UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION-KUMASI

EXPERIMENTAL INVESTIGATION OF COOLANT FLOAT SENSOR AND ENGINE SWITCH OFF CIRCUIT UNIT TO CONTROL ENGINE OVERHEATING

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AUGUST, 2021

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A Dissertation in the Department of Technology, Faculty of Technology Education, submitted to the School of Graduate Studies, University of Education, Winneba in partial fulfillment of the requirement for award of the Master of Philosophy (Automotive Engineering Technology) degree.

BY

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(200030711)

AUGUST, 2021

DECLARATION

I, CLETUS AKASIKA declare that this thesis with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either part or whole, for another degree elsewhere by another person.

SIGNATURE: ……..……………….. …… DATE: …………………………….

SUPERVISORS DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: DR. S. K. AMEADOMY

SIGNATURE: ……………………………

DATE: ……………………………………

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DEDICATION

To my wife Mrs. Jane-Frances Halaeh and kids: Sandra Akasikama Akasika, Seth Agemga Akasika, Sabina Akasika and Sion Nsobire Akasika.

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ABBREVIATIONS

CCL……………………………………………………………….Control Circuit Lamp

LCL ……………………………………………………………….Load Circuit Lamp

C.I ……………………………………………………………….Compression Ignition

NC ………………………………………………………………...Normal Closed

NO ………………………………………………………………...Normal Opened

NO. ……………………………………………………………….Number

DMM ……………………………………………………………...Digital Multi Meter

^{O}C……………………………………………………………….Degrees Celsius

PULL IN…………………………………………………………..Close

PULL OFF…………………………………………………………...Open

ABSTRACT

This thesis looks at devising a model to control engine overheating. A series of experiments were conducted on the engine/coolant sensors of a four-cylinder four stroke cycle diesel engine to assess their effectiveness in monitoring engine running temperatures. A magnetic float sensor circuit model was developed to monitor the coolant level in the radiator as a backup device to the temperature sensors.

This backup model had the ability to turn off the engine in an event of coolant losses which could trigger overheating. The results show that, this model was sensitive to coolant levels in the radiator and prevented the engine starting or running under low coolant level.

The results also showed that under low coolant engine running, both engine and coolant temperature sensors indicated a large temperature disparity, as high as 130^{O}C and as low as 20^{O}C respectively. However, they displayed a slight margin of difference under full coolant level at 45^{O}C and 40^{O}C respectively.

The results further indicated that, at very low or dry coolant ran, the engine temperature sensor indicated higher figure (130^{O}C) than the coolant temperature sensor (20^{O}C); however, at high coolant level the opposite was the case. This was so because at high coolant level, the coolant absorbs more heat from the engine walls therefore runs at a higher temperature than the cylinder wall. Though the results show that the sensors worked well, they did not have the capacity to switch off the engine to prevent overheating during coolant lose because they are only able to sense the coolant temperature but not able to measure the system coolant level or quantity and this is a setback.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Internal combustion engines produce work from heat as a result of the burning of fuel. These engines depend on heat to function efficiently. However too much of heat is detrimental to the engine component materials. The end result of too much heat in the internal combustion engine is overheating (Gupta, 2012).

When an engine overheats the aluminium material can begin to warp, swell, expand and even crack and a warped cylinder head could separate from the engine block, creating a leak in the head gasket. A leaky head gasket will cause your engine to start burning oil and coolant.

Engine overheating is dangerous and destructive when it is not detected early. It is one of the main leading causes of engine failure and damage. It can damage and destroy an engine permanently if it is allowed for too long. Therefore overheating has been identified as the number one killer of many engines (Tom, 2014).

Engine failure and damage is rampant in Ghana as a result of overheating. This is bad news to hear because it makes drivers, passengers and good especially perishable goods stranded on transit. These vehicles are left on the road for too long, obstructing traffic flow and hence causing accidents. It also comes with some economic burden and mental discomfort to vehicle owners, drivers, and passengers.

It is an undeniable fact that drivers are seen struggling to resolve an overheating they encounter on the road. In many of these cases they get themselves burnt by steam in the process of attempting to open the radiator cap. This is because the ordinary driver knows that the first aid in an event of overheating is to check the coolant level as seen demonstrated in figure 1.1 below (Muydinov D., Zokirjonov A. 2021)

Figure 1.1 picture of an overheating engine on the highway

Engine overheating means the engine is operating at an abnormal temperature, temperatures higher than the melting temperatures of the materials used in the construction of the engine parts and elements. It is a condition of an automotive engine where the running temperature of the engine is more than the normal typical engine operating temperatures, in most cases experts agree that the engine should run between 190^{O}F and 210^{O} F (Burtz, 2015).

Normally it is difficult to monitor engine temperature without using instruments. So to keep track of the engine running temperature, some form of heat sensing devices are deployed to enable drivers and operators to monitor the engine temperature constantly during operation. In internal combustion engines, semiconductor devices such as thermistor, thermostat or thermo-switch are coupled to gauges, warning lamps or alarm accessories to read the engine running temperature (David, 2015).

These devices are deployed to offer an opportunity for constant monitoring to warn and alert the driver of the engine running temperature. These devices have been considered outstanding when it comes to engine temperature monitoring for the past decades (Sturtz 2015). However these devices and their coupled mechanism can sometimes fail or mislead the driver on the engine running temperatures (Motoi 2014). They are not 100% reliable due to many factors, ranging from ineffectiveness and failure especially when the device orengine runs out of age and coolant respectively (Magnus 2021).

1.2 Statement of the Problem

Either past, sooner or later, every vehicle driver or owner have or will deal with an issue of engine overheating. An important variable that needs monitoring and control is temperature. High temperature results in overheating, and may reduce or cause engines to malfunction. This could lead to inefficiency and destruction of the engine if it is not stopped in time (Hanson 2019). Engine overheating has become a growing concern because of the numerous lamented complaints among road vehicle users and need to be dealt with, with all seriousness.

Over the years research works on the prevention of engine overheating has been carried out to ensure engines work under safe temperatures (Basil et. al 2013). Despite all these numerous research outcomes and recommendations from experts and manufacturers, the problems of engine overheating persist. The problem is that the available research only revolved around two areas in trying to curb engine overheating (i.e. relying on the assistance of the temperature devices and driver vigilance).

However reliability is not guaranteed because first and foremost the devices as a matter of fact are not 100% accurate all the time due to many factors which usually leads to constant fluctuations and incorrect readings of the engine and coolant temperatures (Duan, F. L., & Lin, Y. 2018). Therefore these devices operate in a deficit because they are not able to curb engine overheating perfectly (100%). They set-up is that they are only able to sense the coolant temperature but unable to detect the coolant level or quantity in the system. So in an event of dangerous coolant loses with a faulty temperature device (circuit break or corroded earthen device) the driver will be handicap and may not be able to detect overheating in such a situation.

Therefore this new design is taken into consideration the level of coolant in the cooling system to monitor the engine temperature. The design have the capacity to automatically turn OFF the engine early to avoid overheating taken into consideration the driver negligence and forgetfulness which is a top most caution from researchers for drivers to minimize engine overheating.

1.3 The purpose of the study

The main objective was to design a coolant level backup monitoring system. This will check and alert drivers of coolant levels in the radiator to possibly initiate an early engine shut down to avoid overheating and damage.

1.3.1 Specific objectives

The specific objectives of the study are:

1. To assess the performance and effectiveness of the existing and conventional coolant temperature sensors (thermistor/thermo switches) when the engine run out of coolant during operation.
2. To design a safer, reliable and efficient model/device to overcome engine overheating through low coolant level in the radiator.

3. To conduct a comparative analysis on the existing and the modified temperature sensors.

1.4 Significance of the Study

It is appropriate to research into methods and ways of reducing engine overheating and breakdown.

Therefore this research will relieve drivers or operators of the emotional trauma they go through as a result of the consequence of frequent engine breakdowns due to forgetfulness or negligence on their part to maintain coolant level in the engine. It will help reduce the possible causes of human errors and to an extent avoid unexpected faults from causing harm to the engine due to coolant losses. It will also add to the literature on the prevention of engine overheating and inform manufacturers of the need to modernize the conventional liquid cooling system to minimize engine overheating.

1.7. Organization of the thesis

This report was structured into five chapters. The introduction, which is the subject of Chapter 1, consists of the background of the study, statement of the problem, purpose of the study, specific objectives, significance of the study, and organization of the thesis.

Literature review is the subject of chapter two and it includes; the review of the history of heat and temperature measurement, the need to dissipate heat in an internal combustion engine, the consequences of engine overheating, how heat is manage in internal combustion engine, the major causes of engine overheating, measures to control engine overheating, temperature monitoring devices, types of temperature monitoring mechanism in automobile, thermistors and thermo-switches as engine temperature sensing devices, the setbacks of the existing engine temperature devices, internal and external backup models to monitor engine overheating, the automobile radiator as a heat exchanger and the float sensor.

Chapter 3 presents the method and materials for the experimental investigation of the coolant float sensor and engine switch off circuit unit to control engine overheating with the designed block diagrams, components and instruments such as the radiator, power unit model, fuse model, ignition key model, indicator lights (lamps) models, resistor model, relay model, float sensor model, engine/coolant temperature devices, multimeter, temperature gauge unit and experimental test procedures.

Chapter 4 presents the results and discussion of the design and simulation of the set-up which consists of results obtained from float sensor in close loop circuit under dry coolant radiator condition, float sensor in an open loop circuit under dry coolant radiator condition, temperature sensors under dry coolant engine test, float sensor closed loop circuit during empty radiator condition, temperature sensors under full radiator coolant level during engine run test condition, float sensor and engine responses during coolant leakage under engine running condition, and circuit break tests to find out the real cause that lead to the engine shutdown. Chapter 5 includes the summary, conclusions and recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Temperature and heat are very critical and widely related measured variables for most engineering and other scientific experiments, operations and manufacturing processes. Accurate temperature or heat measurement is critical to ensure quality and safe production, operation, transportation and storage of high quality products.

Temperature is the measure of thermal or internal energy of the molecules within a solid object, liquid or gas or the measure of how much internal energy a substance has (Rajput, 2005). For example, fast-moving gas molecules will always feel "hot" and will easily transfer some heat energy to any cooler object it touches, by warming up that cooler object. The sensing of the transfer of this energy is heat. Therefore, heat is the transfer of energy from a hot object to a colder object or substance (Sari 2017).

Heat is a useful energy needed in everyday activity that involves liquid, solid and gas processes and processing in all fields of life. However, too much of heat in a process or processing of experiments, productions and operations can be detrimental sometimes to the safety of whatever is being processed and the purpose will be defeated (Piątkowski 2010). Therefore, during a process or processing, heat must be monitored and controlled to keep the temperature at a safer level particularly the internal combustion engine which is the focus of this discussion.

2.2 History of Heat and Temperature Measurement

The issue of temperature and overheating monitoring and control had been a long outstanding issue battled with till the growth of technology. The technological trends towards using accurate and safe methods for tracking overheating on processes of all kinds including automobile operation has led to numerous researches.

Before the invention of temperature measuring and monitoring instrument and gauges, greater knowledge was already gained as man attempted to work with metals through the bronze and iron ages (Marsh 2012).

Some of the traditional technological processes at that time required a certain degree of control over overheating, but to control overheating they needed to be able to measure the temperature of what they were processing. For example the glow colour of a hot metal was a good indication of the correct temperature for a process to begin which seems inappropriate (Camufo et.al, 2012).

2.3. The Need to Dissipate Heat in an Internal Combustion Engine

Chemical energy in fuel is transformed into thermal energy (heat) by internal combustion engines which run on heat when the fuel is burned and is further converted to mechanical energy to push the piston, spin the crankshaft and drive the vehicle on the road (Heywood, 2018).

Heat makes an engine work but when the heat is controlled, it makes the engine work better, safer and longer. Ironically the hotter an engine runs the more efficient it becomes. But there is a limit because aluminum pistons and heads can only get so hot before they start to soften and melt and the same goes for cast iron (Samal, et.al, 2020).

Most internal combustion engines are designed to operate within a normal temperature range of about 195^{O}F to 220^{O}F. This is relatively a constant operating temperature essentially for proper emission control, good fuel economy and engine performance, hence protects engine components from melting (Joe 2017).

However, temperatures within the combustion chamber of an engine reaches values on the order of 2700K and above when the fuel burn. But the materials for the engine parts cannot tolerate this kind of temperature and would quickly fail if proper heat transfer does not occur. In addition, hotter combustion chamber walls will lower the average combustion gas temperature and pressure by a given mass of fuel within the cylinder. This heat transfer affects engine performance, efficiency and emissions (Badruddin, et. al, 2015).

A simple fact of internal combustion engines is that they generate heat in order to produce power, but they are unable to convert all the energy produced by the fuel into power. It turns out that only a small percentage of the heat generated actually gets converted to mechanical force. The remaining is expelled through the exhaust, the cylinder walls, cylinder head, and crankcase walls or the engine oil. Accordingly one third (1/3) of the engine heat generated is dissipated to the outside air. Also, for an engine to perform perfectly, the operating temperature must be controlled within a tight range (Mukhtar et.al, 2014).

One of nature's basic laws (second law of thermodynamics) says that heat always flows from a hotter region to a cooler region and not vice versa. The best way to cool hot metals is by keeping them in cooler liquids and a perfect way is to keep the coolant at a constant height in convection currents circulation mode (Jim, 2015).

The dissipation of heat in the engine is highly critical and necessary; this will maintain the normal working temperature of the engine parts at different conditions. This ensures that maximum power; efficiency and longevity are attained at all engine operating conditions. Indeed, cooling system failure is the most common mechanical failure in engines. This is unfortunate, because these failures are usually easy for drivers/operators to prevent (Tom, 2018).

2.4 The Consequences of Engine Overheating

When an engine overheats the next thing that happen is detonation; this is a condition where the engine pinks and starts to lose power under load as the combination of heat and pressure increases beyond the fuel octane rate. In this case, there is the possibility of some hammer-like blows which are likely to damage the rings, pistons or the rod bearings if the detonation problem persists.

Overheating can also cause pre-ignition; this is caused by hot spots developed inside the combustion chamber and becomes a source of early ignition for the fuel. The unregularly pattern of the combustion in older vehicles with carburetors can cause detonation as well as engine run-on. Hot spots can also be very damaging and burn holes right through the top of pistons (Хрулєв, et. al, 2021).

Another consequence of engine overheating may be a blown head gasket which is common. Overheating also make aluminum expands possibly three times faster than cast iron when it is heated. It end effect is a distorted cylinder head with swell-up at the very hot areas, such as spaces between exhaust valves in adjoining cylinders and areas that have restricted coolant flow such as the restricted area between the cylinders. The outcome is loss of torque around the gasket which allows coolant and combustion leaks to occur when the head cools down (Ebrinc et.al, 2007).

In the case where the coolant gets hot enough to boil; it is likely to cause old hoses or weak radiators to burst under the high pressure. If busted hoses or radiators are not noticed early, the engine will get hot which could lead the pistons to swell up, scuff or seize in their bores, which could cause serious engine damage. Exhaust valve stems may stack or scuff in their guides. This in turn may cause valves to hang open which can then damage pistons, valves and other valve train components.

The importance and/or the need to dissipate heat in an internal combustion engine cannot be over emphasized. However, it is important to mention that the cost of preventing parts from overheating are less expensive than fixing the damage overheating might have done. But there are exceptions to this rule; of course prevention they say is better than cleaning up the mess afterward. Indeed the challenge is how to remove the waste heat in a most efficient and reliable manner possible in internal combustion engines to avoid overheating.

2.5 How Heat is Manage in Internal Combustion Engine

When fuel is burnt in an engine heat is produced. The thermal to mechanical conversion efficiency is within the range of 25% to 35%. The 65% or more left over available heat which is not converted to mechanical output has to be expelled or disposed-off in some manner. Part of this heat goes out the exhaust tail pipe as heated exhaust gas; while some radiate off the exhaust system and other engine parts as infrared energy with some more carried away by thermal conduction to surrounding air (Mukhtar et al 2014).

According to Endo et al, (2007), two-thirds of the energy produced by a gasoline engine is lost through waste heat. About 35% of the total energy that enters an engine from the fuel is turned useful through the crankshaft to propel or turn other components, and about 30% of the energy is carried away from the engine through the exhaust in the form of enthalpy and chemical energy. This leaves about one-third of the total energy that must be dissipated to the surroundings by some mode of heat transfer (Jadhao et. al. 2013).

Steve (2000) explained that engines converts about a third of their fuel's energy to mechanical energy to move the car. About a third goes out the tail pipe unused and most of the remaining third is released as heat. Heat must be conducted away from the engine, or the engine will reach temperatures fatal to it life. According to another school of thought, the overall heat distribution in an engine is in five folds. About 25% is used to keep the engine running (power output), 10% is used to overcome friction, and 30% is expelled through the exhaust. Pumping of liquids (oil and water) and gasses (compressors) within the system is taken care off by 5% while the cooling system absorbs 30% of the heat energy as it is indicated in the table in Figure.2.1 below.

Method of heat distribution	**Percentages distribution**
Power output	25%
Cooling system	30%
Pumping (liquids and water)	5%
Exhaust system	30%
Friction	10%
Total heat distribution	100%

Table 2.1 Heat distributions in internal combustion engine by percentages

Heisler (2000) contribution suggest that the total heat generated within a running engine is managed in three forms to quickly and continuously remove excess heat to avoid overheating and engine damage. The assumption is that nearly 50% of the fuel energy in an engine is wasted out the exhaust stacks, 30% is absorbed in cooling, pumping and friction factors and only 20% turns into horsepower.

2.6 The Major Causes of Engine Overheating

Overheating is deadly to an engine. Anything that decreases the cooling system's ability to absorb, transport and dissipate heat will lead to overheating. It could be low coolant level resulting from internal or external coolant leaks, poor heat conductivity in and outside the engine because of accumulated deposits in the water jackets and outer walls.

Others include defective thermostat that doesn't open, poor air flow through the radiator, a slipping fan clutch, an inoperative electric cooling fan, a collapsed lower radiator hose, an eroded or loose water pump impeller, or even a defective radiator cap among others (Larry, 2019).

Manufacturers and researchers in their observation on engine overheating are of the view that the number one cause of engine overheating is driver or operator negligence and failure to properly maintain and service the cooling system as outlined in the owner's manuals. It has always been attributed to human errors and failure such as driver failure to stay alert and monitor the engine temperature and coolant level during operation (Justin 2021).

Also auto mechanics are rife with stories of customers with leaked radiators who managed to keep things running by adding water on short trips. The "I'll get it soon done" mentality of drivers has killed more engines than anything else. That applies to everything from not replacing a radiator with a known leak to not checking the coolant level regularly, not inspecting the cooling system hoses and failure to do coolants change when necessary.

However, there are some causes that are outside the driver's control. For instance, a faulty radiator cup, thermostat, coolant circulation pump and other less obvious causes are outside the driver's control and little can be done about it by drivers. Luck of lubrication of engine is another serious cause of engine overheating. It causes the parts to dry up completely and melt down. Wrong engine timing is another obvious cause of engine overheating; however the focus is on causes affiliated to coolant shortages or losses in the engine. Overheating is obviously trigged by coolant loss or empty coolant system as the main cause and it prevent the engine from getting rid of heat and cause excess heat accumulation in the engine itself (Steve 2002).

2.7 Measures to Control Engine Overheating

Various researchers and manufacturers have suggested numerous solutions to curtail engine overheating and it replica effects and yet engine overheating is a daily lamented complain especially among road vehicle drivers, operators, users and owners.

According to Akinnuli, et.al, (2013) to avoid overheating of an automotive engine of bulldozers the cooling system must be functional. A constant correct coolant level should be maintained at all time as a first aid measure. It is a safety advice to frequently check and maintain the cooling system by ensuring that there are no cracks, leakages, clogged of bugs and debris, grease, or any other substance on radiator and core plugs on engine block or cylinder head near the head gasket. This ensures that engine is not covered and prevented from fresh air getting contact with engine metals.

