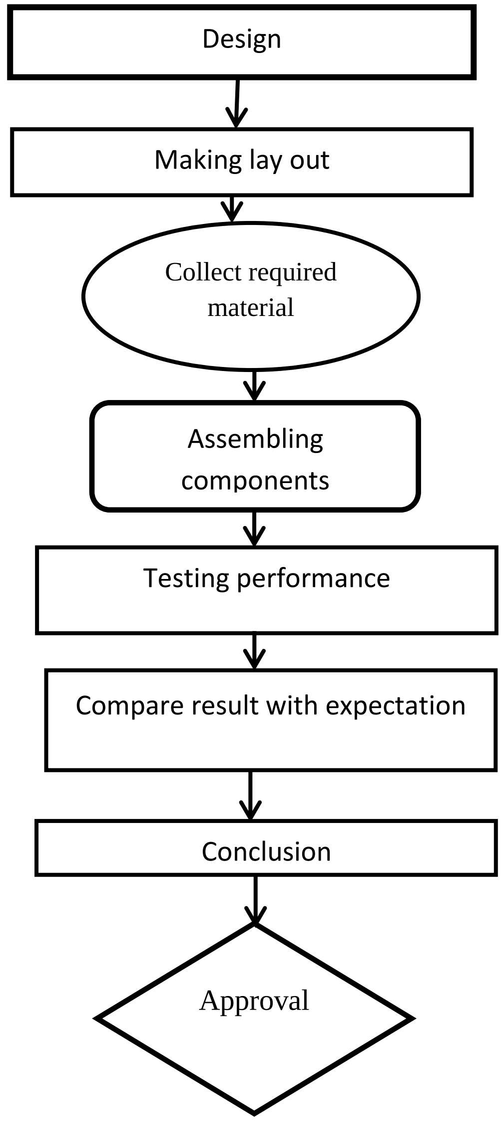

Figure 27: Flow chart of steps followed the development of mechanical components

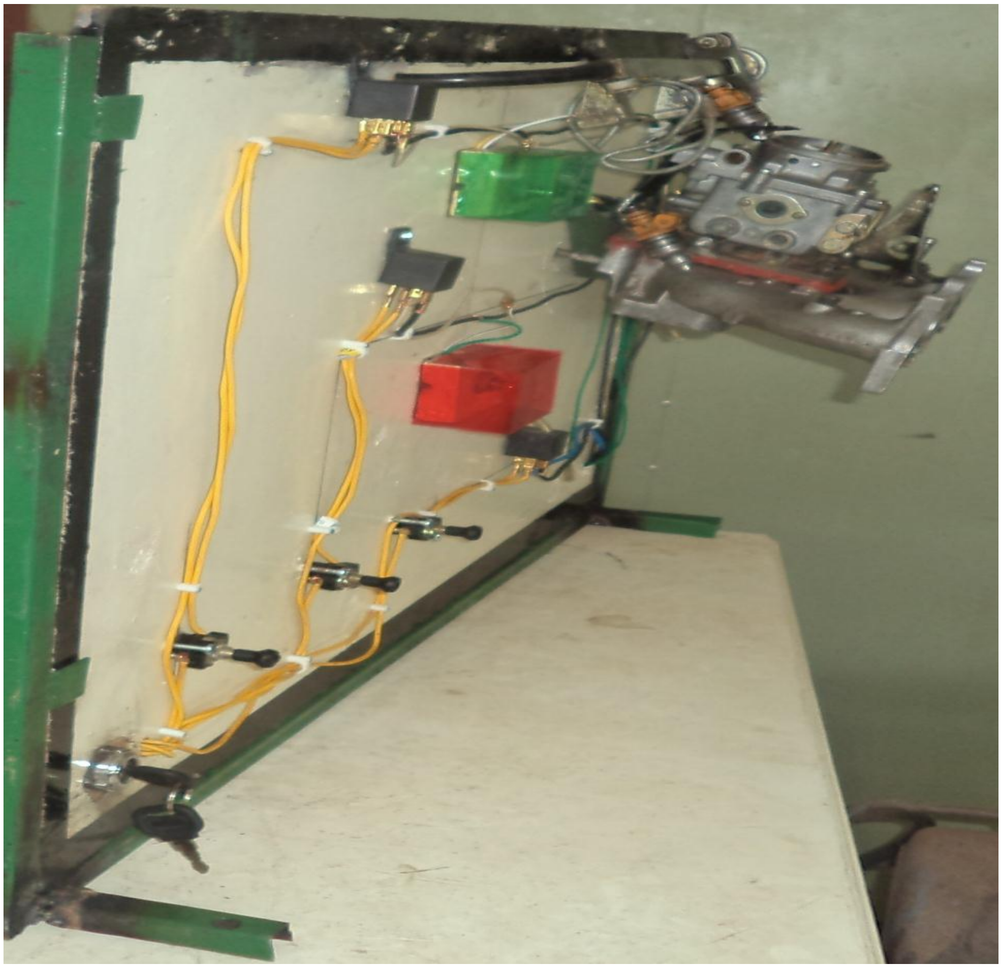

Figure 28: Mechanical components of TBI

Electrical circuit of throttle body fuel injection for easily makes a model of the throttle body injection system.

