Palestine Polytechnic University

College of Engineering and Technology

Mechanical Engineering Department

Graduation Project

Detection of Minor Cooling Water leakage Using Non-Reactant Chemicals in ICE

By

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Submitted to the College of Engineering

In partial fulfillment of the requirements for the

Bachelor degree in Automotive Engineering

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Sep 2020

Dedication (إهداء)

الى السنابل الخضراء وغصن الزيتون . . . الى الجميله التي تلتف بالسواد . . . الى الزهره وسط االشواك لالرض المباركه زهره المدائن ... الى (فلسطين) .

الى زهره االيام وعبير الصباح . . . الى بسمه السنين وجمال الحياه . . . الى نبع الحب والحنان . . . يا اجمل اسم نطقت به حياتي . . . (أمي الحبيبه) .

الى من علمني معنى الحياه . . . الى صاحب القلب الكبير . . . الى من ياخذ بيدي حين التعثر . . . دمت ذخرا لنا طيله الزمان . . . (أبي العزيز) .

الى السند واالمان . . . الى الشجره الوارفه التي ال تميل . . . الى السور العالي الذي ال ينحني . . . . يا قطعه من القلب و الروح . . . (أخي العزيز).

الى من تميزو بالوفاء والعطاء . . . الى ملح الحياه . . . الى عالم المحبه واالخوه . . . (أصدقائي االعزاء).

الى الشجره التي نستظل بها ونأكل ثمرها . . . الى سيوف الحق ورموز العلم . . . (اساتذتي الكرام).

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Abstract:

The project aims to determine the source of undetectable water leakage in the vehicles so that the consumption can be in the engine or from other sources, by adding chemical elements to the water in the radiator, detect the presence of compounds the chemical element with exhaust gases, if compounds are present in the exhaust that’s mean water leakage is caused by the engine or the exhaust, and this leads to saving time and effort in solving the problem.

In this project, a chemical detection material was chosen to facilitate the detect water leakage. We also show the effect of the detection material on the engine and its theoretical calculations and work to discover its existence to determine whether there is a leak in the engine or not and its location.

Where we found that hydroiodic acid is suitable in many ways, including the effect on the engine and the ease of discovering its compounds.

The results were distributed as follows: In the first case the color of the detector paper changed to black, this indicates that the combustion is normal and that the leakage in the cooling pipes, and the second case the color of the detector paper changed to the purple color, which indicates that the leakage in the combustion chamber and in the third case the detector paper contained Two colors, black and purple, indicating that the leakage is directly in the exhaust.

يهدف المشروع إلى تحديد مصدر تسرب المياه غير القابل للكشف في المركبات بحيث يمكن أن يكون االستهالك في المحرك أو من مصادر أخرى ، عن طريق إضافة عناصر كيميائية إلى الماء في المبرد ، والكشف عن وجود مركبات العنصر الكيميائي مع غازات العادم ، إذا توجد مركبات في العادم وهذا يعني أن تسرب المياه ناتج عن المحرك أو العادم ، وهذا يؤدي إلى توفير الوقت والجهد في حل المشكلة.

في هذا المشروع ، تم اختيار مادة كيميائية لتسهيل اكتشاف تسرب المياه. مع توضيح أثر ذلك على المحرك وتم حساب الحسابات النظرية له والعمل على اكتشاف وجودها لتحديد ما إذا كان هناك تسرب في المحرك أم ال وموقعه.

حيث وجدنا أن حمض الهيدروديك مناسب بعدة طرق ، بما في ذلك التأثير على المحرك وسهولة اكتشاف مركباته.

كانت النتائج على النحو التالي: في الحالة األولى تغير لون ورق الكاشف إلى األسود ، وهذا يدل على أن االحتراق طبيعي وأن التسرب في أنابيب التبريد ، والحالة الثانية تغير لون ورق الكاشف إلى اللون البنفسجي الذي يشير إلى أن التسرب في غرفة االحتراق وفي الحالة الثالثة احتوت ورق الكاشف على لونين ، أسود وأرجواني ، مما يشير إلى أن التسرب موجود مباشرة في العادم.