The incorporation of engine temperature monitors coupled to indicator systems (temperature gauge, warming lamp or alarm bell) helps drivers/operators and users to know when and whether the engine is overheating or not. The general caution is that drivers should always keep an eye on the temperature gauge or pay heeds to the warning light or alarm at all time to prevent serious temperature rise in the first place (Tsukasa, 2021).

Others suggest that, in the event of engine overheating the best to do to save the situation is to turn the engine off, let it cool down and then try to find and fix the causes before attempting further travel. This will avert further engine overheating and therefore safer way to save the engine life during an unexpected event which might lead to coolant losses or monitoring device failure.

2.8 Temperature Monitoring Devices

A wide variety of temperature monitoring devices are in used today and it depend on what you want to measure, how accurate you need to measure it, if you need to use it for control or just mere monitoring, or if you want, you can even touch what you want to monitor with your hand to feel the temperature.

Practically it is hard to tell behind the steering wheel of a vehicle whether or not the engine is overheating without the use of any device/instrument. The need to monitor temperature accurately and precisely in automobile engines cannot be accomplished without the use of these devices (The Chemical Educator 2000).

The most and common engine/coolant temperature sensors used today are "thermistors and thermostats". On early applications, a "dual range" coolant temperature sensor was used and on some older vehicles, a different type of coolant sensor was used. Some of these were essentially an on/off switch that open or close at a predetermined temperature. The sensor may be wired directly to a relay to turn the electric cooling fan on and off, or it sends a signal to a warning light on the instrument panel. These older coolant sensors were typically single wire sensors.

On other older applications, a single wire variable resistor temperature sensor that grounds through threads were used to send a temperature signal to a gauge on the instrument panel. These were typically called temperature "senders" rather than sensors (Steve 2012).

2.9 Types of Temperature Monitoring Mechanism in Automobile

In automobile, temperature monitoring can be accomplished using several types of sensing mechanisms which generally consists of the device (sensor) couple with a Transmitter and an external power supply and wiring that connect the components together. The signal or warning systems take three categories.

These include;

- A temperature gauge (mechanical/electrical)
- A warning light (red or yellow) will come on or blink when the engine temperature is too high and
- A messaging system (alarm or flashing) of an "engine overheating" icon in the driver information center. Usually, the message comes in the form of a signal between a flashing icon of a radiator, radiator fan or "engine overheating" icon.

The adoption of any of these categories of engine temperature warning systems attempt to always signal or warn drivers of a cooling system issue. However regardless of the category of engine/coolant temperature warning system mechanism, all are tied to a sensing device unit.

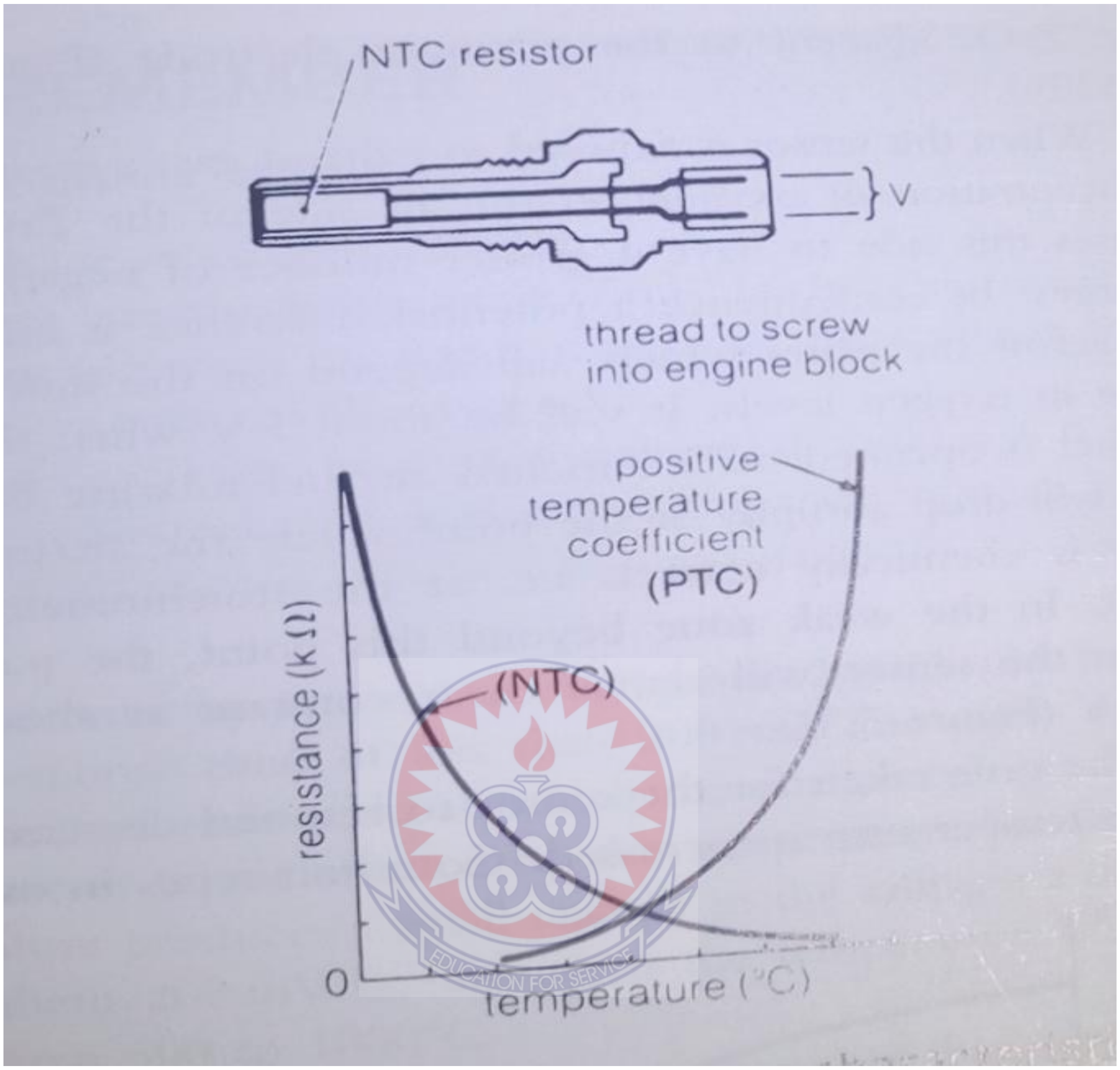
2.10 Thermistor sensor as an Engine/Coolant Temperature Sensing Device

A thermistor is a semiconductor device with an electrical resistance that is proportional to temperature changes. The name is formed from a combination of the words "resistor" and "thermal" as indicated in figure.2.2a. This device is a type designs purposely and suitably for liquid coolant units particularly the internal combustion engine.

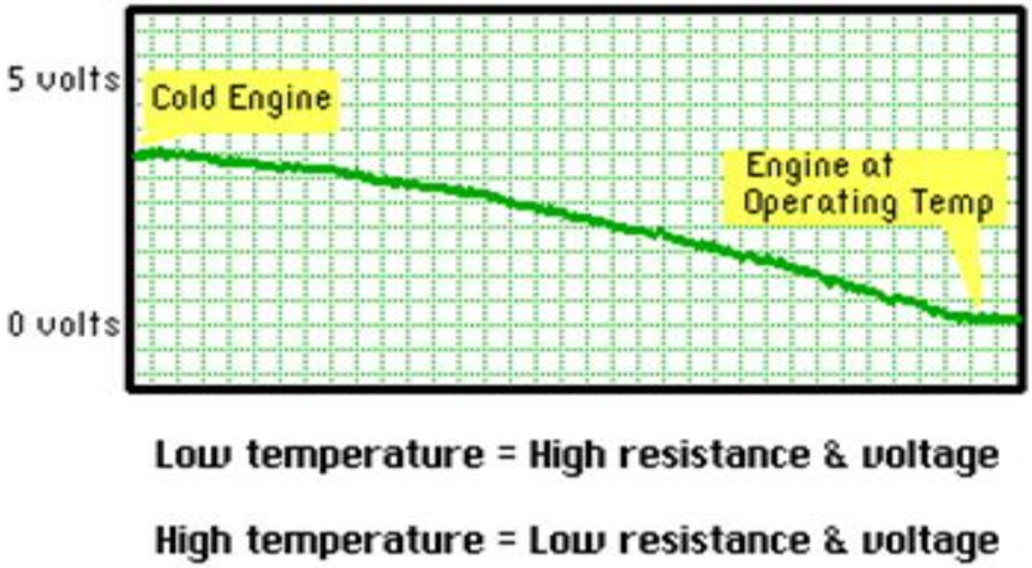
The thermistor sensor comprises of a brass bulb that must be in contact with the substance it's sensing. The bulb contains a capsule called a thermistor. Temperature influences thermistor resistance in an inverse proportion. This is because as the temperature rises, the resistance of the engine's coolant drops and this in turn decreases the potential difference output which is confirmed by the formula below and indicated by the graph in Fig.2.2b:

$$R= R_{0e} [\beta (1/T-1/T_0)] \qquad \text{Eq. (1)}$$

There are two types of thermistors, namely Positive Temperature Coefficient of Resistance (PTC) and Negative Temperature Coefficient of Resistance (NTC), however NTCs are the most common types of thermistors used in automobile. They have temperatures that vary inversely with their resistance, so when the temperature increases, the resistance decreases; and when the temperature decreases, the resistance increases (White, 2017).



(a) Thermistor sensor characteristics graph



(b) Potential difference of a thermistor output graph

Fig.2.2 Thermistor sensor characteristics and potential difference output graphs

2.11 Thermo-Switch as an Engine Temperature Sensing Device

Thermistors are generally predicated on taking the temperature of the coolant. However, if the cooling system fails due to a pump shutdown, or air pocket in the coolant, or a coolant leakage, the thermistor usually becomes disabled and malfunctioned and sometime not give the correct temperature reading. Therefore, there is the need for a backup device to monitor the engine temperature directly and this is the work of a Thermo-switch or thermostat (Larry 2003).

A thermostat device used for direct engine temperature monitoring consists of two bimetallic strips, with contact points. One bimetallic strip is heated electrically, the other strip bends to increase the tension of the contact points as shown in figure.2.3. The different in positions of the bimetallic strip generate the indicator readings. Unlike the thermistor that operate by taking the temperature of the coolant, this device (thermostat) will continue to work regardless of whether or not the coolant level is maintain, circulate properly through the system or not.

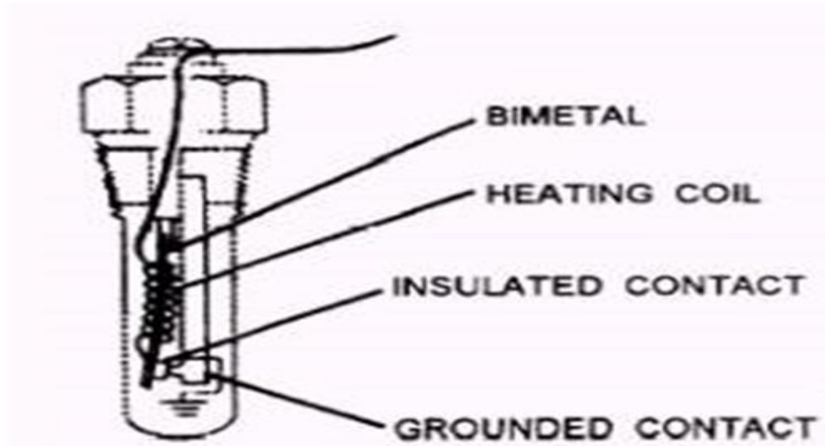


Figure.2.3: Detailed thermostat (Thermo-switch) device

2.12 Setbacks of Existing Engine Temperature Devices

Engine temperature increases and leads the parts to get hotter and hotter when they continually work. The heat will build-up to the melting point of engine parts if not controlled (Ken 2009).This might have prompted the need for monitoring and control of the engine temperature by the deployment of the cooling system and temperature monitoring devices respectively to enable the driver monitor the engine temperature, condition and performance.

However, there are causes and cases complained about the failure of these systems. Though these indicators help keep the driver from being surprised by a change in engine performance they are not 100% accurate all the time. Because it is hard to tell when the gauge needle or warning lamp will stop working entirely as a result of a mechanical or electrical fault. But whether a new or experienced driver, it can be to overlook the indicators easy on your dashboard because things don't go wrong often, so the possibility of cooling system malfunction isn't something that most of us think about on a daily basis (Ismail et. al. 2013).

While the temperature indicators alert drivers to changes in the engine performance, they will do him no good unless he understand and comply with the instruction. For example, if out of negligence the driver fails for one or two reasons to act by the alertness of the temperature gauge, warning lamp or alarm massage the engine will overheat and damage (which is the case always and persistent especially among road vehicle engines). All the same, it's important to keep an eye on your temperature indicators and attend to any issues promptly (Ismail et. al. 2013).

Therefore aside the negligence and failure of drivers to stay focus on the engine temperature gauge and warning lamp and failure to observed safety practices relating to engine cooling system maintenance, the temperature monitoring system itself is not 100% guaranteed all the time. (E.g. Gauges, alarms, indicator light and sending and sensing units can fail to read accurately because they go through fatigue or rust over, or simply lose their electrical connection to ground). The bimetallic spring on the thermostat for example can fatigue overtime, rendering the gauge, lamp or alarm inaccurate/inoperable. For instant a short circuit can cause any of the temperature monitoring mechanisms to malfunction aside the internal mechanical failure of the gauge, lamp or alarm housing.

The fact that the existing temperature monitoring and indicator systems, help engine operators and users to know when and whether the engine is overheating, or not the above mention setbacks cannot be ignored. These setbacks require backup systems (both internal and external measures) that will be able to arrest the situation should the main monitoring device fails.

2.13 Internal Backup Models to Monitor Engine Overheating

It has be found out that, an engine could lose all of it coolant and yet the coolant sensor sometimes never trigger any sign of overheating warning to the driver of the vehicle. To alleviate this problem, later model vehicles deployed two or more temperature sensors on the same engine. In many cases a cylinder head temperature sensor is added to the engine coolant temperature sender which serves as a layer of protection and a redundant safety measure to the temperature warning system (Eric 2014).Though they all sense temperature differences they are meant for different purposes, and for easy identification one is labeled sender and the other sensor, therefore if there is a problem with one, the other is independent.

2.14 External Backup Models to Monitor Engine Overheating

The high temperature of running engines displaces some amount of coolant in the system due to high pressure build-up. In modern engine cooling systems an expansion or recovery tank is added to the cooling system to collect these lose water as shown in figure.2.4.

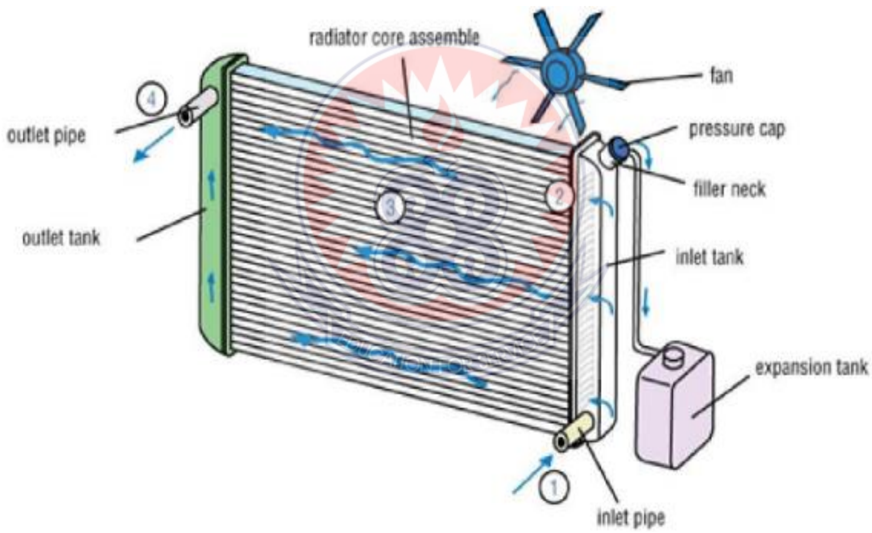


Figure.2.4: Engine coolant recovery tank system

In some engine cooling systems, a level sensor is fixed in the coolant recovery tank to monitor coolant level. It measures the amount of coolant in the recovery tank and serves as a watch dog (Johnson 2015).

Quite obvious from its name, liquid level sensors are used to measure the level of the free-flowing substances like water. They measure the water level against a pre-set reference. But one disadvantage of this design is that, the recovery tank may have water while the radiator suffers water starvation due to leakages. This is possible because when there is loss of communication between the radiator and recovery tank along the linkage line, the radiator could run dry without the level sensor noticing any loses in the radiator. This is because a sealed linkage between the radiator and tank allows water exchange. But in an event of leakage on the link line there will be a complete loss of perfect seal which will prevent the syphoning force from radiator to draw back water from the tank.

In that case the water in the tank cannot automatically be syphoned back to the radiator due to vacuum loses and though the tank may have water the radiator will be starved. So while the sensor feels some reference water level in the recovery tank, it will mislead through the gauge that there is enough coolant in the system while there is none in the radiator and this will trigger overheating.

Base on the mislead signal when the engine is supposed to trigger off by the sensor it will not, because the sensor still detects water level signal in the recovery tank though the radiator is empty. This possibly will lead to overheating which may not be reliance by the driver behind the steering system. This idea is one among others that draw the attention to this research. The new design is an electronic model that serves as a watch dog and automatically turns off the engine on behave of the driver in the event of low water levels in the radiator to avoid engine overheating.

2.15 Automobile Radiator as a Heat Exchanger

The radiator is a device designed to dissipate heat in an engine. It is responsible for preventing the engine from overheating because the engine produces a lot of friction and heat when it is in used. The radiator is connected to the engine with channels through which the liquid is pumped through. It holds a large amount of water in tubes or passages which provide a large area in contact with the atmosphere. It usually consists of cores, with water-carrying tubes and large cooling area, which are connected to a receiving tank (end cap) at the top and to a dispensing tank at the bottom. Internal combustion engines are often cooled by passing a liquid coolant through the engine block, where it is heated and then passes on to the radiator to lose the heat to the atmosphere, and then cold water return back to the engine in a closed loop (Alborz 2006). Radiators are used for cooling internal combustion engines and others such as aircraft, railway locomotives, motorcycles, and stationary plants. Twenty-first century radiators are increasingly becoming innovative in style, colour and form, however it is important to look into their purpose and origin (Claire 2013).

2.15.1 Basic Structure of an Automotive Radiator

The radiator is part of the cooling system of an internal combustion engine as shown in figure 2.4. The bench mark for heat transfer of current radiators is 140 kW of heat at an inlet temperature of 95^{O}C, but the basic radiator has a width of 0.5-0.6 m (20-23“), a height of 0.4-0.7 m (16-27”), and a depth of 0.025-0.038 m (1-1.5”).These dimensions vary depending on the make and model of the automobile engine.

Radiator designs come in different types; however most of them have a few common and main components:

- An inlet and an outlet
- Two tanks
- Tubes that connect the tanks

- Fins in between the tubes

The tanks make up the main structural components of the radiator, and are sometimes connected by frames. These tanks are referred to as top and bottom takes or in some design at side's ways of the radiator. The inlet and outlet are typically placed on the opposite tanks, but that isn't the case always.