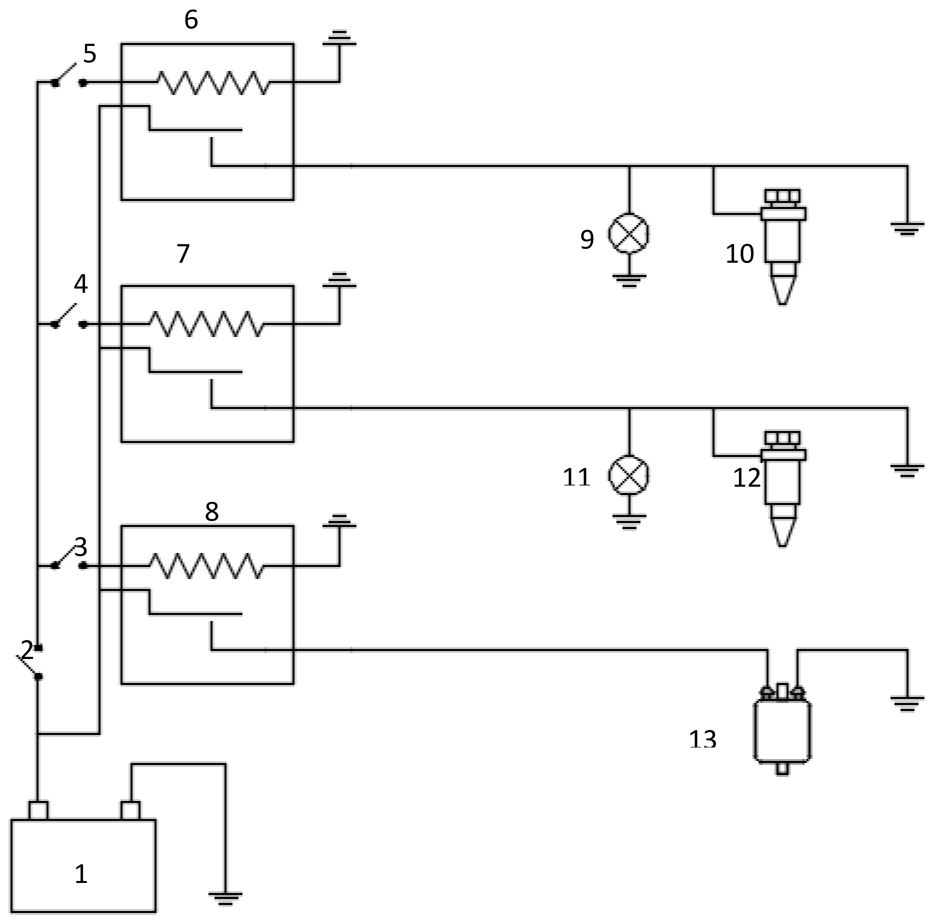

Figure 29: Electrical circuit diagram of TBI

Where

1. Battery2.Ignition switch 3. Fuel pump switch. 4. 3,4,5, switch5. Main injector relay switch6. 6,7,8 relay. 9. Mini injector indicator lamp. 10. Main injector 11.cold start injector indicator lamp 12. Cold start injector 13.Electrical fuel pump.