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Prepare the diagnostic material

https://drive.google.com/file/d/1eoa2o9caOWUWPbkvR3Ti7yk8nhznQtsz/view

CHAPTER ONE

INTRODUCTION

1.1 Introduction.

1.2 Background.

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1.1 Introduction

This project idea based on a previous project (Water Consumption Diagnostic Tool for Gasoline and Diesel Engines), Where the previous project aimed to use a device that condenses water and calculate the proportion of water in the exhaust, The current project aims to find a chemical that detects water consumption without the need to condense.

With the increase in the number of cars and the emergence of many car manufacturers and the intense competition between these companies to increase technologies and amenities to make them smarter and safer on the roads, which resulted in increasing the existing parts besides the car engine, which makes it difficult to find the problem and maintenance in case of occurrence, where finding the cause of the problem costs time and effort.

One of the problems that are serious on the internal combustion engine is the consumption of water and the imbalance of the cooling system, where it is necessary to maintain the problem and not neglected because negligence entails large problems and may be very expensive as the coolant lies its importance to reduce high-temperature engine to normal limit because the height limit of normal causes significant economic losses.

1.2 Background

Internal combustion engines (combustion chamber inside the engine) where the energy in these engines is generated by chemical combustion between fuel and air. Kinetic energy produced is used to move the piston inside the engine, the resulting heat may be destructive to the engine if not controlled.

The temperature is controlled and ensure that it does not reach high temperatures causing a danger of the engine using the coolant (water cooling) or by air cooling (using fans to push the air) or both were often and with many parts around the engine became air cooling alone is not enough, so we use water cooling to keep the engine safe by control temperature better.

Of the reasons that lead to the disruption of the cooling system, are not limited to being a closed circuit in the presence of a leak in which either the leak is internal (inside the combustion chamber) or external (pipes) outside the engine.

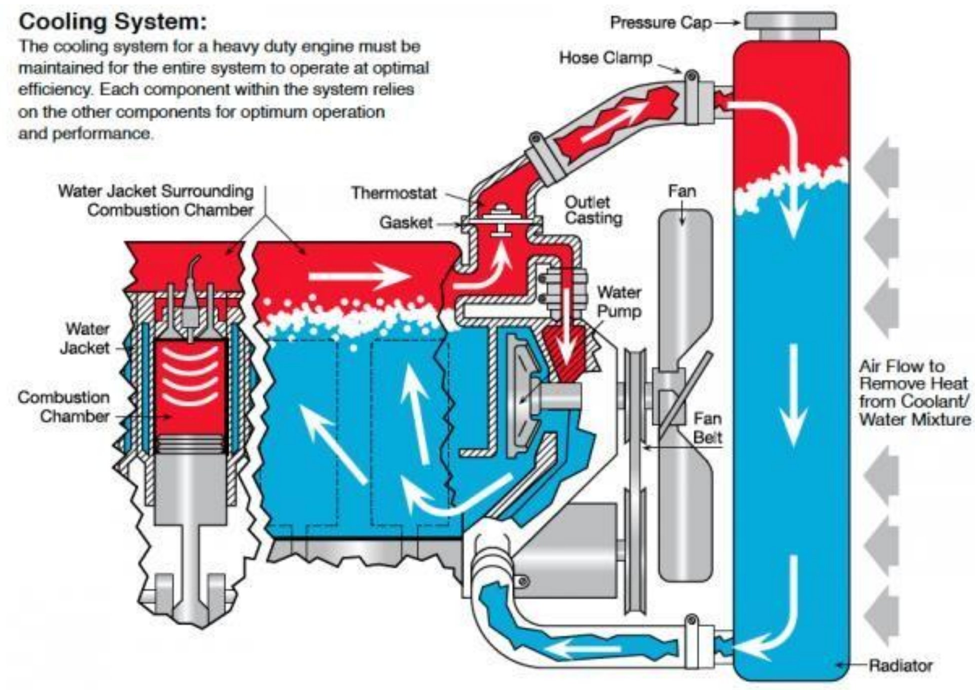

Figure 1.1: cooling system

1.3 Problem Definition

Leaking water into the combustion chamber is one of the most important reasons that lead to general weakness in the engine and increase in fuel consumption of the engine[1], the leakage of water is a problem that is difficult to detect because it has multiple causes.