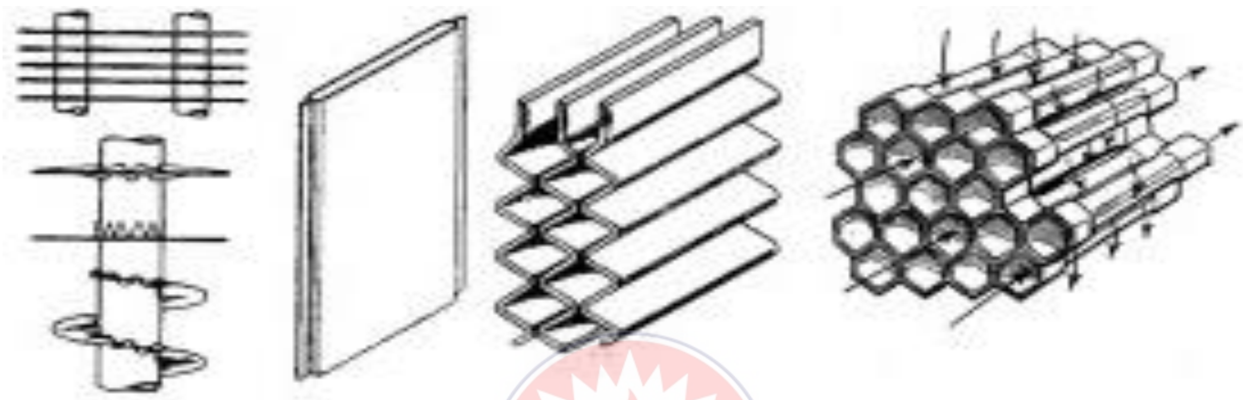


Figure 2.5 methods of radiator construction techniques

The tubes connect the tanks and allow coolant to circulate round the system. These tubes are typically flat and very thin; to maximize the surface area of the tube so that the coolant is exposed to as it passes through the system. Between the tubes are thin fins which help to add more surface area to the radiator and the combine design nature of the tubes and fins are referred to as the radiator core (see fig.2.6).

2.15.2 Radiator Construction Materials

Radiators are constructed from different metals in in combination to plastic components. Until recently, radiator tanks were typically made out of brass, and radiator cores made from either copper or brass. However, the tanks are made from plastic and the cores made from of aluminum.

It mainly consists of light copper, brass or aluminum alloy or hard plastic upper and lower tanks however both tanks are bolted to cast side pillars. The upper tank is connected to the water outlets hose from the engine jackets and the lower tank connected to the inlet through water pump by means of hose pipes.

2.15.3 Effects of a fault Radiator

Radiators failure can be influence by a number of reasons, but the end result is always an overheated engine. Some of the common problems a radiator can suffer from include:

- leaks
- internal plugging of the tubes
- external debris occluding the fins

For the fact that the above motioned issues can result in an overheating engine, and once overheating can cause severe engine damage, it is relatively important to repair or replace a radiator at the first signs of a defect.

The engine relies heavily on the radiator to run on normal temperature. The defect and failure of the radiator is the main cause of engine overheating because through it the heat in the coolant from the engine is dissipated and cold water return to the engine relative to what comes out the engine to cool it. Besides, it holds part of the coolant and maintains a pressure that prevents the coolant boiling at 100^{O}C.

Natural failures due to component age cannot be ignored as radiators begin to fail as age caught up with them and other possible defects are cracks and torn water hoses and many other causes leading to coolant losses. All these defects triggers engine overheating and the end effect is engine inefficiency and breakdown. This needs to be dealt with carefully, to ride off these effects and hence the need to modify the radiator to accommodate a built inn float sensor that will regularly monitor the coolant level in the radiator.

2.16 Introduction to liquid leaks sensors

Visually monitor liquid levels in boilers or storage tanks are a very essential requirement in process industry. Hence there are many limitations in using the armored glass sight gauges to monitor the liquid level. Magnetic Level Indicators are used wide-spread in global industries, this overcome the problems such as breakage, leaks, or bursting at high pressures and temperatures.

Magnetic Level Indicators utilizing a combination of buoyancy principles along with the benefits of magnetism. The float dynamically tracks the surface of the liquid in the chamber as fluid inside rises and falls. The magnet assembly inside the float generates a magnetic field that penetrates through the chamber wall to couple the visual indicator. The float is sized and weighted based on the density of the liquid to be measured.

Liquid leak sensors are typically manufactured for compatibility with specific liquid types. For example, manufacturers may design sensors to detect water leaks, corrosive fluid leaks, or petroleum-based leaks. Sensors may also be configured to effectively detect leaks in foamy, dirty, or opaque liquids.

Liquid leak detection products are typically specialized float switches, conductivity sensors, or seal failure detectors which operate according to one of the principles listed above or on the Liquid Leak Detectors Search Form. These sensors output data to a compatible meter in the form of voltage, current, or frequency.

2.17 Introduction of Float Sensors

Liquid level measurement is considered as one of the primary process measurements, i.e. temperature, pressure, flow, and level. Measuring any of these parameters is difficult due to the harsh conditions involved. High temperature, high pressure, corrosive environments, turbulence, etc. are a few of the conditions a measurement device must endure if will fulfill its main goal of accuracy and dependability. Due to these factors, numerous and various level measurement devices have been developed to effectively handle a particular type of application (Henry 2004).

In few applications, a rough indication of level is needed, and simple devices such as dipsticks or float systems are adequate instruments for such purpose. However in some other cases where high accuracy is demanded, other types of instrument must be used. In this case liquid level float sensors and switches are discussed here.

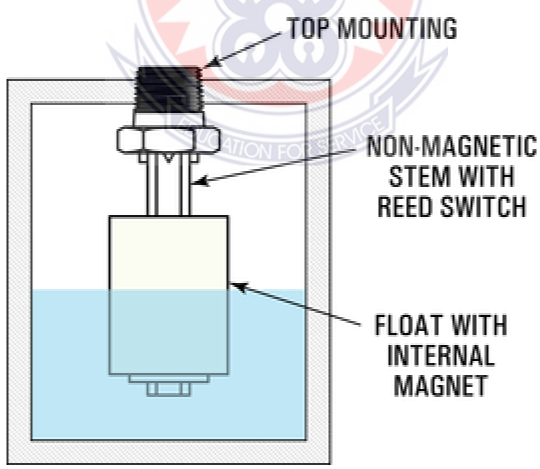


Figure 2.6 sample computational float sensor

Liquid Level switches and sensors are electromechanical and electromagnetic devices that open or close an electrical circuit in response to a change in the level of a liquid in storage areas such as tanks, reservoirs, sumps and wells. Liquid level sensors and float switches are in three basic sizes: full, miniature and sub-miniature, and in a wide variety of mountings, construction materials and sensing technologies. Float switches and liquid level sensors are manufactured with proven reed switch technology and offer trouble-free service with precise repeatability.

Float Types of level sensors are based on the principle of buoyancy which is the upward force produced on a submerged object by the displaced fluid. This force is equal to the weight of the displaced fluid. Float sensors take their measurements at the interfaces of materials, where the movements of the float and/or the force on the float are caused by the differing densities of the float and the fluid. There are two broad categories of Float Type level sensors: Buoyancy and Static; however our discussion is based on the Buoyancy type.

Buoyancy level sensors are less dense than the fluid and thus change position along with the fluid level. The movement of the float transmits the level information through some mechanical linkage to an output such as a valve or operator observation. There are basic three types of mechanical linkage - chain / tape sensors, lever / shaft mechanisms and magnetically coupled devices.

Chain / Tape sensors – The linkage is by a flexible chain or tape.

Lever / Shaft mechanisms – The linkage is a rigid shaft.

Magnetically coupled devices – These devices are similar to the Chain/Tape sensors, except a magnet is attached to the float and another is acted upon by the floating magnet moving a tape like the chain/tape type devices. The moving magnet can be sequestered from the float attached magnet for use in corrosive media.

2.17.1 Function of a Float Sensor

The purpose of a Float switch is to close or open a circuit following the level of the rising and falling of the liquid. Liquid level float switches float in liquids and are used to measure the level of a liquid inside a container/tank. These floats can simply indicate the level of the liquid, or they can hold other functions like turning pumps on or off when they reach a certain level in the container. How they are made and installed dictate what they will do and how they will work.

2.17.2 Principle of a Float Sensor

All float operated liquid level controls operate on the basic buoyancy principle which states that "the buoyancy force action on an object is equal to the mass of liquid displaced by the object." As a result, floats ride on the liquid surface partially submerged and move the same distance the liquid level moves. Because of this, they are normally used for narrow level differential applications such as high level alarm or low level alarm.

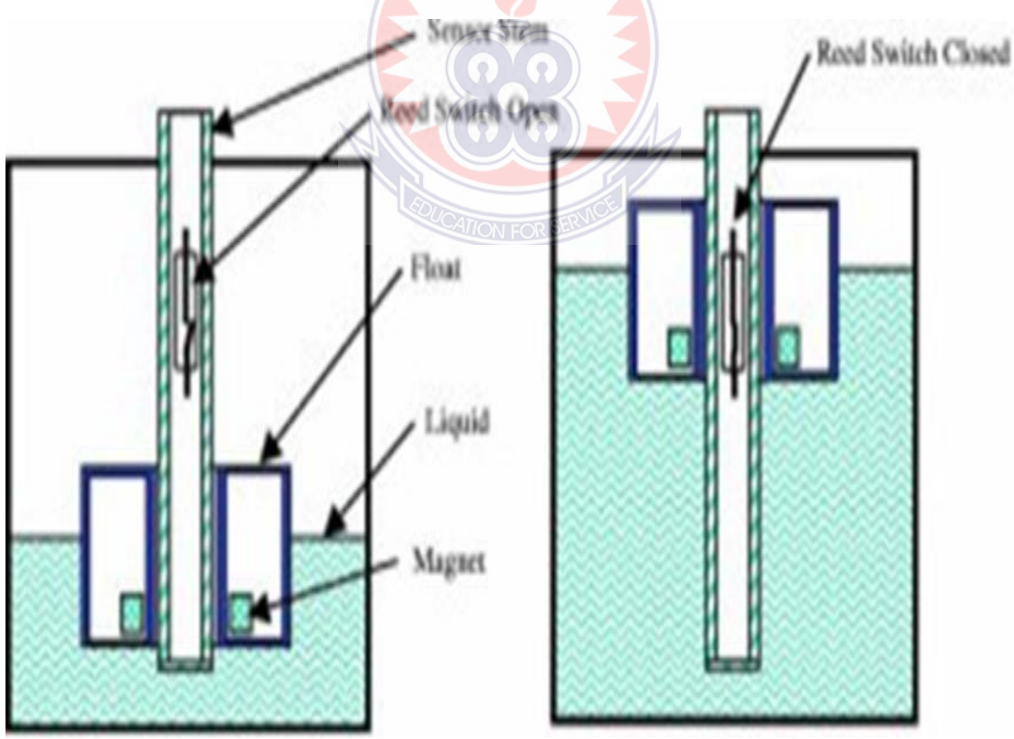


Figure 2.7 principles of float sensor

2.17.3 Theory of Float Sensor

Magnetic level gauges work on the principle of communicating vessels; therefore the level in the measuring (float) chamber will be the same as the level in the vessel (radiator). The measuring chamber is fitted with a float, which has a magnet inside. The float with magnet will float on the medium and the magnet in the float will turn the flaps of the indicating rail (reed switch). Each flap in the indicating rail is fitted with a permanent magnet which makes this level gauge unaffected by shocks, vibrations and high temperatures. Also moisture and / or an aggressive environment are no problem for this level gauge.

This magnetic level gauge is available with plastic or stainless steel flaps. The flaps can be placed in a plastic, aluminium or stainless steel housing. All the magnetic level gauges are fitted with a float. This float is standard in stainless steel, but the float is also available in Titanium or Hastelloy. The float must have enough buoyancy and the magnet must be fitted at the right position inside the float. So it is always important to select a float which is suitable for the process conditions.

In order to select the correct float the following process conditions are necessary;

- Medium
- Density
- Working pressure and
- Operating temperature

The lowest density, for which we can supply a float is 380 kg/m3 but this depend on the before mentioned process conditions. When a fluid is very aggressive we can also coat the float with a suitable lining. When we have a choice between an open float and a pressurized float we prefer the pressurized float. Because the open float will eventually sink, condensate will build up inside the open float. For example our pressurized floats are suitable for 208 bars at 375°C with a density of 650 kg/m3. The float inside a magnetic level gauge can be fitted with a torriodal (360°) magnet or a magnetic bar.

All our floats are fitted standard with a torriodal magnet, because a float with a magnetic bar can lose their guidance/ indication rail by rapid movement inside the level gauge. As a result the magnetic level gauge will not work properly for a while. Torriodal magnets are not affected by rapid movements of the float and can move freely inside the level gauge. This is also why you can place a level switch at all the sides you want.

2.17.4 Types of float sensors

Different types of liquid level float switches and sensors are made out of different materials and for different purpose. The most common types are made of plastic. Others are made out of polymers, and some are made out of stainless steel. Many of them are simply visual. They indicate the level of a liquid in a vessel or take of some kind.

2.17.5 Reed Switche

When you mount a magnetic switch on the level gauge it is possible to get a signal. With more switches you can make a pump control (pump on / off) and / or obtain a high / low alarm. We can supply general purpose switches, switches for hazardous areas, or switches suitable for marine applications.

Typically, liquid level detection is achieved by a magnetic float moving up and down on the outside of a hollow brass cylindrical tube (figure 2.8). Inside of the tube is the reed switch that opens or closes as the magnetic float moves into position over the reed switch. There are stops placed on the tube to restrict the movement of the float to the proper range around the reed switch. The magnetic level sensor can have multiple levels of sensing built into one tube.

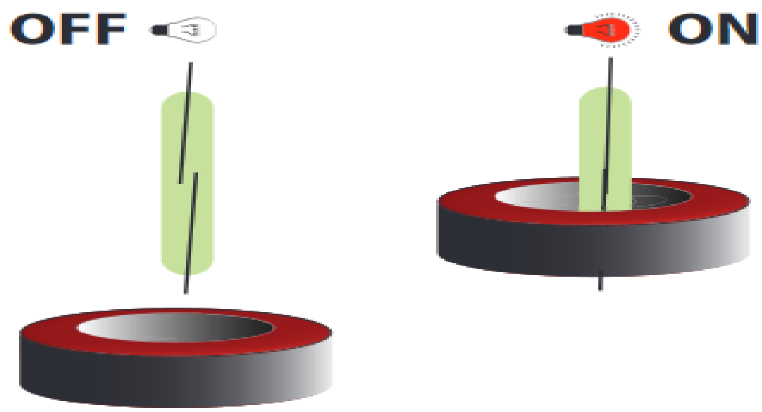
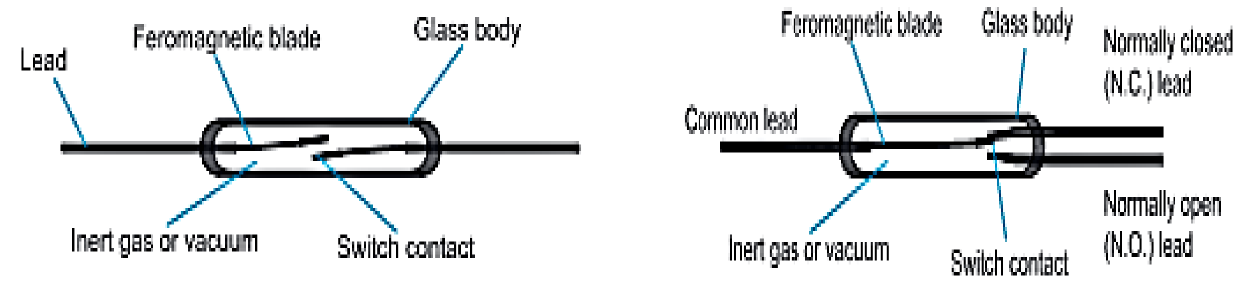


Figure 2.8: action of magnetic float moving up and down to closes or opens the reed switch

2.17.6 Types of reed switch categories

Reed Switches consist of two or three ferromagnetic blades (or reeds) hermetically sealed inside a glass envelope. The construction ensures protection from the external environment. Three types are available: Form A (normally open), Form B (normally closed), and Form C (changeover). Form B reed switches are obtained by two methods: By using normally closed blade of a Form C switch, or, by using a Form A switch, and biasing the contacts closed using a small block magnet. The switch is then able to re-open by the use of another stronger external magnet of opposite polarity. Sensitivity of a reed switch is measured in ampere turns (A.T.) and it should be noted that lower switch (A.T.) ratings are more sensitive as they require less magnetic field strength to operate them. Various voltage and current switching levels are available and contact plating materials can be varied to accommodate specific types of load. REED switch is the base for magnetic sensors.



(a) (b)

Figure 2.9: Types of reeds switches (a) form 1A normally open reed switch (b) form 1C three lead reed switch.

2.18 Float Chamber

Float chambers are used to facilitate the external mounting of the float switch onto a tank or pressure vessel, particularly where space inside the vessel is restricted or where the control must be isolated for routine maintenance whilst the plant is in operation as shown in figure 2.12. A wide range of cast or fabricated chambers is available. Exotic materials are also available. Process connections may be specified as top-and-bottom or side-and-side, and can be flanged, screwed or butt welded in a choice of sizes to suit most plant installations.

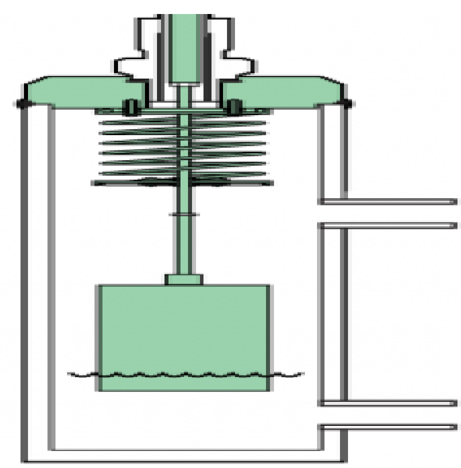


Figure 2.10: computational float chamber

2.19 Magnetic Float Sensor Layout and Operating Temperatures and pressures

Float sensors operate efficiently in cooler liquids. But for the purpose of this work the magnetic float sensor used operates under high temperatures between 80-150 ℃. It is deployed in hot liquid vessels in homes and industrial liquid heater systems to regulate and indicate the liquid level in the vessels as electromechanical safety device to control overheating

However magnetic effectiveness reduces when too much heat is around the magnetic zone (Mike 2007). In order to minimize heat effect on the magnet which could affect the effectiveness of the unit the mechanism operates at lower radiator tank coolant temperatures.

2.20 Control of the coolant-Level Process

The idea of the float sensor model system is to maintain a hydrostatically stable equilibrium of the coolant level at a certain pre-defined depth or density layer, at which the float must be neutrally buoyant. Therefore, a detailed and accurate model of the float's buoyancy is required. This section introduces the displacement and buoyancy model for the float and its components to monitor the coolant level hC at the desired level hV in the face of disturbances (leakages) in the vessel (engine cooling system).

2.21 Float Sensor Design

In float design, two major criteria must be satisfied.

1. The float buoyancy and weight must be balanced and the magnets are in the same plane as the liquid surface or the liquid interface.
2. Float must withstand the design pressure and temperature.

Furthermore, the float must be providing an accurate level indication and which is least dependent on the liquid's density changes.

2.21.1 Float Buoyancy

For accurate indication of fluid level, the float must be positioned in such that the maximum magnetic intensity shall be at the fluid surface or the interface. The buoyancy and the weight of the float must balance properly to achieve this.

$$Mass\ of\ float = submerged\ volume\ \times fluid\ Density \qquad \text{Eq.2}$$

Submerged Fraction,

$$SF = \frac{Submerged\ Volume}{\text{Float volume}} \qquad \text{Eq.3}$$

Generally, the submerged fractions of the floats are as follows.