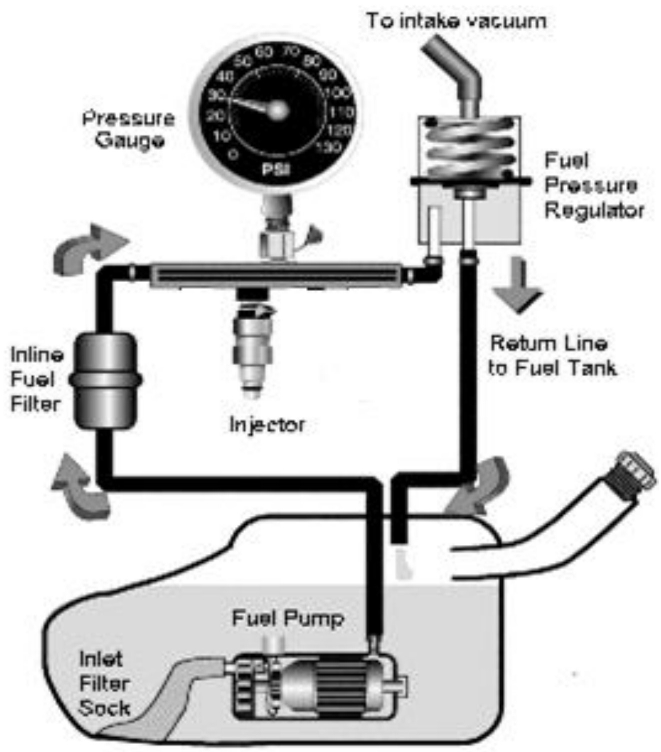

Figure 30: TBI with pressure gauge to measure the pressure of common rail[12].

3.14. Demonstration of functionality of TBI model

The model of TBI system constructed was successfully demonstrated on the board. Also the system was installed on the engine of a car and checked for it functionality. Basic tests were conducted on the engine. Comparison was made between carburetor system and throttle body injection system in terms of engine response like RPM at different throttle position.