Where it can leak, whether it is leaking from the water stream to the combustion chamber as a result of some defect or specific crack in the cylinder head of or engine block or gasket. In the other case, when water leaks directly from its streams to the exhaust manifold.

1.4 Known diagnostic methods

1. **Visual examination of external components of the radiator:**

   Through the visual examination of the connections of the parts of the radiator using the light on the external parts to detect external leakage.

2. **Coolant pressure system test:**

   The pressure test can help you locate or confirm hard to find leaks. The test uses low pressure to force coolant to come through the exterior leaking spot or prove that the system can't hold pressure if you're dealing with an internal leak or a damaged radiator neck[2].

3. **Water Consumption Diagnostic Tool :**

   The project was designed to compare the proportion of water out of the exhaust with the fixed-rate through a device that converted to the liquid state and compared to the original value if the value is different then there is a leak in the cooling system inside the engine if the value remained constant then there is no internal leakage and external leakage (In the pipe)[3].

1.5 Project objective

Reducing the cost, time, and human effort to discovering the cause of water leakage in internal combustion engines (ICEs) by adding chemical detection material to the vehicle radiator, so that it detects the presence of leaks in the engine head or external leaks in the pipes.

The obstructive of this project are:

1) Know the reasons for an increase in water consumption in the vehicle.

2) Save time at diagnosis, especially if the problem relates to the internal engine components.

3) Save effort and diagnostic cast, in addition to the rapid diagnosis with more accuracy in measurement, detect and diagnose.

1.6 Advantages of the Chemical Detection Materials

The advantages of the chemical detection material:

1. The engine is not affected negatively by the additive.
2. Ensure that the compounds from the combustion process are not highly toxic.
3. The materials used are available and not expensive.
4. The material does not change the fuel properties negatively.
5. The material used not be suitable for military use.
6. It does not affect the cooling ducts of the engine.
7. The soluble material is good with coolant.
8. Viscosity should not be an obstacle to the leakage of the material to the existing incision.

1.7 Principle of Operation

Adding a chemical detection material into the radiator at the vehicle so that it detects the presence of leaks in the engine head or external leaks in the pipes.

Such a chemical detection material added to the radiator so that it enters with the coolant through cracking at gasket into the combustion chamber or directly to the exhaust and not affect at the work of the engine, where it will take into account, that the material is being detectable.

There are many options for capturing the material from the sensor, chemical material, sunflower leaf change, smoke color change.

If this material was captured by the sensor or reacted with the chemical material or change the color of the sunflower leaf, or change the color of the resulting smoke means there is a crack in the head of the engine, either inside the combustion chamber or directly to the exhaust and the leak is not external in the pipes but the engine head.

Methods to detect the presence of this substance in the exhaust:

In the first case: Change smoke Color

Figure 1.2: change smoke color

If the material is monitored by changing the color of smoke coming out of the exhaust,

We deduce from the change of the color of the car exhaust smoke in the presence of the material that was added to the car exhaust and burned in the combustion chamber or appears in one of the exhaust gases by color.

In the second case: if the material is monitored by a sensor (For example NOx sensor)

Figure 1.3: NOx sensor

If the sensor gives information about the presence of this substance in the exhaust gases, we conclude that its presence and entry through the notch with the coolant into the engine to come out with the exhaust.

In the third case: Sunflower leaf

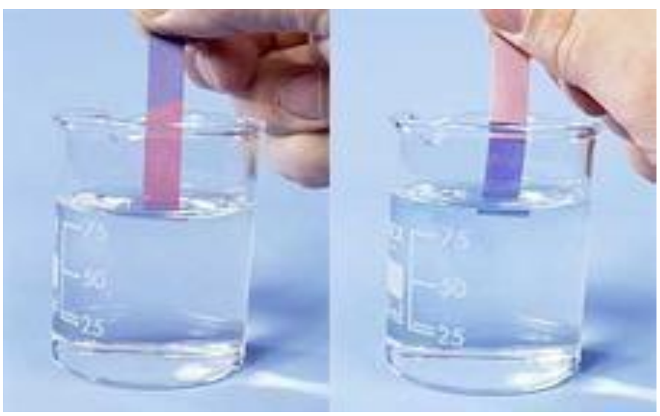

Figure 1.4: Sunflower leaf

The color change of the sunflower leaf is an indication of the presence of the substance in the exhaust gases.