Submerged Fraction: Top level float – 0.8, Interface Level Float - 0.5

2.21.2 Float net buoyancy

At any given depth, the float buoyancy force FB is calculated using the surrounding fluid's density ρ and the volume of fluid that is displaced due to the immersed float $\nabla|T,P$ according to

$$FB = g \times \nabla|T,P \times \rho(T,P,\eta), \qquad \text{Eq(4)}$$

where g is the standard gravitational acceleration, P is the ambient hydrostatic pressure, T is the ambient temperature and η is the water salinity. The float's buoyancy will thus vary depending on $P,T,$ and η. The net buoyancy is the resulting force between FB and the float's gravitational force

$$FG = m \times g \qquad \text{Eq(5)}$$

where m denotes the total float mass. At a neutrally buoyant position, these two forces should be equal, and the net buoyancy therefore zero. In order to predict the buoyant behavior of the float to achieve neutral buoyancy at a desired depth assuming constant m, it is necessary to model the effect of changes in $P\ and\ T$ on all relevant components.

2.21.3 Float displacement model

The float's displaced volume is composed of the elements as seen in figure 3.7, excluding its inner components. The geometric dimensions and material properties of all components affecting the displaced volume are the float variables necessary for calculating the change of displaced volume.

2.21.4 Calibration

Ambient pressure and temperature at a given depth affect the displacement of each component in terms of $dP\ and\ dT$, their relative change to their values at surface calibration. A slight vacuum inside the tube is an option that could facilitate perfect sealing of the chamber. Hence, temperature and pressure calibration is crucial and requires initial, user-defined setting. For simplicity and reading facilitation, it is generally referred to dP, dT, P_{cal} and T_{cal}, in the respective calculations.

2.21.5 Displaced volume

The displaced volume at time of calibration, $\nabla 0$, is equal to the addition of the components according to figure 3.7

$$\nabla 0 = \nabla 0_{tube} + \nabla 0_{end,tube,upper} + \nabla 0_{end,tube,lower} + \nabla 0_{form} + \nabla 0_{drop} \qquad \text{Eq(6)}$$

The momentary float displacement is $\nabla|T,P$ $u$nder compression and material deformation due to dP and. in the following, $\nabla|T,P$ will be derived by calculating the effects of stresses and strains separately for the cylindrical tube, the two tube end, foam volume and dropweight. It is assumed that the working stresses between the components and the reduction of effective VBS volume are negligible. Thus,

$$\nabla|T,P = \nabla 0 + d\nabla|T,P, \quad \text{Eq(7)}$$

where

$$d\nabla|T,P = (\mathrm{d}\nabla_{\mathrm{tube}} + \mathrm{d}\nabla_{\mathrm{endtube,upper}} + \mathrm{d}\nabla_{\mathrm{endtube,lower}} + \mathrm{d}\nabla_{\mathrm{form}} + \mathrm{d}\nabla_{\mathrm{d}\nabla\mathrm{drop}})|T,P. \quad \text{Eq(8)}$$

2.21.6 Displacement change due to deformation of float chamber

Pressure and temperature differences between the environment and inside of the float cause longitudinal (indexed L) and tangential (indexed T) stresses, σL and σT , in the cylinder wall. These cause an elongation or compression of the cylinder radius dR and length dL in longitudinal and tangential direction by a factor ϵL and ϵT, respectively. While the stresses are purely dependent on the tube geometry, their effect in form of ϵ depends on the chosen material's Elasticity modulus E, Poisson ratio v, and coefficient of thermal expansion αT. The amount of change in displaced volume can therefore be influenced by choice of material, which will be presented in table 2.1. The pressure and temperature change is assumed constant over the length of the cylindrical tube. The overall induced displacement

change from the cylindrical tube is then

$$\mathrm{d}\nabla_{\mathrm{tube}} = \mathrm{d}\nabla_{\mathrm{tube,press}} + \mathrm{d}\nabla_{\mathrm{tube,temp}} \quad \text{Eq(9)}$$

with the pressure and temperature induced strains and stresses calculated separately according to below formulas.

2.21.7 Pressure influence on float chamber/tube

For thin-walled pressure vessels according to Roark et al, the displacement change of the cylindrical tube due to pressure, $d\nabla_{tube,press}$, is computed as

$$\sigma L = dp \times \frac{R}{2t_{tube}} \qquad \text{Eq(10)}$$

$$\sigma T = dp \times \frac{R}{t_{tube}} \qquad \text{Eq(11)}$$

$$\epsilon L = dP \times \frac{R^2}{E_{tube}} \times t_{tube}\left(1 - \frac{v_{tube}}{2}\right) \qquad \text{Eq(12)}$$

$$\epsilon T = dp \times R \times \frac{L}{E_{tube}} \times t_{tube}(0.5 - v_{tube}) \qquad \text{Eq(13)}$$

$$dL_{press} = \epsilon L \times L \qquad \text{Eq(14)}$$

$$dR_{press} = \epsilon T \times R \qquad \text{Eq(15)}$$

$$d\nabla_{tube,press} = \nabla 0_{tube} \times \left(R + dR_{press}\right)^2 \times \left(L + dL_{press}\right) - \frac{LR^2}{L} \times R^2 \qquad \text{Eq(16)}$$

2.21.8 Temperature influence on float chamber/tube

Similarly, since there will exist a temperature difference dT between the temperature at point of calibration and the momentary temperature during operation, thermal deformation ϵt must be accounted for, resulting in a displacement changed $\nabla_{tube,temp.}$ This is determined using the coefficient of thermal expansion αT of the material:

$$\epsilon t = \alpha T_{tube} \times dT \qquad \text{Eq(17)}$$

$$dL_{temp} = \epsilon t \times L \qquad \text{Eq(18)}$$

$$dR_{temp} = \epsilon t \times R \qquad \text{Eq(19)}$$

$$d\nabla_{tube,temp} = \nabla 0_{,tube} \times \left(R + dR_{temp}\right)^2 \times \left(L + dL_{temp}\right) - L \times \frac{R^2}{L} \times R^2 \qquad \text{Eq(20)}$$

2.21.9 Float Material & Thickness

The float must withstand the pressure, temperature and corrosive properties on the particular application apart from achieve buoyancy in the process media.

The selected material of the float has the following features.

- High yield strength to withstand the design pressure & Temperature.
- Low density for use in liquid having low specific gravity
- Anti-Corrosive nature for corrosive fluids.
- Cost effective

The thickness of the float must withstand the design pressure as per ASME BPVC Viii, UG-28. Stiffeners shall be used for lesser thickness shells to maintain the strength.

2.21.10 The float Magnets

The float magnet is a permanent single annulus (360°) magnet used in the float and the strength of the north field to be identical around the circumference area, but the intense of magnetic field shall be lesser. Hence the float will rotate frequently inside the chamber and the toroidal magnets give full circumferential coverage to assure the uninterrupted indication.

The magnet is magnetized in a radial direction, i.e, the inner surface provides South Pole and the outer surface provides North Pole and the field strength of the magnet dependent only on the characteristics of the magnet, the material of which it is constructed, and the degree of magnetization of the materials.

The strength of the magnetic field is one of the major factors when selecting a magnetic level gauge. The magnetic field is the heart of the magnetic level gauge – the stronger the field, the more reliable the instrument will function.

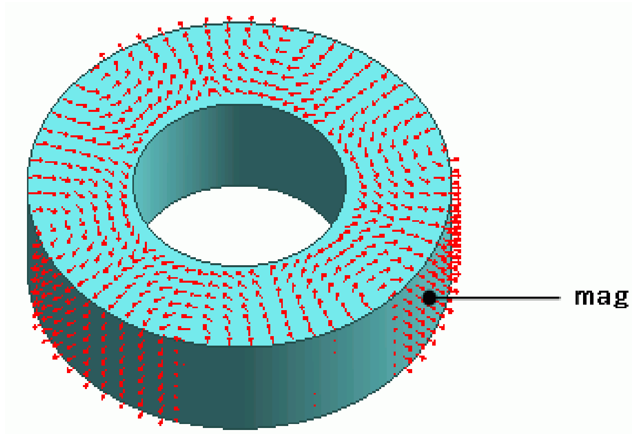


Figure 2.11 wire ring permanent magnet

2.21.11 Permanent ring magnetic field model

This section presents the analytical calculation of the magnetic field of a permanent ring magnet whose magnetic polarization is axial. The extensive calculation is presented only for one annular charged plane. The field produced by a ring magnet of outer radius $R_1$and inner radius R_2 is obtained by the principle of superposition, adding the fields produced by a cylindrical magnet with magnetization $+M\hat{z}$ and radius R_1, and another cylinder with magnetization $-M\hat{z}$ and radius R2 (Wang, et al., 2016). In terms of Fig. 3.10, the scalar potential and the field on the axis are given by:

$$\phi axiz(z)=\frac{M}{2}\left[\left(\sqrt{(z-L)^2}+R_1^2-\sqrt{z^2+R_1^2}\right)-\left(\sqrt{(z-L)^2}+R_1^2-\sqrt{z^2+R_2^2}\right)\right] \quad \text{Eq. (21)}$$

$$B(z)=\frac{\mu_0 M}{2}\left[\left(\frac{z}{\sqrt{z^2+R_1^2}}-\frac{z-L}{\sqrt{(z-L)^2+R_1^2}}\right)-\left(\frac{z}{\sqrt{z^2+R_1^2}}-\frac{z-L}{\sqrt{(z-L)^2+R_2^2}}\right)\right] \quad \text{Eq.(22)}$$

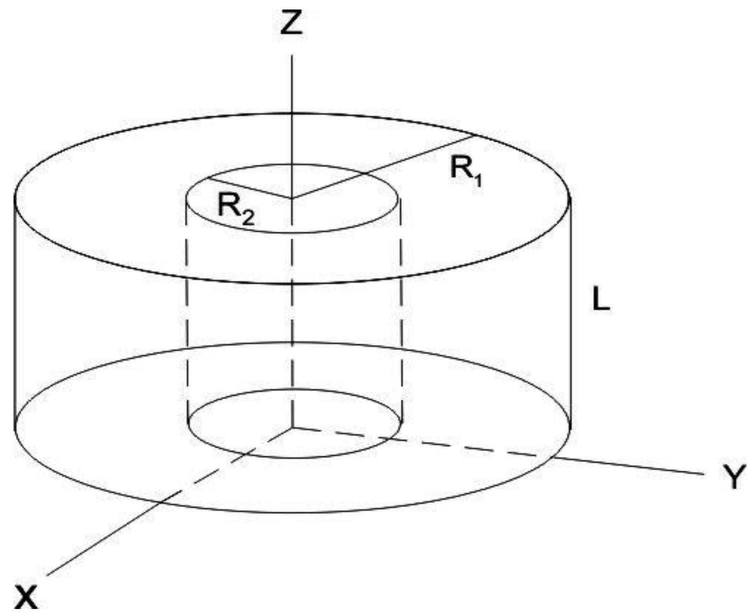


Figure 2.12 Schematic of a ring magnet

2.22 Summary

The chapter elaborated clearly on the need for heat usage in every day's dealing across all fields and sector of life. The emphasis was on the need to monitor heat in processes to bring temperatures under control in all activities especially in the automobile operations to attain maximum power, efficiency and to prolong engine life.

It has also informed readers of the consequence of too much heat in the internal combustion engine specifically underlining engine detonation, pre-ignition, blown head gasket, and parts failure as the main consequence of engine overheating. However, some remedies were suggested to curtail these effects. This includes ensuring that waste heat within the engine is conveniently and reliably removed to avoid engine running into hotter temperatures. Some of this ways include sufficient discharge of the heat through the exhaust, lubrication and cooling systems.

The chapter discuss and underlines some causes of engine overheating, these includes defective parts associated to cooling system; for example a faulty water pump, thermostat, radiator and specifically emphasized on low or empty water levels in the system. It however recommends measures to control engine overheating, such as ensuring constant correct water level in the system at all time, ensuring the functionality of temperature sensors and reading equipment and finally suggested that engines should quickly be turn off as soon as an overheating sign is noticed.

The chapter constructively discussed the details and setbacks of thermistor and thermostat as the types of engine temperature devices, basically pointing at the mechanical and electrical possible failures of this devices and their reading mechanism. The need for internal and external backup temperature monitoring systems, are also explained in this section due to the setback of the existing modules which also has their own setbacks.

CHAPTER THREE

METHODS AND MATERIALS

3.1 Introduction

This chapter describes and presents the materials used in the design and the methodology. An experiment was also conducted on a four-cylinder four-stroke diesel engine with the design concept of a built-in coolant float sensor circuit. This proposed design was modeled using local automobile electronic components except the float sensor which is rare in auto application.

The design circuit is split into two sections, namely the control circuit and the load circuit units. The control circuit section is traced between the fuse block and the relay coil section which mainly include a float sensor, an indicator lamp and the relay coil coupled with cables as shown in Figure 3.2. The load circuit consists of the resistor, relay switch, fuel solenoid switch and an output signal lamp which source power from the battery through an ignition key and a fuse box as shown in the design system block in Figure 3.3.

The first step of the design procedure was by gathering the required information for the design specifications. The exact system components used were calculated and placed on computer aided design software known as multisim which was used for the design simulation of the paper design to ascertain the functionality of the model.

3.2 Design Circuit Block Diagram

The approach used in this work was the modular design approach where the overall design was broken into functional blocks, where each block in the diagram represented a component in the circuit that carried out a specific function. The major components used in the design circuit are; a 12v battery, an ignition key, a fuse block, ballast resistor, a normally closed loop relay switch, and a normally opened reed switch magnetic float sensor. The rest are indicator lamps coupled with cables and connectors on a live stationary diesel engine as shown in Figure 3.1; however their configuration is explained in the next section.

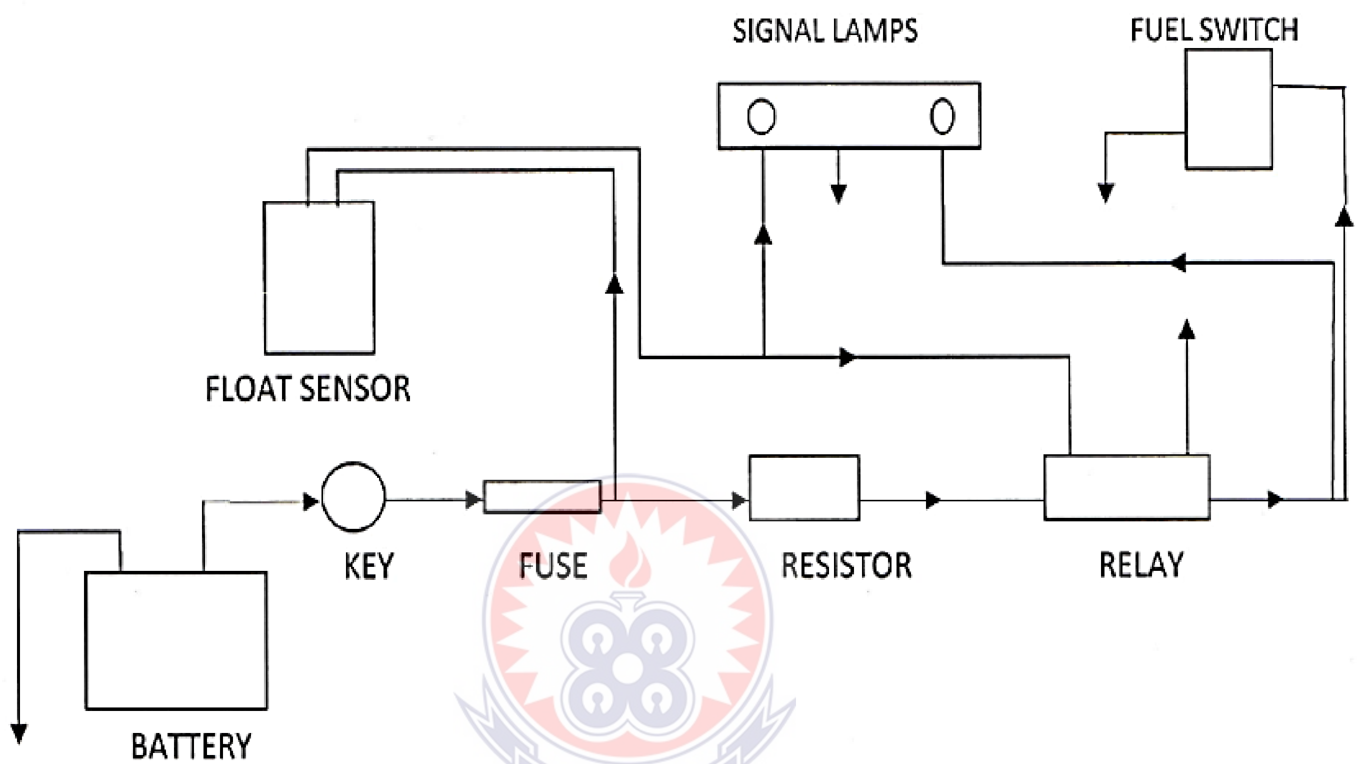


Fig. 3.1: Block diagram of design circuit for monitoring engine coolant level

3.2.1 Components Configuration

With reference to block diagram in Fig. 3.1, beginning at the left lower side and working towards right and top left to right the components are;

1) the battery pack which provides electricity
2) the ignition key, which control the flow of electricity through the circuit from the battery
3) the fuse block, which protect the circuit against short circuiting and excess current
4) the magnetic float sensor unit which is use to interrupt the flow of electricity in the relay switch

5) the resistor work is to pass on battery voltage/current to the relay not more than 12v.
6) the relay switch which is use to interrupt the current flow to the engine fuel solenoid unit
7) indicator lamps connected in series to the control and load circuits which glows on the dashboard to alert the operator of the functionality of the control and load circuits and
8) the load unit (fuel solenoid switch) which is connected at the tail end of the relay output
9) The key component to the system is the float sensor unit which is equipped with reed switch contact points and magnetic float weight to open and close to interrupt the current flow in the relay switch. The key component (float sensor) and it associated elements were carefully selected to work safely with existing engine electrical apparatus standards.

3.2.2 The Design Circuit Block Diagrams

The design circuit comprises of two (2) sub-circuits as stated early, which are interconnected and interacts to monitor the coolant level. In responds they communicate and command the engine to shut down in an event of coolant losses by simply cutting off battery current to the fuel switch. The two circuits are the control circuit and the load circuit.

The control circuit section of the design circuit is traced from the battery through the ignition key, fuse box, magnetic float sensor, control indicator lamp and the magnetic coil end of the relay unit. The main components that differentiate the control circuit from the lord circuit are the float sensor and the control indicator lamp.

The float sensor is mounted on a separate chamber attached to the side of the radiator unit and connected between the fuse and the relay coil terminal pin NO.85 by cables. The indicator lamp is fixed on the dashboard also connected to the relay coil terminal pin NO.85 and earth as shown in Fig. 3.2.

The illumination of the lamp indicates there is a coolant loss below normal level or something is wrong with the system. The lamp performs two functions; first it glow to inform the driver or operator of a coolant problem and secondly it help in easy tracing of electrical faults along the circuit during an event of fault tracing. The bulb can take any shape, size and wattage but must function under 12v dc.