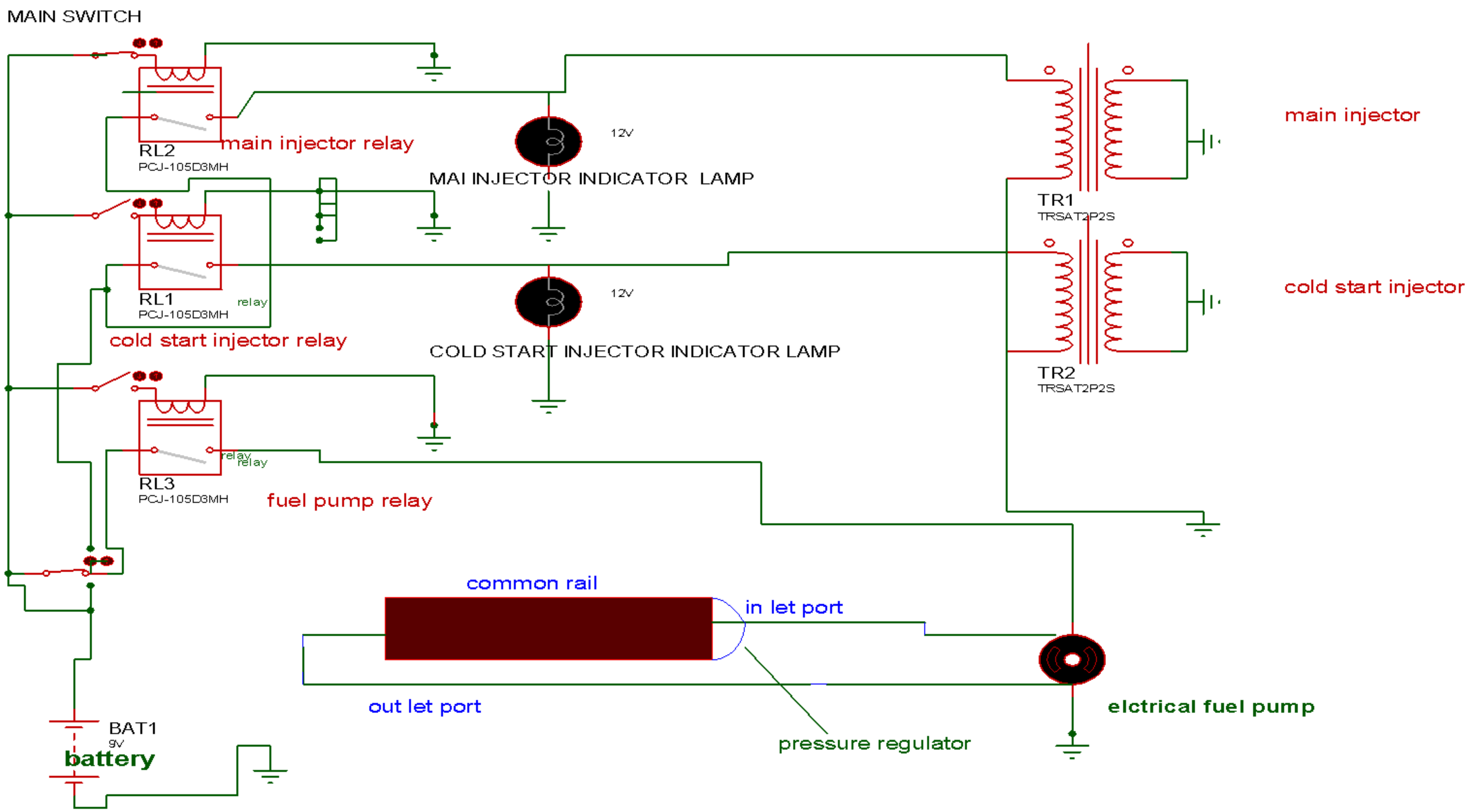

Figure 31: The circuit diagram for throttle body fuel injection

4. RESULTS AND DISCUSSION

The TBI system was constructed with all necessary components to fulfill the set objective. The electric circuit was prepared using proteus software to check for its functionality. The total TBI system, which was assembled on the board, tested for its functionality. In addition, the engine test was conducted to compare the performance of TBI system with carburetor fuel system.

4.1.Demonstration of TBI system

The TBI system assembled on the board was successfully demonstrated for functionality. It is found to be working as per expectation. The complete functional model on board is shown in figure 30.