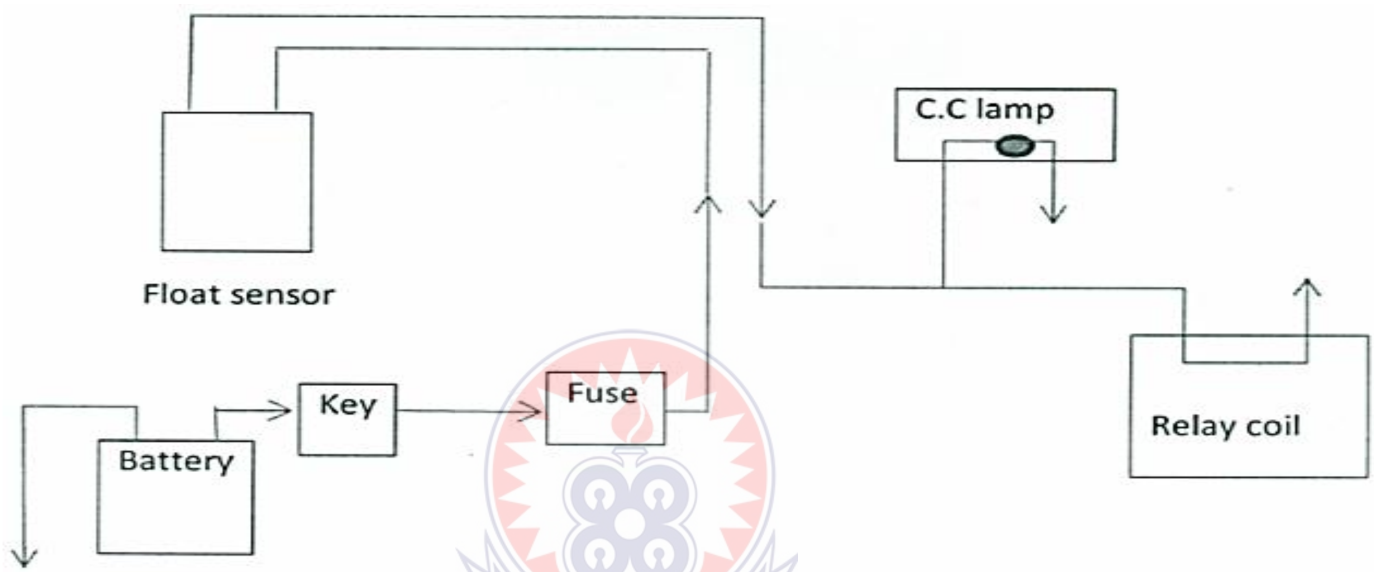


Fig.3.2: Control circuit block diagram of design circuit for monitoring engine coolant level

Most C.I engine injection pumps deploy solenoid switches that control the entering of diesel fuel into the pump. These switches are fixed on the fuel flow line in the pump to control the flow inn of fuel to the pump (s). By their design they are electrically energized or de-energized to open or close the fuel path to allow or prevent fuel flow into the pump chamber respectively.

The load circuit comprises the battery, ignition key, fuse, relay, fuel solenoid switch and a load indicator lamp as shown in figure 3.3 below. The design detail and mode of operation of each component is however discussed later in the chapter.

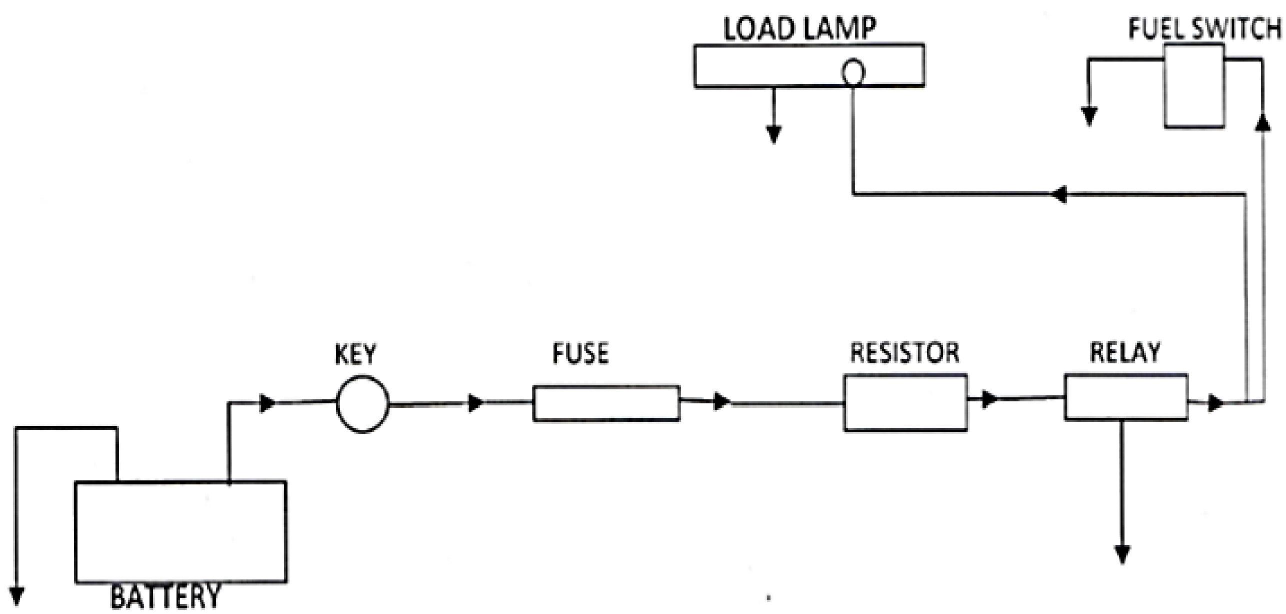


Fig.3.3: Load circuit block diagram of design circuit for monitoring engine coolant level

3.3 Design components

The design circuit was modeled with the appropriate selected components on the engine used for the experiment. The basic components used for this design are commonly used in automobile and are available in different sizes, capacities and voltage/current rating except the Magnetic Float Sensor which is rare and not popular in automobile usage. The selected components are analyzed based on their basic theory suitable for this design.

3.3.1 The Engine

An internal combustion engine converts gas into motion by burning crude oil to generate power to propel a vehicle and for other purposes. This process is called "internal combustion." where the engine use small, controlled explosions to generate the power needed to move the car about the places it needs to go.

The internal combustion engine operates under a four-stroke or two-stroke combustion cycle. This cycle of operation of strokes includes the intake, compression, combustion, and exhaust strokes. The strokes are repeated over and over, generating power to move the car. To understand this combustion process a closer look at what happens during each phase of the combustion cycle is discussed on the four-stroke cycle which was used for this experiment.

During the induction stroke, the intake valve opens while the exhaust valve remains closed with the engine the piston moving downward. This is the beginning of the cycle during which air is send into the engine cylinders. When the piston ends it intake stroke, the compression stroke begins, with the piston moving up to push the air in the cylinder into a smaller space; a smaller space means a more powerful explosion.

When the compression stroke is about to end the air is compressed at a very high temperature. An injector sprays diesel fuel into the hot air in the cylinder to ignite and explodes the compressed air. The power of the explosion, forces the piston downward faster than before. The cycle ends on the exhaust stroke, where the exhaust valve opens to release waste gas created by the explosion. This gas (smoke) is moved to the catalytic converter, where it is cleaned, and then through the muffler exits through the tailpipe of the engine.

The engine used for the investigation was a 2.0 litres Toyota diesel four-stroke four-cylinder engine as shown in fig 3.4, and has a high pressure common rail fuel system with two valves per cylinder. The engine for the experiment was a It is a diesel engine with a compression ratio of 9.8 to 1 and operates on Otto-cycle and water cooled with a tank capacity of 4.5 litres. Table 3.1 shows the main characteristics of the engine and more specific information about the engine cooling system.

Figure 3.4: Setup engine for design circuit experiment

Year	**2000**
Manufacturer	Toyota
Model	8.99.54c
Engine Capacity	1597cc
Engine Type	GA 16
Number of cylinders	4/DOHC
Engine Firing Order	1-3-4-2
Compression Ratio	9.8:1
Cooling System capacity	5.5 litres of water
Thermostat	opening 76.5c
Radiator Pressure	0.78-0.98 bar
Ignition timing basic BTDC	Engine/rpm 10+2/625
Idling Speed	750+50 rpm

Table 3.1: Setup Engine Specification

3.3.2 The Radiator

The radiator used for this experiment was a serpentine-fin cross-flow type measured 55 mm × 25 mm in length and breadth respectively as shown in Fig.3.4. The number of tubes was one row of 55 tubes with a thickness of 1.5 mm. The fins were copper made of 0.5mm thickness, a height of 12 mm and spaced 2 mm apart.

Figure 3.5 specified radiator used for experiment

In operation, hot water is pumped from the engine to the top (receiving) tank of the radiator, where it gets spread over the tops of the tubes. As the water passes down through the tubes, it loses its heat to the air stream which passes around the outside of the tubes and the water get back to the engine cooled. The radiator is located in front of the engine in order to benefit from the airflow drawn by the cooling fan.

3.3.3. The Float Chamber

In order to achieve the required experimental conditions, some modification attachment is introduced to the radiator to accommodate the float sensor separately. The modification is a cylindrical brass tube linked to the lower tank of the radiator at side way, where the float sensor is submerged in the water at radiator lower tank coolant temperature condition but at upper radiator tank coolant level.

3.3.4 Source of Power

A 12V lead acid battery with a 6.5 Ah energy capacity was used to power the engine and it accessories. The battery was capable of delivering 35 kW power at nominal state-of-charge. The design circuit relied heavily on the battery as the main and initial source of power supply. The circuit takes it power directly from the battery as a primary source but source power from the generator during engine operation. Any voltage below 6v dc or above 12.6vdc will not be suitable to operate the unit efficiently.

3.3.5 Ignition Key Model

The entire circuit was controlled by the ignition key. It is the diverging point of power distribution to the various units in the engine. The circuit was supplied with power direct from the key, so that the circuit was only energized when the key was is turn ON and stays OFF until the key was turn ON so that it does not drain the battery when the engine is not running.

3.3.6 Fuse Model

To ensure safe operation of the circuit and it components the circuit is protected by a fuse. The amount of voltage/current demand of the fuel switch and indicator lamps was considered for the selection of the fuse size.

The selected fuse was rated at 40 Ohms to associate with this circuit to withstand components demand voltage/current. The selected fuse was located at the common fuse box and rated by the used of the basic Ohms law formula (V=IR) to meet the standard of the circuit.

Figure 3.6 Fuse block

3.3.7 Selected Float Sensor

The float sensor consists of a float encircling a stationary stem which is equipped with powerful, permanent magnets and contains hermetical sealed reed switch and made from stainless steel stem non-magnetic metal material. Reed switch is a ferrous small device material with two reed contacts. The contacts (which look like metal reeds) are made from magnetic material and are housed inside the stem of the sensor. One of the contacts is a magnetic north pole, while the other is a south pole

Figure 3.7: float sensor

3.3.8 Indicator Lights (lamps) Models

The circuit contains two signal lamps connected and placed at the dashboard face. They include the 'CCL' (float signal lamp) which signals to indicate the full operation of the control circuit, and the 'LCL'(relay signal lamp) which glows to assure the functionality of the relay unit as indicated by figure3.5. The 'CCL' light ON when the control circuit was energized and on the other hand the LCL light when the load circuit was powered through the relay unit. For identification the control circuit lamp was identified as (CCL) while the load circuit indicator was labeled (LCL) on the dashboard however both lamps were rated 12vdc, 25w.

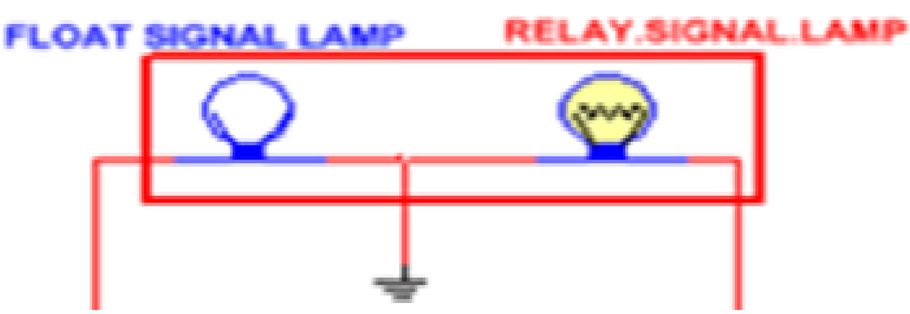


Figure 3.8 circuit signal lamps

3.3.9 Choice of Resistor

Resistors are devices used to regulate the flow of current in a circuit. There are some popularones that are used throughout in automobile however a ballast resistor is used in this work as indicated in the Figure 3.5. This type was selected to match the C.I circuit with a minimum and maximum output voltage of 9.5v and 12v respectively for the solenoid switch. It has a linked resistance element on it terminal post which allows a minimum and maximum voltage flow of 9.5v and 12v respectively to pass on to the load circuit. Any sort less or more current than expected will not be allowed into the load circuit. Therefore during operation it element allows a current suitable for the lamps and fuel switch to flow through to energize the units base on ohms analysis. Which states that current is proportional to voltage; circuits are ohmic if they obey the relation V=IR.

Figure 3.9 circuit signal lamps

3.3.10 Selected Relay

There are two variables that must be consider when selecting a relay for use in the automobile industry; i.e. the coil voltage and the current carrying capacity of the contacts. The maximum and minimum coil voltage for relays used in automobiles is 12 volts and 6volt respectively. What this means is that if you apply 12 volts to the coil, it will "PULL IN" and stay until the applied voltage is removed from the coil and voltage less than 6v may not be able to "PULL OFF" the contact. These are safe operating voltages for efficiency and safety of the circuit at all times.

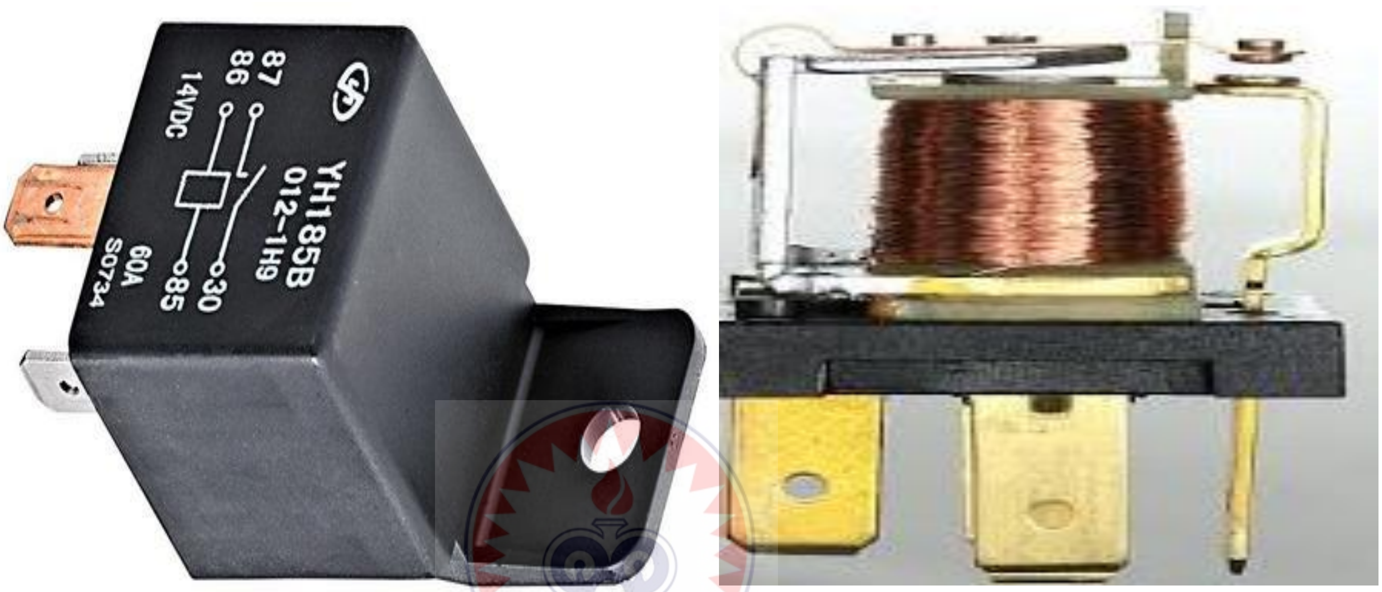


Figure 3.10: The relay

Also there is the need to consider the amount of current that should be allowed into the relay. The current rating on relay contacts tells how much current can flow through without causing damage to the contacts. Some relays have different current ratings for those of normally closed (NC) contacts which are held together by spring tension and those of normally opened (NO) contacts which are held together by the electromagnet.

However the relay used for this work is a normally closed (NC) contacts type with four pins rating at 40amps. The terminal values assign

to the pins for easy identification are shown and explain below.

- Dimensions (mm): 28.0×28.0×25.0

- Pin no. 30 : Power into the relay from battery
- Pin no. 87 : Relay switched power out to fuel
- Pin no. 85 : Positive hot line to activate the relay coil from float sensor
- Pin 86 : Coil ground line to the relay

Table 3.2 model relay specification

3.4. Experimental Setup

The experiment was roll out in two folds; first virtual components were selected and connected to form the final circuit and was simulated using multisim software as shown in Figure 3.6 below. Base on the diagram layout the idea was translated into real components connection on the setup engine. To ensure proper functionality of the components, each component was tested using a digital multi-meter (DMM) and other local means to certify the functionality of each component before it was fixed on the circuit.

From the circuit shown below, current flows from the battery through the fuse unit to the control circuit.

Deducing from the diagram, the float sensor switch is opened indicating full coolant level in the system. Therefore the position of the float sensor reed switch prevented current flow to the control circuit loads (i.e. the CCL and relay coil).

The cut off of current by the float sensor, de-energize the relay coil and therefore switch off the CCL and collapse the magnetic force on the relay coil. The collapse of the magnet coil force, releases the relay contact bar to close the contacts. The closure of the relay contacts allows current flow to energize the LCL and fuel switch, positioning the engine at ready to start as soon as it is cranked. This is indicated in the diagram below in figure 3.6.

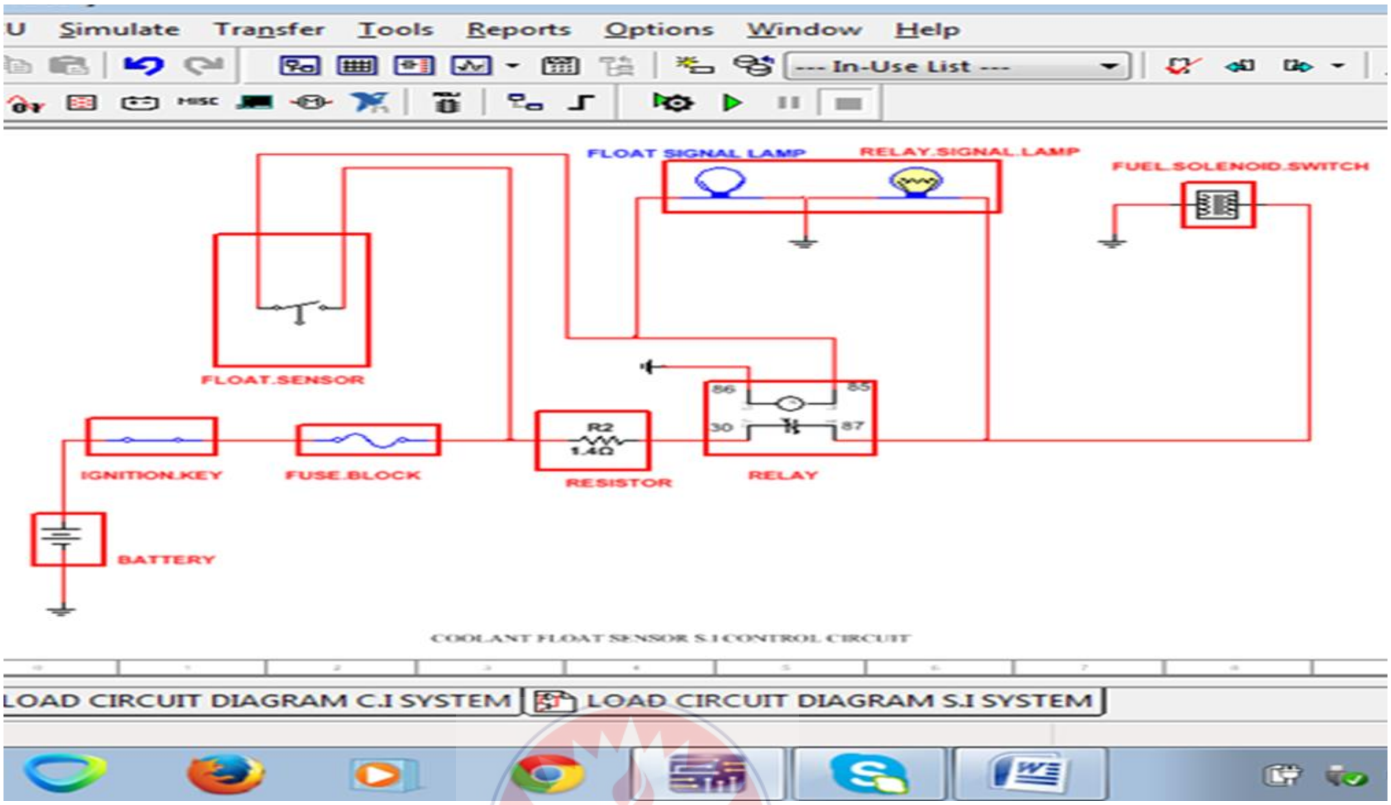


Fig.3.11: Detail design circuit diagram for monitoring coolant level in the engine

3.5 Temperature Devices

Two different types of temperature sensors are inserted onto the setup engine and were used for the investigation. They were engine temperature sensor and coolant temperature sensor as shown in figure 3.9 and figure 3.10.

3.5.1 Engine temperature sensor

The engine temperature sensor is located on the side wall of the crankcase of the engine with two leads to read the engine temperature by conduction as shown in figure 3.12. It is an electromechanical conductor that senses the temperature of metals (conduction).

Fig.3.12: investigated engine temperature sensor positioned on engine crankcase

It works on the principle that when the temperature increases, the resistance decreases; and when the temperature decreases, the resistance increases. Base on this principle, when the engine runs and it temperature begins to raise the device element resistance decreases and this is converted to readings on a gauge in this case, but in some other cases the signal is send to the ECU to influence other functions.

3.5.1 Coolant temperature sensor

The coolant sensor has one lead and is screwed onto the thermostat case to read the outlet coolant temperature of the engine as shown in Fig.3.13. It works on the same principle as that of the engine sensor; however it functions perfectly under the principle of convection (sensing the temperature of liquids perfectly than metals).

In it operation, the heating element when submerge in hot water from the engine converts the heat of the coolant to an electrical signal which is send to the gauge as a temperature reading in figures or numbers. This indicates the temperature at which the engine is running.

Fig.3.13: investigated coolant temperature sensor positioned on coolant outlet tube of the engine

3.6 Measuring Instruments

A temperature gauge instrument unit was used to record the temperature readings of both sensors at different stages of engine running temperatures (Fig.3.14 left). The unit was used for recording temperature difference for both sensors during testing by simply plugging and de-plugging sensors leads interchangeably onto the instrument unit.

A digital multi-meter was also used for other preliminary test of some components during set-up and experimental test processes (Fig.3.14 right). This instrument was used to test the resistance and continuity of components and circuits respectively during set-up and operation process.

Figure 3.14: Reading instruments: temperature gauge unit (left) and multi-meter (right)

3.7 Experimental Procedure

The completed design was tested for durability, effectiveness and functionality and also to ascertain if there was the need to modify the design. The circuit was first assembled on the set-up engine used for this exercise according to the connection layout in Figure 3.6.

The components were assembled and the tests were carried out at various phases and stages to determine whether the design would actually be able to fulfill it intended purpose in the event of coolant loses. The experiment was conducted in the following phases;

1) the engine was ran tested without any water in the system under closed temperature monitoring through the engine and coolant temperature sensors alternatively connected to the temperature gauge unit
2) the same engine was run tested filled with water and performance observed and compared to the first test
3) Other alternative tests (continuity test) were carried out on what was described as self-created circuit faults to ascertain whether or not a defective float sensor will have any negative impact on the whole system. This was specifically centered on the control circuit.

3.8 Design Operation

The design circuit as state above comprises of two circuits in one: the control circuit and the load circuit.

3.8.1 Operation at full radiator coolant level

When the float sensor is installed at full radiator coolant level, the float with the in-built magnet raises up along it stems to close the reed contacts. The closing of the reed contacts allows current flow to energize the relay coil which generates magnetic flux to pull closed the relay contacts along the load circuit path. When the relay contacts are closed current flows to the load lamp on the panel and the solenoid switch in the fuel injection pump to energize it ready for fuel delivery. At a crank the engine will start. Take note: during this period both control and load lamps stay ON.

3.8.2 Operation at low radiator coolant level

When the engine is running and there happens to be any coolant leakage, the coolant level in the radiator will drop. As soon as the coolant level drops below the pre-set of the float sensor, the float magnet run down along it stem causing the reed contacts to open.

The opening of the reed contacts collapse the relay coil magnetic field allowing the relay contacts to open. This will cut off current to the load lamp and fuel solenoid switch therefore cutting off fuel delivery to the engine. The engine will automatically seize to avoid overheating. At this stage the control lamp stays ON while the load lamp stays OFF indicating a coolant problem.

CHAPTER FOUR

RESULTS AND DISSCUSSION

4.1 Introduction

This chapter looks at the data obtained and discusses the results from the experiment conducted on the four-cylinder four-stroke diesel engine with an in-built coolant and engine temperature sensors. It demonstrates the differences, and the need for the backup model developed in this thesis. It also discusses other issues underpinned in this experiment that validates the work.

4.2 Float Sensor in Close Loop Circuit under Dry Coolant Radiator Condition

As shown in Figure 4.1, when the ignition key was turned to the ON position, because the radiator was without coolant (empty) the float sensor switch in response, closed and completed the control circuit where battery current was allowed to flow through to energized the control lamp and relay coil. The control circuit lamp (CCL) glowed ON (yellow spot on diagram) while the energized relay coil opens the load circuit at the relay contacts which resulted to battery current cutting off to the load circuit lamp (LCL) and fuel magnet switch in the injection pump. It was observed that when the key was turned to engine START position, the engine fails to start even with several attempts of cranking the starter motor. To satisfy the design curiosity of this experiment the exercise was taken to a next phase (test two).

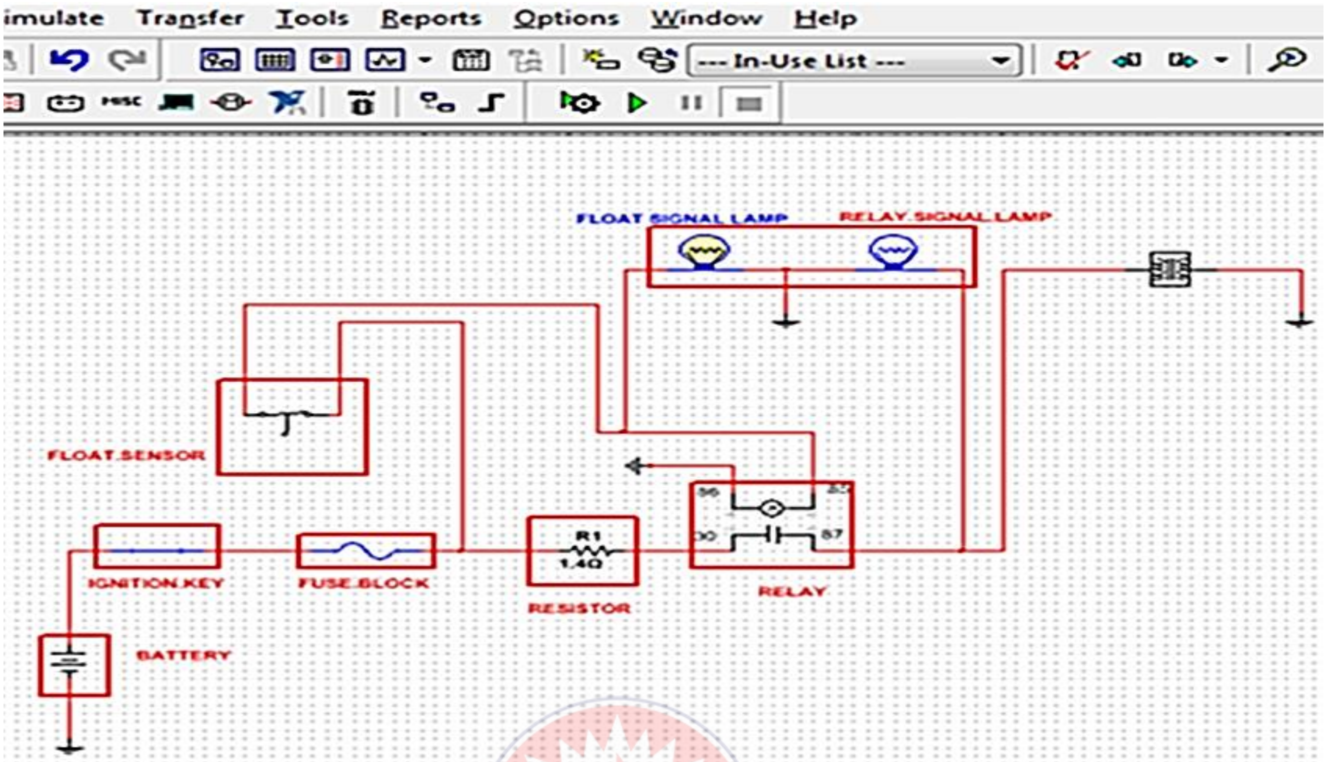


Fig.4.1: Signal diagram of design circuit with activated Float Sensor

4.3 Float Sensor in an Open Loop Circuit under Dry Coolant Radiator Condition

Finding out why the engine did not start at several cranks of the starter motor during TEST ONE, the float sensor was un-activated by disconnecting its OUTLET lead. As indicated in Figure 4.2, it was noticed that the control lamp (white spot) suddenly went OFF while the load lamp lighted ON (yellow spot). As soon as the float sensor lead was disconnected and the starter motor cranked, the engine responded and started working (idling) without coolant in the radiator.

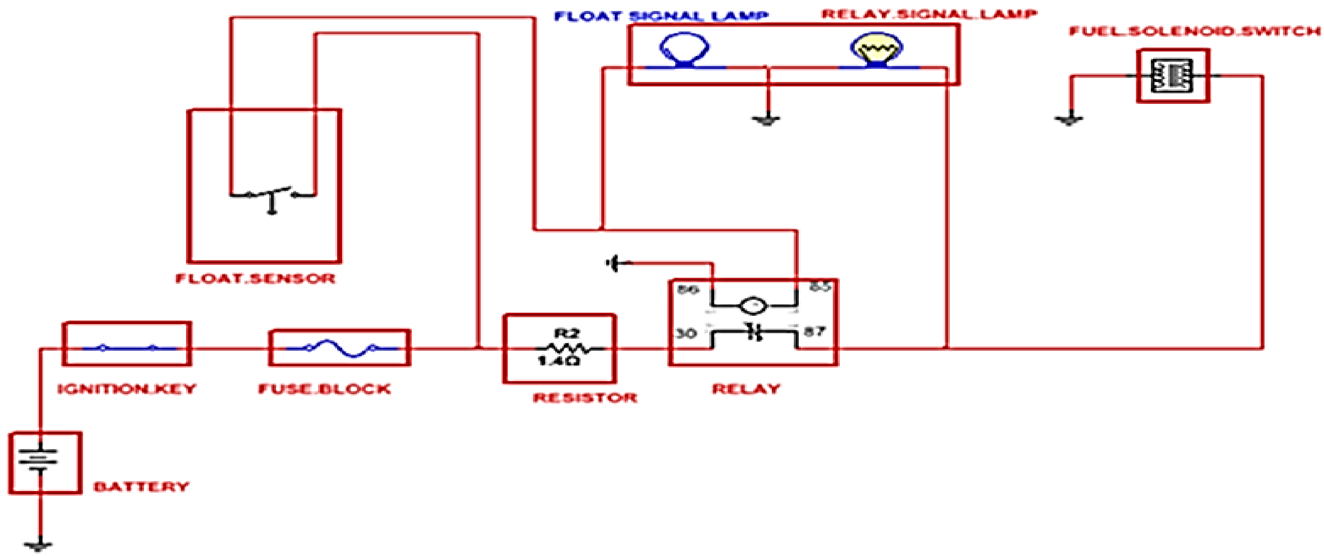


Fig.4.2: Signal diagram of design circuit with un-activated Float Sensor

4.4 Results Obtained from Temperature Sensors under dry Coolant Engine Test

The engine at the end of test two was allowed to idle without coolant in the radiator. During the run the results obtained when both temperature sensors performance were compared as indicated by the graph, shows that both sensors read differently though on the same engine as shown in Figure 4.3. It was observed that there was an increase in engine sound corresponding to increase in temperature in both sensors cases. However the Engine Sensor's reading jumped to as high as 130^{O}C, as soon as the acceleration started at the sixth minute which was reflecting the true ran temperature of the engine compared to the coolant sensor reading which misinformed that the engine was running at twenty degrees celsius (20^{O}C).

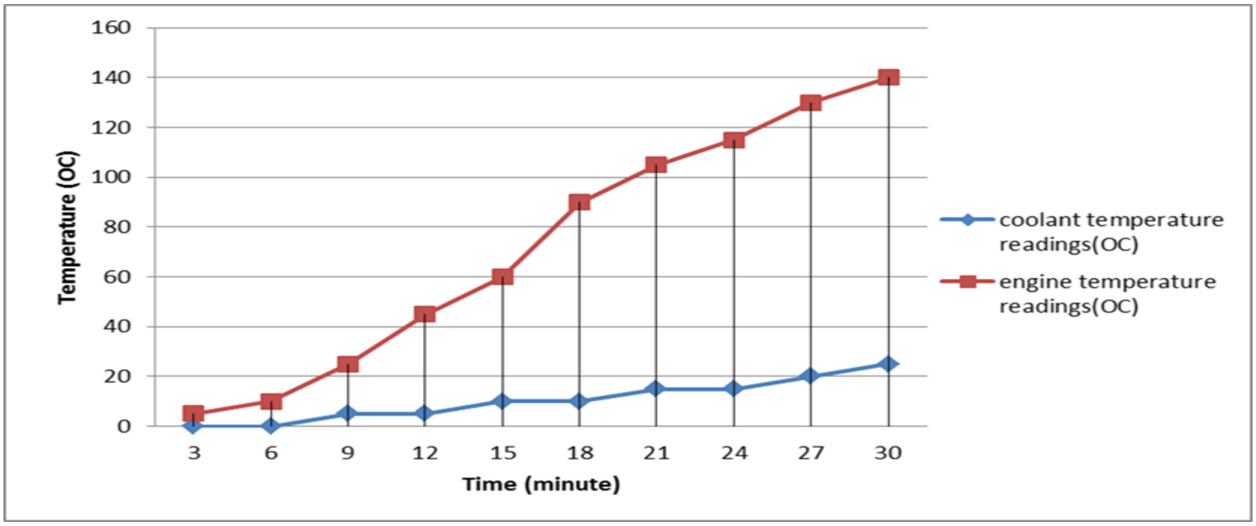


Figure 4.3: Temperature/Time graph on engine and coolant temperature sensors performance during dry engine test.

4.5 Results Obtained from Float Sensor Closed Loop Circuit during Empty Radiator

The float sensor OUTLET lead was reconnected while the engine idles during this test (test four). It was observed that the control lamp (CCL) suddenly turns ON while the load lamp (LCL) and engine triggered OFF as shown in Figure 4.1. This confirms that the float sensor was re-activated, and that allowed current flow to the control circuit to de-energizes the load circuit that shut down the engine.

4.6 Results Obtained from Temperature Sensors under Full Radiator Coolant level during Engine Run Test

While the ignition key remains on the ON position the radiator was filled with water to a level near the neck. The result observed showed the control lamp suddenly switched OFF while the load lamp lighted (ON). The engine was restarted again after filling the water and allowed to idle under full coolant level in the radiator. The temperature of the engine and coolant were monitored under this full coolant level condition through the temperature sensors to observe their responses.

As shown in Figure 4.4, the results obtained when the two sensors readings were compared, indicated that both sensors read almost the same Figures with a slight difference, where the coolant sensor reading was a bit lower than the engine sensor reading. This is indicated by the graphs below at 45^{O}C and 50^{O}C respectively.

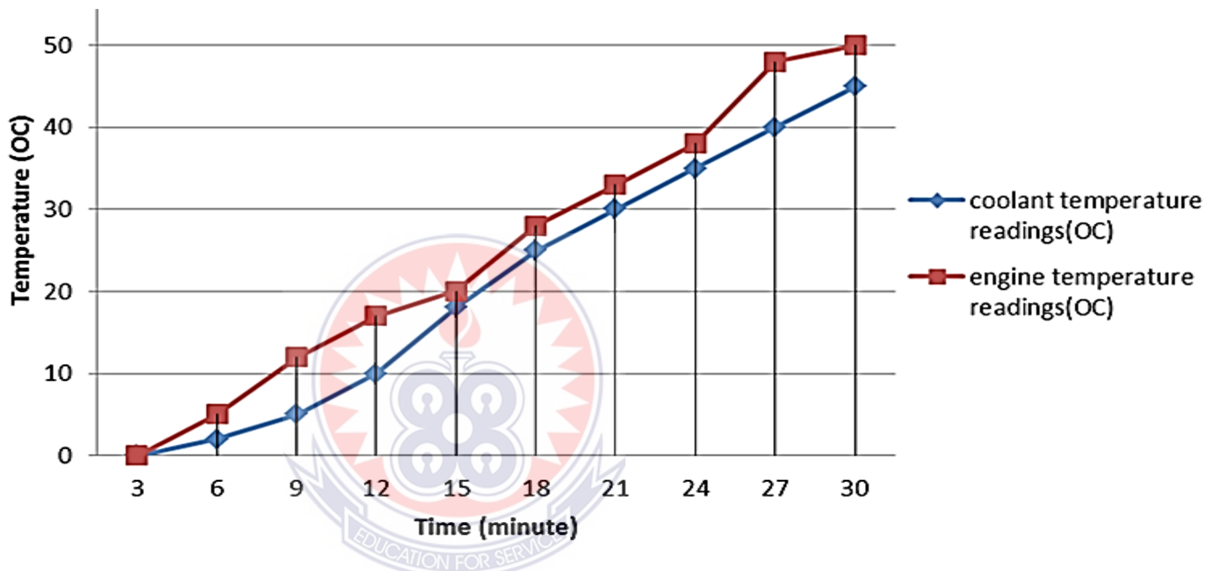


Fig.4.4: Temperature/time graph indicating the performance of temperature sensors during full radiator coolant level with engine running

4.7 Results obtained from float sensor and engine responses in the event of coolant leakage during engine running

This phase of the test was to observe the action of the float sensor and response of the engine in an event of coolant losses through leakage and any other way which could result in engine overheating during operation by lowering the water level in the radiator. In the exercise the drain plug under the lower tank of the radiator was used as a leak-point to discharge water from the system to observe the response and action of both float sensor and engine.

The results obtained when the leakage was created with the engine in running for some time, showed that in the process the water level fell below the required preset height of the float sensor. The sensor in the chamber detected the low water level in the radiator and suddenly signaled by turning ON the control lamp and energizing the relay coil, and in response, turned OFF the load lamp and engine as indicated in Figure 4.1.

4.8 Results obtained from circuit break tests to find out the real cause that lead to the engine shutdown during test six

To find out why the engine went off during test six, three preliminary circuit break tests were carried out on both circuits using a multi-meter to diagnose the cause of the engine seizure.

4.8.1 Demonstration and Results

Step One

During the demonstration set-up of step one, the red (positive) lead of the multi-meter was connected to the inlet (IN) terminal of the Float Sensor while the black (negative) lead was connected to earth. The meter read 12.7vdc when it was turn ON.

Step Two

Test step two was conducted by connecting the red (positive) lead of the meter to the float sensor outlet (OUT) lead at relay terminal NO.85 and the black (negative) lead to earth. The outcome reading on the meter was 12.6vdc.

Step Three

This test conducted is known as continuity test on the load circuit. In this round of the exercise, the meter was set on the continuity alarm with the red lead of the meter connected to the input terminal NO.35 and the black lead connected to the output terminal NO.87 of the relay unit to determine the position of the relay contacts in relation to the activation of the control circuit.