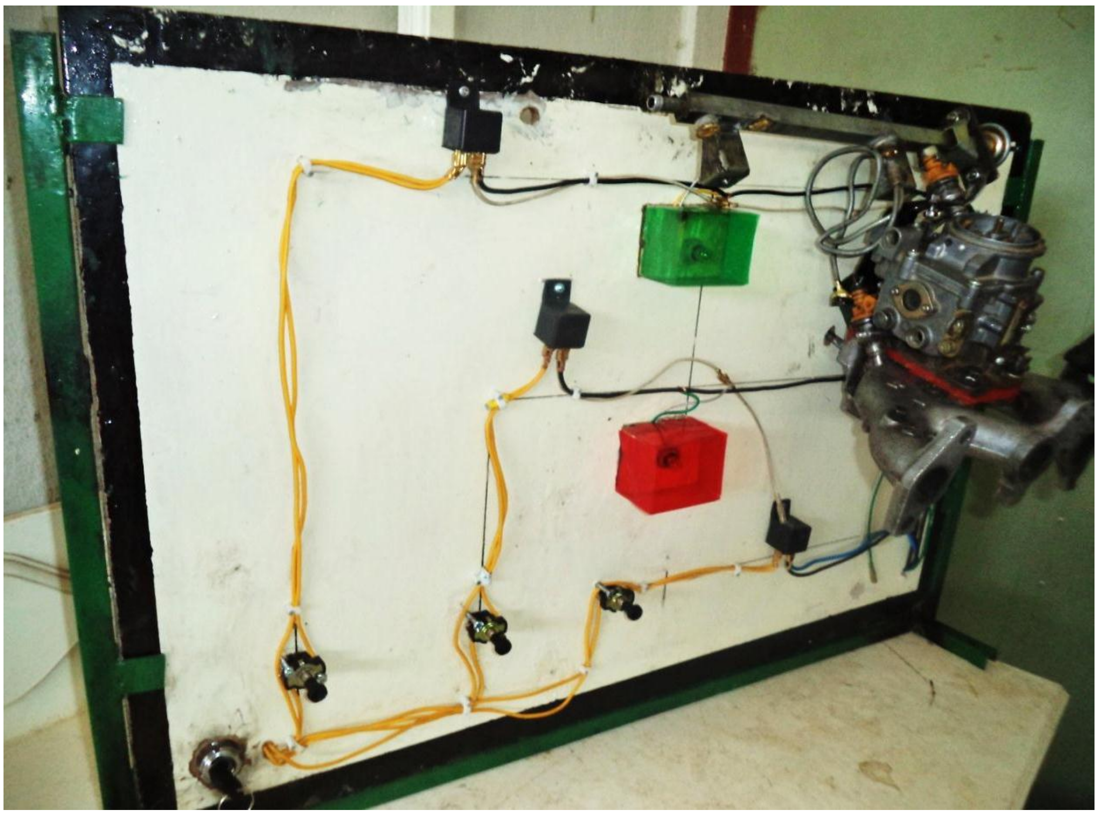

Figure 32: TBI system on board

4.2. Engine test

A test was conducted to see how engine is working at different throttle positions with TBI system. These results are compared with carburetor fuel system.

Procedure to test the engine RPM at different opening angle of the throttle valve

1. Check the 3k Toyota engine for its operation condition.
2. Warm up the 3k Toyota engine for 15 minutes by carburetor fuel system.
3. Measure the RPM of the engine using tachometer at different throttle position.
4. Change the carburetor as put common rail with injector at the top of the carburetor close the cold start fuel line and crank the engine.
5. Record the data using the tachometer at different the throttle valve position similar to the carburetor.

Table 3: Engine RPM at different throttle positions

Operation condition	Angle of throttle valve	Engine RPM Carburetor	Engine RPM TBFI
Idle or slightly open throttle valve	5°	850	750
part opening angle of the throttle valve	15°	1425	1600
Half opening angle of the throttle valve	45°	1820	2215
Full opening angle of the throttle valve	90°	3213	4000

From the data given in Table 2 above we can conclude that the throttle body fuel injection system is more efficient than carburetor because the TBI is able to run the engine at low speed and at other throttle positions the engine speed is higher than carburetor system. Other than idle speed, all speed are higher for TBI system. It is due to higher pressure injection; the fuel atomizes quickly and mixes properly with air which is leading to better combustion with more energy release in the combustion chamber.