4.9 Discussion of Results

The results obtained during the test from the responses of the sensors are compared and conclusions deduced systematically as explain below.

The results obtained during the activation of the control circuit compared to that obtained during un-activated mode of the same circuit as shown in Figures 4.1 and 4.2, observed that in the absence of coolant (water) in the radiator, the ‘float sensor’ permitted a flow of battery current through it switch contacts.

The current flow energized the relay coil and produces magnetic forces which open the relay contacts resulting in voltage/current cut off to the load lamp and fuel switch in the injection pump and therefore the engine could not start even at several cranked attempts of the starter motor.

However, during the un-activated mode of the float sensor where the sensor OUTLET lead was disconnected, the relay coil was de-energized which released the relay contacts to complete the load circuit which allowed the flow of battery current to the fuel switch and at a crank by the starter motor the engine started and idled.

This could be explained by the fact that the float sensor was functional when the outlet (OUT) lead was not disconnected hence was able to energize the relay coil that continually kept open the relay contacts. However when it was un-activated it could not disrupt the 'load circuit' and this resulted in full flow of battery current through the Load circuit to the fuel switch that allowed the engine to start at a crank as indicated in Figure 4.2.

In reference to Figure 4.3, the performance of both temperature sensors were compared. It was observed that the engine sensor recorded higher temperature than the coolant sensor under the same speculated time on the same engine under dry radiator run test. This reading contradicts and so far as keeping track of engine temperature was concerned, it was not normal and safe to keep the engine running.

This can be explained that the coolant sensor is a convectional device (i.e. it performs perfectly when in direct contact with liquid substance than gases or solids) while the engine sensor works perfectly under conduction (i.e.it performs perfectly when in direct contact with solids (metal components).

Therefore in an event of dry radiator engine run as a result of water shortage in the radiator such as the experiment conduced in this case, the coolant sensor gave wrong information about the running temperature. Base on this as far as engine overheating was concerned if reference was not made on the engine temperature reading, relying on only coolant sensor reading would have been a disaster.

Because the engine would have go on overheating without the operator's noticing it. This means that the coolant sensor reading cannot always be rely upon all the time as the only means of monitoring the temperature of the engine. Otherwise it will always take drivers surprise why their engines overheat when the sensor does not signal any sign of that sough, like what happen in this exercise and which is usual the case and common among road vehicles.

The results obtained from the coolant sensor performance under full radiator coolant level compared to that obtained by the engine sensor as shown in Figure 4.4, shows that the coolant sensor in full radiator coolant contact was reflecting the true running temperature of the engine. Because while the engine sensor was reading as high as 50ºC under the full radiator coolant mode the coolant sensor read 45ºC which was normal temperature of the engine within the speculated time, compared to results obtained when the engine was dry ran tested as shown in Figure 4.3.

Also results obtained when coolant in the radiator was intentionally drained out slowly by a self-created fault through the radiator drain plug, observed a sudden shutdown of the engine. It was caused by the action of the float sensor as explained in section 4.5. The Sensor's action prevented the engine from continue working, which if had been allowed, could lead to or trigger overheating if the engine had ran empty or dry (without water) for a longer time. This response fulfilled the desired result expected of the design arrangement; that when the control lamp is ON, the load lamp and engine must go OFF or vice versa in the event of coolant losses.

Comparing the temperature of the engine sensor under dry and full radiator coolant running scenarios, it can be observed in Figure 4.5 that the significant results obtained had the sensor indicating an alarming temperature at dry engine ran at the thirtieth minute. This is dangerous as long as keeping track of engine temperature (overheating) was concern, compared to its performance in full coolant engine running condition at the same thirtieth minute observation.

In general observation the temperature of the engine increases exponentially during dry run as compared to the slow notice of the sensor readings during operation under full radiator coolant condition. This is due to the fact that when there is no or limited coolant in the engine, less heat is taken out, thus increasing the internal temperature of the engine as observed in Figure 4.5. Under full coolant scenario, since the engine is filled with coolant, the coolant absorbs and picks up the heat from the engine walls and out to the atmosphere through the radiator. This decreases engine temperature (blue line indicator on graph) as compared to dry engine ran condition (red line indicator on graph).

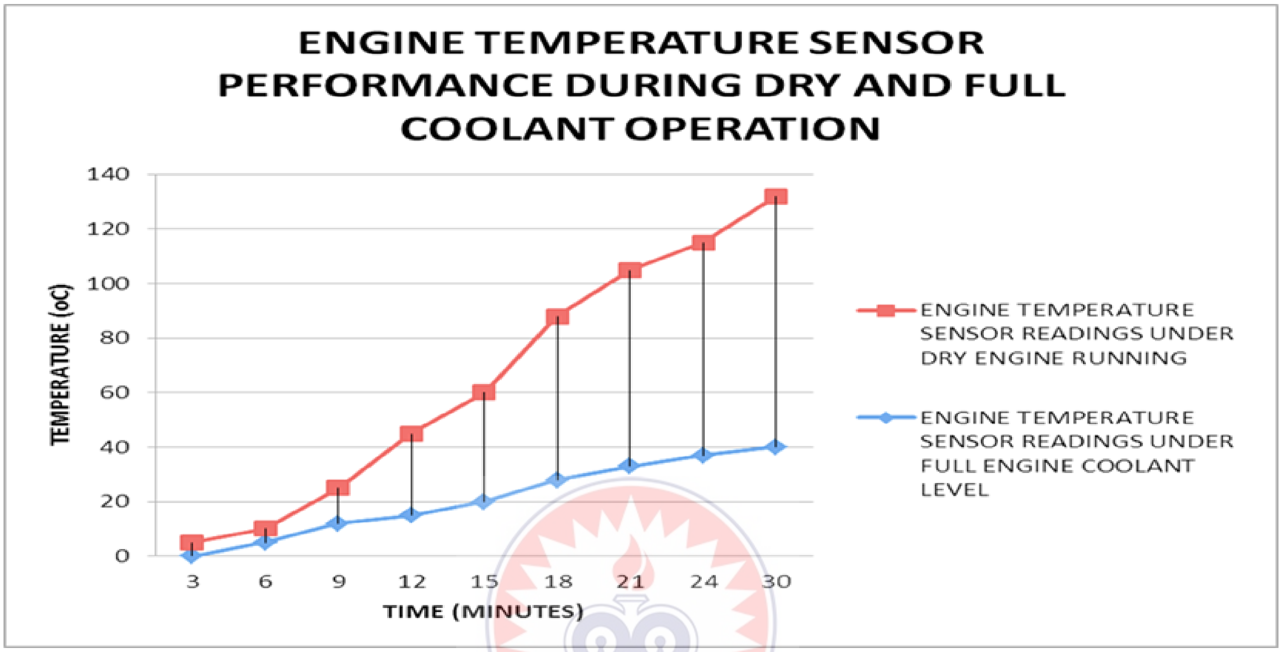


Fig.4.5: Comparison model graph of engine temperatures obtained under dry and full coolant test

It was also observed by the results obtained for the experiment as shown in Figure 4.6, that the coolant sensor predicted the correct engine running temperature. Because heat transfer was quite well in full coolant engine ran, however at dry engine ran the Sensor predicted wrong temperature at which the engine was running. This was perhaps due to the fact that water presence was a better contact medium that promoted the Sensor efficiency than vapour which is usually the heat transfer medium at dry engine ran as already stated earlier.

It was generally observed that, when the engine was dry ran tested, the coolant sensor reading was not reflecting the actual running temperature of the engine therefore remain as low as 20^{o}C as the highest temperature at the thirtieth minute compared to its performance at the same time under full coolant operation. This can be explained that the effective heat transfer from the source (engine wall) to the sensor was through hot gases (radiation) emanating from the engine which is a bad heat transfer medium for coolant sensors to absorbed heat fully, thereby limiting the quantity of heat transmission to the sensor.

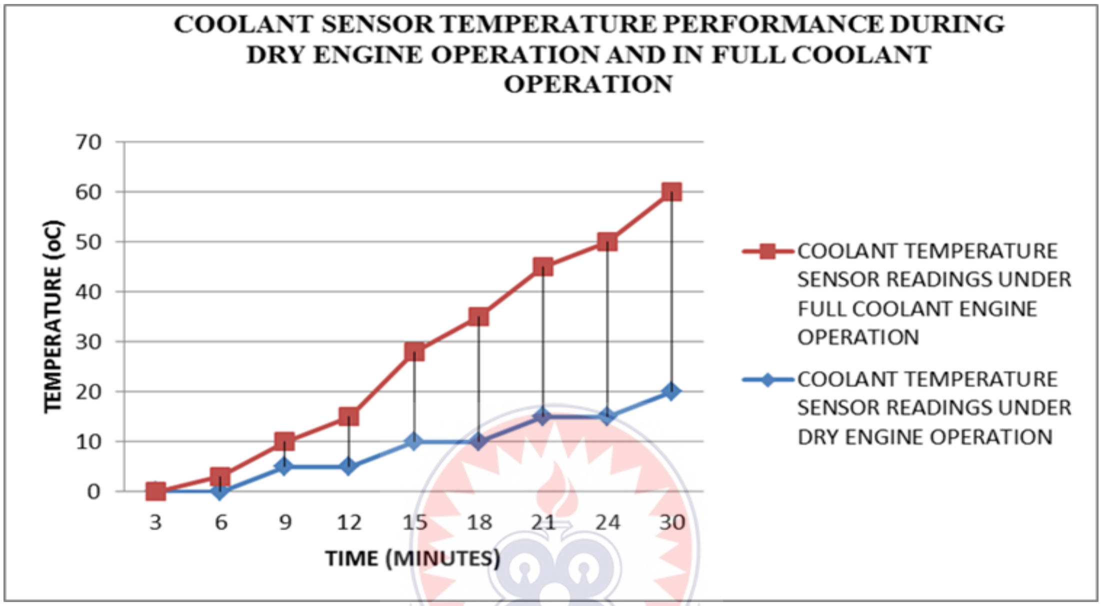


Fig.4.6: Coolant temperature sensor comparison model graph under dry and full coolant level engine run test

Presenting the result of Figure 4.7, shows a graph of volume of water reduction against coolant and engine temperatures as the system ran short of coolant. It was generally observed as indicated by the graph below that, there was a corresponding increase in both engine and coolant temperatures. This was as a result of the system running out of water (0.5 litre) in every five minutes leading to a percentage decrease of the water in the system gradually due to the leakage created in the system. In the observation as clearly indicated on the graph, the coolant temperature turns to be more than the engine temperature. This is so because the more the coolant quantity reduces the more it absorbs heat from the engine walls.

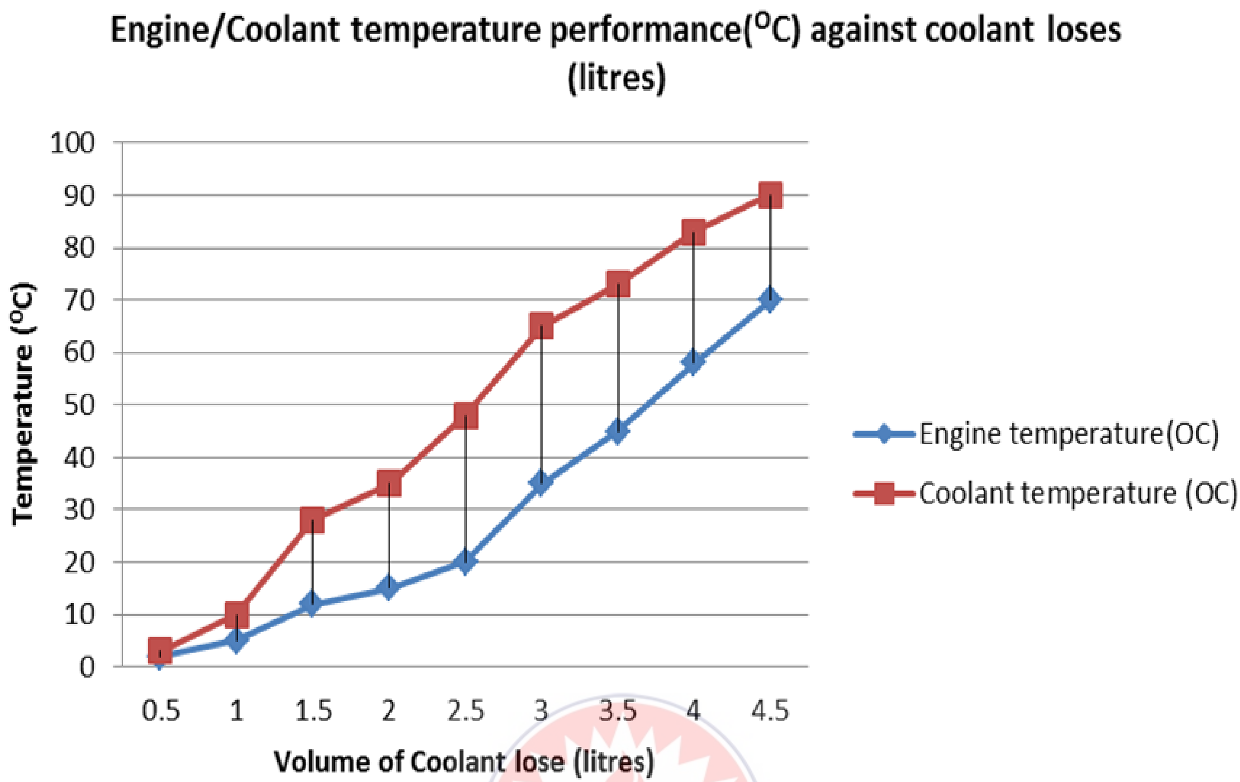


Figure 4.7: Temperature/coolant volume graph of engine and coolant in the radiator

Figure 4.8 also shows a graph of how the loss of water influences the percentage increase of temperature during the event of water leakage. It can be deduce that in every 0.5 litre loss of water, the engine and coolant temperatures kept increasing, this means that the more the leakage the higher the temperature of both engine and coolant which is detrimental to engine health and operation.

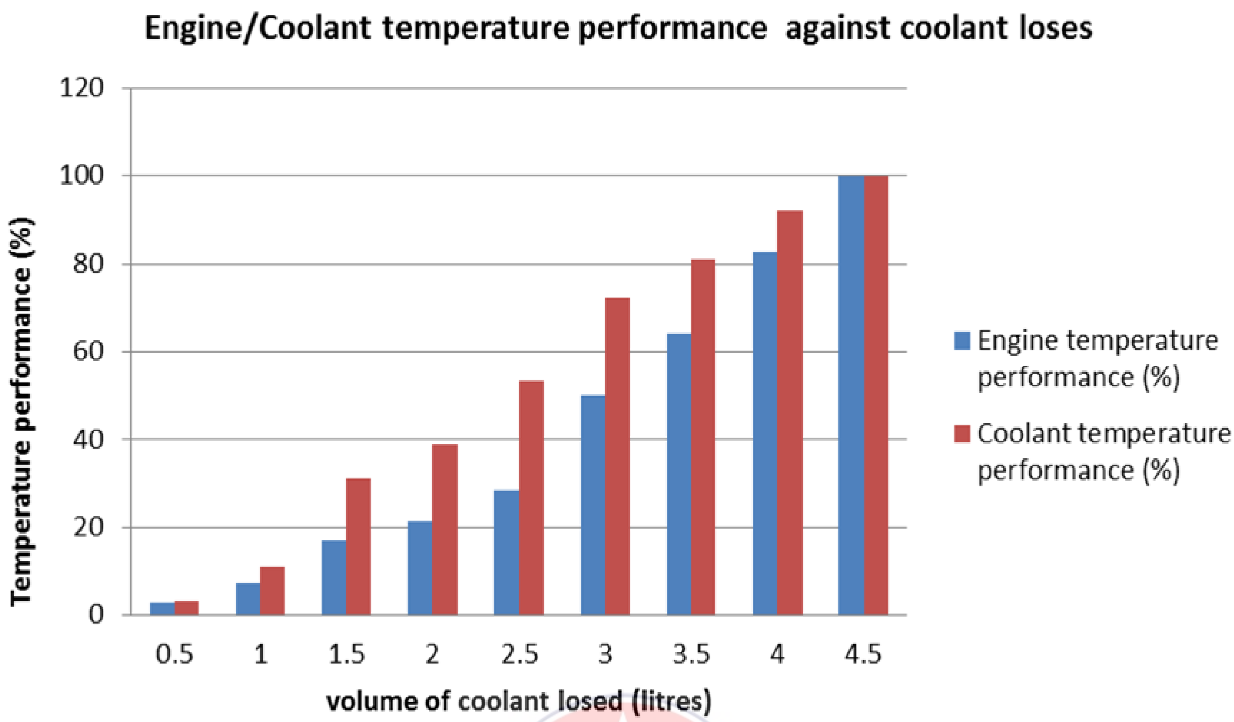


Figure 4.8: Comparison of temperature performance (%) verses volume of water lose (liters) during leakage

The temperature figures for both engine and coolant at full operation were compared by a bar chart as shown by the graph in Figure 4.9. From the graph it can be deduced that there was a corresponding increase in both engine and coolant temperatures as the system losses 0.5 litre of water at various intervals during the preset time (30 minutes). It was noticed that before the thirty minutes timing, the engine started discharging smoke from within the cylinder head area. This was observed to be a sign of head gasket burnt and if had allowed for long would have end up destroy the engine because a complete burnt of the gasket would lead to compression loses and end up opening ways for engine oil to run into the water ways or vice versa.

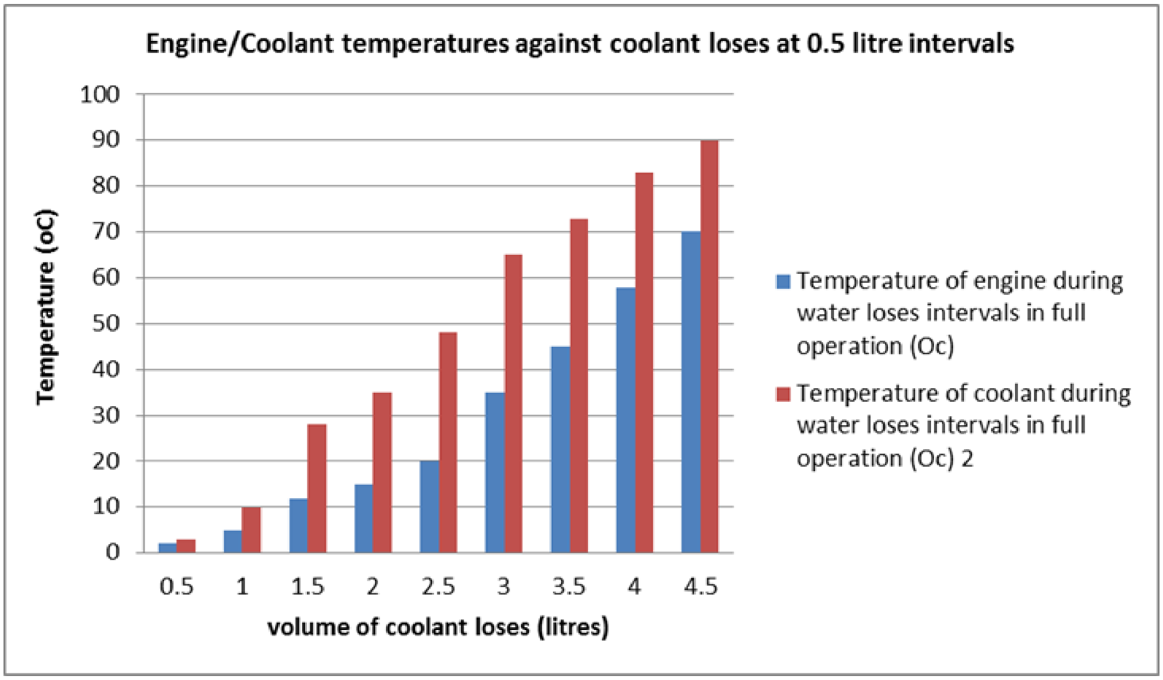


Figure 4.9: Temperature variations of engine and coolant against water loosed at discharged intervals

Water boils at 100 ^{O}C when heated. The radiator neck is usually corked with a pressure cup to prevent the water boil at 100^{O}C. The cup used on the radiator for this purpose provided a pressure of 15 psi to prevent the water boil at 100^{O}C. It was observed that at full coolant operation before the leakage was created, pressure started building up in the system with a corresponding temperature raise of both engine and coolant. At a higher engine speed under acceleration, when the leakage exercise began it was observed that the system pressure collapses gradually as indicated in Figure 4.11 with a simultaneous increased in both engine and coolant temperatures as the water level kept reducing as a result of the leakage.