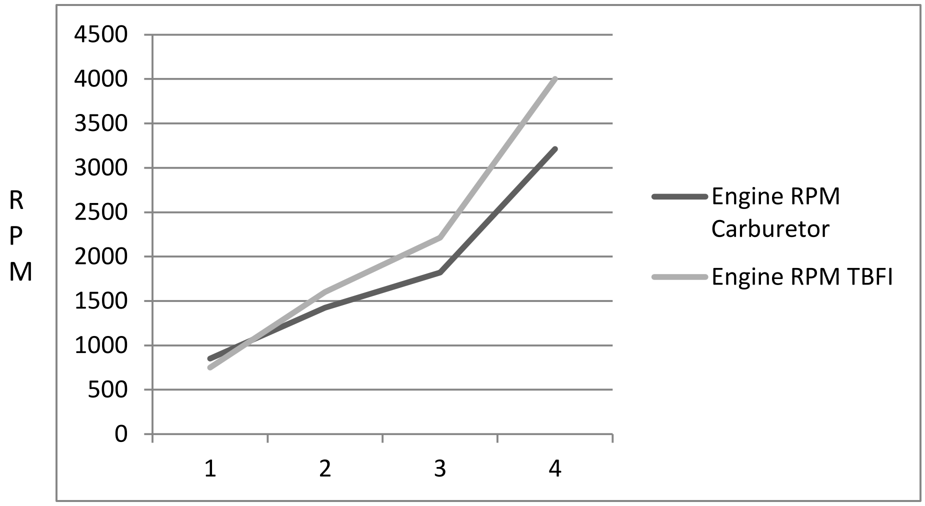

Figure 33: Engine speed at different throttle position

4.3. Rate of Fuel injection

The rate at which the main injector is injecting the fuel was measured. The fuel injection flow rate when measured the fuel in the injector testing tube at different time was get different injection volume, so, increase injection time volume also increase.

Table 4: Rate of fuel injection

No	Time in second	Injection volume in ml	Flow rate ml\s
1.	0:00:00.50	2	4
2.	0:00:01.09	4	3.7
3.	0:00:01.41	5.9	4.18
4.	0:00:02.93	8.6	2.93
5.	0:00:02.57	10.3	4.008
6.	0:00:03.24	13.1	4.04
7.	0:00:03.51	13.8	3.93
Average rate of fuel injection			2.83 ml/sec

From the table 3, indicates that the developed TBI system is able to injection the fuel at the rate of 2.83 ml/sec.

Throttle body injection system electrical circuit prepared by protues software. The throttle body electrical part was functional when it got power sours from the battery.

5. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1. Summary

Ethiopia is suffering with many carbureted vehicles on the road which are less efficient causing higher pollution, consuming more fuel. It is leading to spending of more foreign exchange in importing of more fuel. This project, aimed to convert existing carburetor system to TBI system to address such problems. TBI system which injects the fuel at high pressure helps in better mixing, improved combustion leading to improved fuel economy and reduce pollution. A TBI system was developed using locally available components. TBI system was assembled on board so that it can be used as a teaching aid to impart the knowledge to the students. The functionality of TBI system was demonstrated.

5.2. Conclusions

The main aim of the study was to construct retrofit TBI system for carburetor vehicles.

5.2.1. Based on performance

The TBI system constructed and observed to be exhibiting expected performance, to the performance, better than carburetor system.

The pressure sensor and actuator are missing in this project due to non-availability of the components, adding which will improve the performance further.

5.2.2. Based engine RPM

From the basic test conducted on the engine by measuring RPM at different throttle positions, it is recorded that TBI system is performing better than carburetor system. TBI system is able to run the engine at low idle speed than carburetor system, the speed at other operating conditions is higher for TBI system.

5.2.3. Rate of fuel injection

Rate of fuel injection was measured by taking number of readings. The fuel injection rate was found to be 2.83 ml/sec.

5.2.4. As a Teaching aid

The TBI system was assembled on the board. Its functionality was demonstrated. It can work as a good teaching aid for teaching and learning process. It helps in learning awareness about the importance of TBI system among student community.

5.2.5. Based on maintenance cost

In general the maintenance cost of throttle body injection system is less than carburetor system due to less number of parts in TBI system.

5.2.6. Cost of construction of TBI

The estimated cost for construction of TBI is detailed below in table 4.