The system pressure collapse was tested by physical means without instrumental figures, comparaed to temperatures of both coolant and engine as the volume of the water kept reducing. The physical pressure collapse observation was tested by simply feeling the pressure on the outlet water hose from the engine to the radiator. What was obseved as the engine was ran tested at a high speed under accleration, noticed that the hose started bloating and hard to squenze compared to it initial softness nature. It was observed that when the water leakage started the hose also started gaining it softness because at a slag of the drain plug the water rust out under pressure because as soon the plug was slagged, a mere hand feel on the hose noticed it original surface softness.

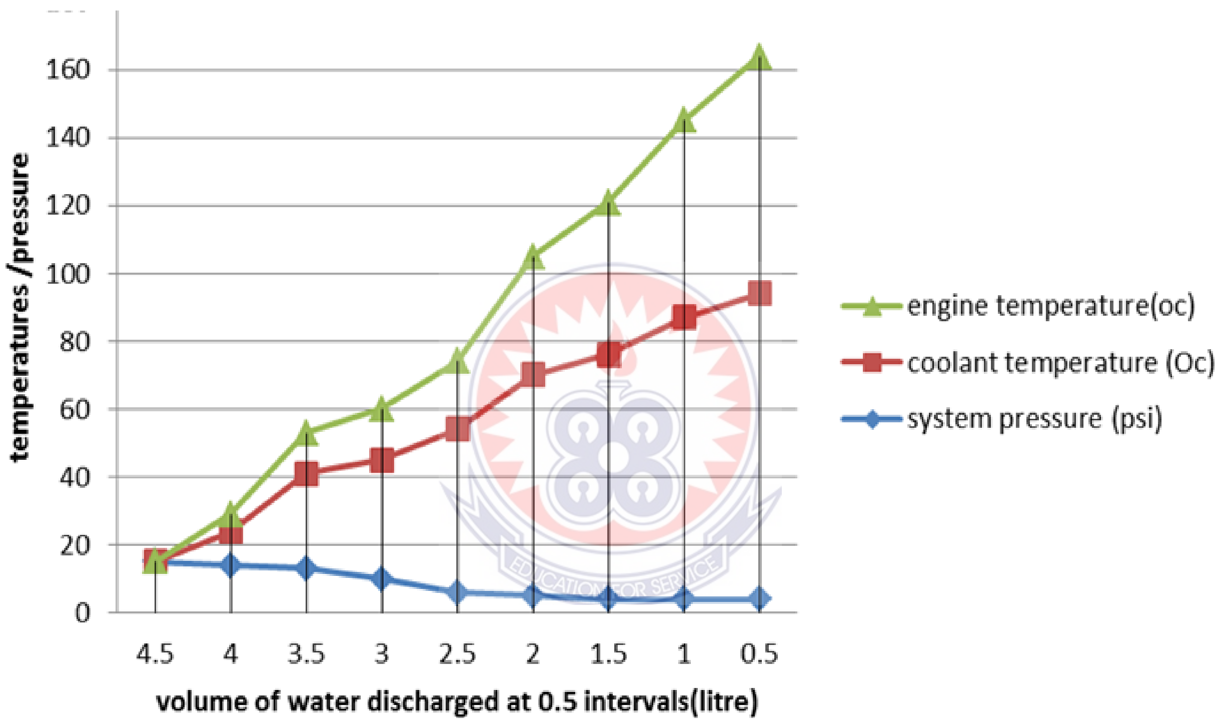


Figure 4.10: Temperature/pressure performance during coolant leakage

Another critical observation that was noticed was the behavior of the temperature sensors during complete emptiness/dryness of the radiator at high and long running operation respectively. As the engine was allowed to run, it was find out that there were no more water droppings from the leaked plug, meaning complete dryness of the radiator. It was observed that while the engine temperature readings were appreciating (increasing) the coolant sensor readings were dropping lower than when there was more or less water in the system. This is indicated by the graph in Figure 4.11. The smoke as a result of the burning gasket escalated coupled with smoke from oil drops on the exhaust manifold.

This could be explain that at empty coolant engine running in the event of coolant loses a time will come if the driver did not notice and stop the engine early, it temperature will continue to increase while the coolant temperature will be reducing. This will mislead the driver to think that, the engine is running at low temperature but in actual fact the coolant reading on gauge though low, the engine will run into higher temperatures. This is because it is the coolant temperature signal that is usually used as reference for engine running temperature monitoring and not engine temperature signal.

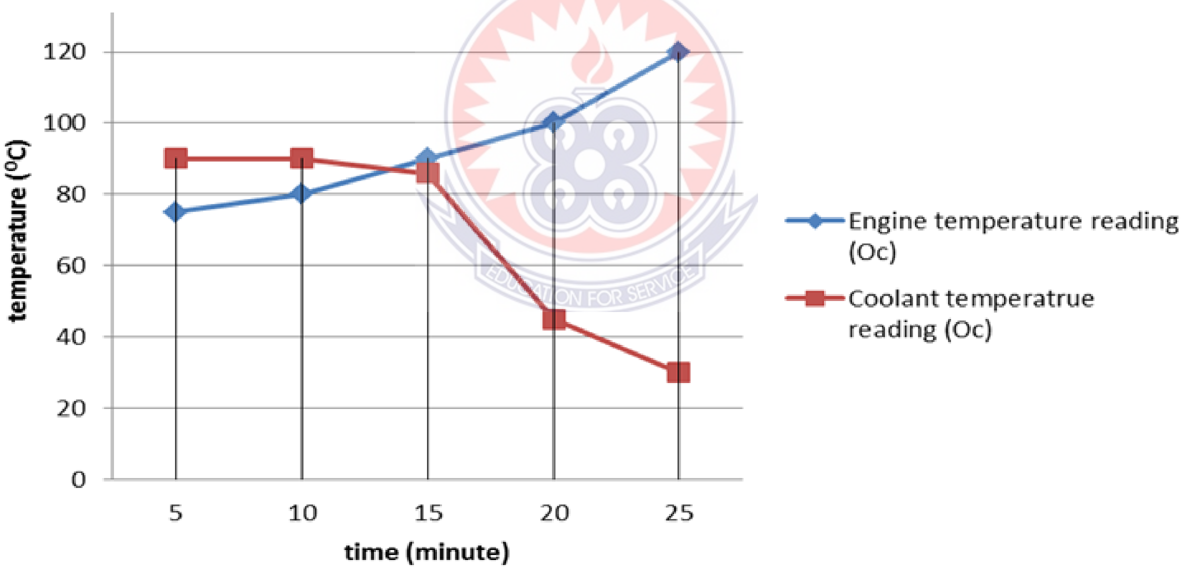


Figure 4.11: Engine/coolant temperature variation during complete dry engine operation

From Figure 4.12, it was observed that the pressure in the system collapses gradually because of the occurrence of the coolant leakage. The pressure fell from the minimum cup pressure limit of 15psi to 2Psi. This could be explained that the system pressure can only be maintained under perfect seal (absences of air). The collapse of the pressure was because of the intake of air therefore reduces pressure and lowers the boiling point of the coolant which usually leads to high running temperatures and boiling of the coolant, hence more coolant loses, which is dangerous to running engines. The figures shown which are not instrumentally proven but base on the observation of quantity of coolant loses at equal interval and litres suggest that any coolant leakage will always lower the system pressure but increases system temperature.

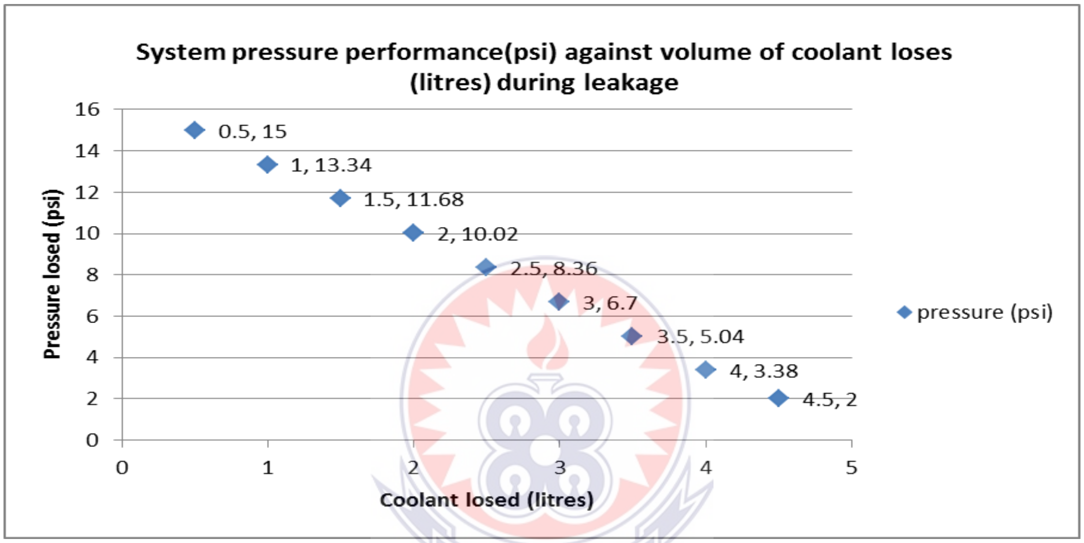


Figure 4.12: Pressure performance in engine during coolant loses

The observation on test seven step one demonstration saw the multi-meter recorded a voltage of 12.7vdc at the input terminal of the float sensor. This means there was full battery voltage flow to the 'INLET' terminal of the float sensor and this indicates that the sensor was fed with the correct voltage that was enough to power the circuit.

In the exercise to determine how effective the load circuit was powered, that enable it to shut down the engine, it was observed that the output voltage of the sensor was read 12.6vdc. Even though reading was normal and enough for automobile purposes, there was a reduction in the output voltage from 12.7vdc to 12.6vdc and this was as a result of the conductor resistance. It was also observed that the sensor switch in it stem was fully closed. This allowed the input battery voltage to jump across to energize the control lamp and relay coil. In response it opens the relay contacts causing the cut off of battery current to the fuel switch and load lamp which lead to the engine shutdown.

During the event of 'Test seven Step Three', it was again observed that, the relay magnetic coil was energized which caused the relay switch to open. The open relay switch disrupted the flow of battery current to the load lamp and fuel switch in the injection pump and hence caused the engine shutdown. The circuit testing results has confirmed that the design was feasible through the responses. The first respond was that when the float sensor was in activation mode the engine was not able to start. This will save the engine from overheating and this was confirmed by the glowing of the control lamp and the shutting down of the load lamp and engine.

In the second and final test the circuit proved that it could automatically shut down the engine without any human intervention. This was confirmed when the engine was shut down as a result of the self-created leakage that lead to coolant losses to empty the system. This confirms that when the design is implemented and adopted on any form of liquid cooling engine or system, it will save a lot of engines from overheating at any time there is any leakage to an extent that could trigger overheating.

4.10 Findings

This chapter gives an account of the outcome of the experiment conducted on a four cylinder four stroke diesel engine with a build-in float sensor circuit to monitor coolant level in the engine in the event of coolant losses to control engine overheating.

It discussed the main and salient review methods that have been put together as well as the outcome results that give value to this thesis, looking at the importance, the difficulties encountered during the course of the work and the results that have been achieved during this work.

It highlighted the aim of this thesis work as a way of devising and testing a method that monitor and control coolant level and engine overheating respectively. So that it will contribute, sustainably and viably to relief engine owners, individuals and government from unexpected financial expenditure incurred and avoid waste of time on breakdown engines as a result of overheating due to coolant losses. It underlines certain challenges that were encountered that almost impeded the fulfillment of the aims to a certain extent, looking at the most important ones such as the difficulty in getting reviewed design methods and related works to build on.

However it pointed to few previously conducted works or already established knowledge that is related to this task. For example, the use of the thermostat and thermistor sensor models as design methods to monitor engine temperature which are closely related and are bases for this work. Notwithstanding it emphasis on some setbacks faced by this convectional engine temperature monitoring models which have been resolved by this new model, such as the need for vigilance and alertness from engine operators' during engine running, especially motor vehicle drivers.

The discussion section also considerably looked at some results obtained when the experiment was carried out and observed in a number of phases and stages. These phases include running the engine without coolant and with coolant at separate instances, where the float, engine and coolant sensors reactions were observed, compared and analyzed using graphs. Some results were obtained and duly explain which saw the need for the adoption and implementation of this new design model.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The aim of this work was to find a solution to engine overheating. Selected automobile electronic components were assembled to build the circuit to fulfill the design purpose. This took two forms: virtual and real design circuits built and taken through stimulation and test processes to satisfy the design curiosity.

The software display function worked well in simulation, testing and implementation. The deviation between the expected result and the actual result was very close after the system design was completed. The design and implementation of the idea of using a magnetic float sensing circuit system to control engine overheating had been achieved in this thesis.

This design can easily be adapted to any mechanism that involves the need to monitor and control overheating in hot liquid vessels and any form of control which requires the use of float sensor in the event of coolant or liquid losses in a system. To effectively design this kind of system, it is necessary to understand the basic sensor characteristics, idea and assembly principles, utilized in the system planning.

The Float Sensor serves as a transducer for low liquid detection while the program testing is fundamental to software design based on the system requirements, specifications, and planned operation. The automatic float sensor switching circuit designed in this work can be employed in industries, laboratories, and residential homes where there is the need to control liquid cooled mechanisms without necessarily requiring any form of human assistance, vigilance and alertness.

5.2 Conclusion

Experimental and simulation studies of avoiding overheating in internal combustion engines using a coolant float sensor were performed. The experimental setup was also conducted to study the performance of the conventional coolant and engine temperature sensors in relation to low coolant engine performance.

The design process for this experiment was conducted and carried out according to the design plan. Both virtual and physical molded circuit units performed perfectly, fulfilling the design purpose. In the real experiment conducted on the engine, there is no doubt of the performance of the main component ability to avoid engine overheating in an event of coolant losses below the preset level in the radiator.

The system worked as desired and as expected, because it main purpose is to ensure that the engine does not overheat in an event of coolant shortage in the radiator which is the main and number one cause of engine overheating. In an observation the conventional temperature sensor needs backups such as the design in this thesis to support in engine temperature monitoring. This is because they can only sense temperature level and not coolant level. This is the reason why engines with conventional temperature sensors sometimes overheat without early notice by the driver.

5.3 Recommendations

Research is a continuous process, knowledge building and improvement by adding value and getting solutions to what is already or yet to be discovered by an individual or group from time to time. Modern vehicle systems are control by a computer unit known as an electronic control unit (ECU). However this model was manually connected as an isolated system independent of the electronic system unit. It will be appropriate to modify the design by incorporating the circuit into the ECU box so that any coolant related problem signal is directed to the ECU to do the monitoring and control of engine overheating.

This work focused on using the coolant level in the engine radiator to control overheating. If further work could be undertaken using the quantity/volume of coolant in the system to monitor and control engine overheating will goes a long way to find a remedy to the problem of engine overheating.

Also I suggest government set-up industries for the production of basic electronic components locally and establish research centers in universities. This will go a long way to promote good and sound practical knowledge on electronic components designs and their operation to help build good electrical/electronic basic knowledge to feed the automobile industries.

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APPENDICES

Table 4.1: Experimental results obtained when engine and coolant temperature sensors performance was compared during dry engine ran test

Time (minute)	Engine temp. (^oC)	Coolant temp.(^OC)
3	5	0
6	10	0
9	25	5
12	45	15
15	60	10
18	90	10
21	105	15
24	115	15
27	130	20
30	140	25

Table 4.2: Experimental results obtained from engine and coolant temperature Sensors under full radiator coolant level engine ran test (Test Five)

Time (minute)	Engine temp.(^{O}C)	Coolant temp.(^{O}C)
3	0	0
6	5	3
9	12	5
12	16	10
15	20	18
18	8	25
21	32	30
24	38	35
27	48	40
30	50	45

Table 4.3: Experimental results obtained comparing the performance of engine temperatures under dry and full coolant level conditions.

Time (minute)	- Engine temp. dry run (^{O}C)	- Engine temp. full coolant run.(^{O}C)
3	5	0
6	10	5
9	25	15
12	45	18
15	60	20
18	90	25
21	105	34
24	115	38
27	130	40
30	140	45

Table 4.4: Experimental results obtained comparing the performance of coolant temperatures under dry and full coolant level during engine ran test.

Time (minute)	dry run (OC)	full coolant run (OC)
3	0	0
6	5	0
9	10	5
12	13	5
15	28	10
18	35	10
21	45	15
24	50	15
27	60	20
30	68	20

Table 4.5: Experimental results obtained from Temperature sensors during coolant loses

Volume of coolant lose (litres)	Engine temperature (^{O}C)	Coolant temperature (^{O}C)
4.5	70	90
4	57	83
3.5	45	73
3	35	65
2.5	20	48
2	15	35
1.5	12	28
1	5	10
0.5	2	3

Table 4.6: Experimental results obtained from water loses during leakage against engine/coolant temperature performance (%)

Coolant lose (litres)	Engine temp. Performance (%)	Coolant temp. Performance (%)
0.5	2.86	3.33
1	7.14	11.11
1.5	17.14	31.11
2	21.43	38.89
2.5	28.57	53.33
3	50	72.22
3.5	64.29	91.11
4	82.89	92.2
4.5	100	100

Table 4.7: Experimental results obtained comparing engine and coolant temperatures (OC) during coolant loses engine ran test.

Coolant loses (0.5litre)	Engine temperature (^{O}C)	Coolant temperature (^{O}C)
0.5	3	2
1	5	10
1.5	12	28
2	15	35
2.5	20	48
3	35	65
3.5	45	73
4	58	83
4.5	70	90

Table 4.8: Experimental results obtained when temperatures where compared to pressure performance in the engine system during coolant leakage

Coolant loses (litres)-	Pressure performance(psi) -	Engine temp.(^{O}C) -	Coolant temp. (^{O}C)
0.5	15	15	15
1	13	38	20
1.5	11	56	40
2	10	60	45
2.5	8	74	55
3	6	105	70
3.5	5	120	75
4	5	140	88
4.5	4	160	96

Table 4.9: Experimental results obtained comparing temperature variations between engine and coolant against time during complete dry radiator operation

Time (minutes)	Engine temperature (^{O}C)	Coolant temperature (^{O}C)
5	90	70
10	90	80
15	88	90
20	45	100
25	30	120
30	20	130

Table 4.10: Experimental results obtained when system pressure performance was compared to system coolant loses

Volume of coolant loses (litres)	system pressure performance (psi)
0.5	15
1	13.34
1.5	11.68
2	10.02
2.5	8.36
3	6.7
3.5	6.7
4	5.04
4.5	2

Table 4.11: Experimental results obtained comparing time (minutes) against engine and coolant temperatures (OC) during dry engine ran test.

Time (minutes)	Engine temperature (^{O}C)	Coolant temperature (^{O}C)
5	90	75
10	90	80
15	85	90
20	45	100
25	30	120

Table 4.12: Experimental results obtained comparing volume of water loses against system pressure performance during coolant leakage.

Volume of water lose (litres)	Pressure lose (psi)
0.5	15
1	13.34
1.5	11.68
2	10.02
2.5	8.36
3	6.7
3.5	5.04
4	3.38
4.5	2.00s