Table 5: Construction material for TBI

No	Item	Unit	Qty	Unit price (birr)	Total (birr)
1.	Switch	Pcs	3	100.00	300.00
2.	Electrical fuel pump	Pcs	1	2800.00	2800.00
3.	Wire flexible 1.5mm any color	Roll	1	800.00	800.00
4.	Relay 12V	Pcs	4	120.00	480.00
5.	Intake manifold	Pcs	1	700.00	700.00
6.	Common rail with injector	Pcs	2	7,000.00	1400.00
7.	Cold start injector	Pcs	1	2900.00	2900.00
8.	Throttle body or carburetor	Pcs	1	5000.00	5000.00
9.	Nut and bolts 10 Ømm,12Ømm	Pcs	30	230.00	230.00
10.	Play wood 80mx4m	Pcs	1	200.00	200.00
11.	Angle iron 4mmØ and 8m LTZ	Pcs	1	140.00	140.00
12.	Other costs	-	-	5000	5000
	Sub total				19950

5.3. Recommendation

- The present study has enable us to confirm that throttle body injection can be used as a resource to obtain best efficient engine performance ,which could offer more opportunity for small micro enterprise (SME), increasing income. However it is recommended to conduct further research in development of better TBI system. Further study has to be conducted on performance testing of engine. Study on techno-economic analysis is also necessary.
- It is recommended to use sensors and actuator for better performance of TBI system.
- It is recommended to government of Ethiopia to take appropriate action to encourage convert existing carburetor vehicles to TBI vehicles, so that the country gets benefited in terms of reduced environmental pollution and improved fuel economy.
- It is recommended that the TVET institutes should include this topic of conversion of carburetor system to TBI system in the curriculum and try imparting the related knowledge and skill to the students.
- It is recommended that the ASTU to develop better vehicle testing facility as the existing ones are not functional.

5.4. Future direction of the project

The future direction of the throttle body injection will be by installing the electronic controlled device such as, different engine sensor, actuator, and engine-controlled module (ECM) and other necessary components to match the TBI system perfectly with the engine requirement at different operating condition. Research is to be continued in testing the performance of the vehicle with TBI system in terms of pollution, fuel economy, power output etc.

5.5. Educational implication

The objective of the national TVET strategy is to create a competent, innovative adaptable work force in Ethiopia, contributing to poverty reduction social and economical development through be facilitating demandable driven, high quality technical and vocational education and training, relevant to all sectors of the economy at all levels and to all people a need of skills development and transferring a new technology (national TVET strategy NOE 2006.

Since the industries are the stakeholder of TVET institutions the program and drop of industry has an impact on the outcome based training. Intensification of the industry and TVET linkage is very important to provide quality and outcome based training. If the industries have equipped with enough machinery and equipment, the training program will be easy and efficient. Through industrial training the enterprise can also develop ownership of the TVET system.

Technical and vocational skill is vital to economic development because it is needed for industries productivity and profitability, as well as, national productivity. Without the necessary technical skills, industry and national growth can be hampered.

TVET educational system is mostly practical based imparting the necessary skills to the students. The functional model of TBI developed helps very much the TVET educational system.

REFERENCES

[1]International combustion engine: ujjwal K Saha, Ph.D. Department of Mechanical Engineering.

[2] The Ohio air quality development 3 Feb.2016,www.lexology.com

[4] State of California Motor Vehicle Pollution Control Board, "California Test Procedure and Criteria for Motor Vehicle Exhaust Emission Control," (January 1964).

[5] Full member of Canada, ON, Jordan February 15, 2012

[6] www.Fi EFi MPFi GDi.com

[7]www.whyhighend.com

[8] Gasoline Engine Management, Bosch Technical Instruction Manual (1994). 21. C. F. Taylor, The Internal Combustion Engines in Theory and Practice, The MIT Press, Massachusetts (1978). Fuel pump

[9] *www. Enginebasics.com*

[10] Ijfeat international journal for engineering applications and technology http://www.ijfeat.org

[11] International journal of innovative research in science, engineering and technology *(an iso 3297: 2007 certified organization)* vol. 4, issue 4, April 2015.

[12] Professor, department of mechanical engineering, dr. SamuelGeorge institute of engineering and technology markapur – 523 316, prakasam (dist.),andhra pradesh,India

[13] Ralph c. stahman & andrew h. rose jr. (1966) emissions from carbureted and timed port fuel injected engines, journal of the air pollution control association, 16:1,15-18, doi: 10.1080/00022470.1966.10468433