Changing the color of the sunflower leaf to red indicates the presence of acidic gases or solutions (1<PH <7) and the change of blue color indicates the presence of gases or basic solutions (14>PH> 7).

In the fourth case: Chemical material

The reaction between the additive to the coolant and the chemical used to detect it. If a reaction occurs, the additive appears at the exhaust if it does not, the additive is not present in the exhaust.

1.8 Project Methodology

Stage one: Identifying the project idea.

Stage two: Project requirement and collecting data.

Stage three: Calculation of Fuel Combustion Equations with Chemical Detection Material.

Stage four: Calculation The Theoretically Result of adding Chemical Detection Material

Stage five: Writing and Documentation.

Stage sex: Testing the Experimental Result.

1.9 Schedule Time and Total Cost for the Project

First Semester:

Table 1.1: Schedule Time-First Semester

Task\Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Identifying the project idea	■	■	■	■												
project requirement and collecting data				■	■	■	■	■	■	■	■	■	■	■		
calculation					■	■	■	■	■	■	■	■				
Writing and documentation.				■	■	■	■	■	■	■	■	■	■	■	■	■

Second Semester:

Table 1.2: Schedule Time -Second Semester.

Task\Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Modifying the project idea.																
project requirement and collecting data																
calculation																
Writing and documentation.																
Testing and experimental result																

Total Cost for the Project

Table 1.3: Total Cost Table.

Tools	Volume(ml)	Cost
H_2SO_4	100	163
Starch	-	20
$HI_{(aq)}$	250	361
C_2H_7NO	250	66
USA $		610
NIS		2135

CHAPTER TWO

CALCULATION

2.1 Introduction

This chapter shows the chemical detection materials and calculation which needed to complete a theoretical part related to chemistry in our projects, such as the density of fuel, the mass of water, and the effect of the detection material on the air-fuel ratio at diesel and gasoline engines.

2.2 Combustion Overview

There are different types of fuel reactions such as halogenation or addition . . . etc.

One of these reactions is combustion reaction, oxygen is necessary to complete the combustion process, This energy which produced from the reaction is used in internal combustion engines, and it is necessary to provide the necessary factors for combustion such as fuel, oxygen, and heat of mixture (air and fuel) both by compressing air into diesel engines or by spark plugs in gasoline engines. Equation of reaction of fuel with oxygen (2.1a):

$$C_aH_{b(l)} + \lambda * ath\ (O_{2(g)}) \underset{high\ temp\ at\ CI}{\overset{spark\ at\ SI}{\rightarrow}} CO_{2\ (g)} + YH_2O_{(g)} \tag{2.1a}$$

λ: is the excess air ratio.

a_{th}: is the theoretical air.

X: number of mole of Co_2.

Y: number of mole of H_2O.

The air is a mixture of oxygen and nitrogen, and at the working conditions of the engine, cannot be separated oxygen from the air, as the engine uses oxygen at the air and the nitrogen will out without reaction in the combustion chamber.

Where the real equation becomes as follows (2.1b):

Let $Z = \lambda * a_{th}$.

$$C_aH_{b\,(l)} + Z(O_{2\,(g)} + 3.76N_{2(g)}) \underset{high\ temp\ at\ CI}{\overset{spark\ at\ SI}{\rightarrow}} CO_{2\,(g)} + YH_2O_{(g)} + 3.76Z\ N_{2\,(g)} \tag{2.1b}$$

2.3 Gasoline Combustion Calculation

We need to calculate the air-fuel ratio for gasoline combustion, before adding the detection material and after adding it to clarify its effect on this ratio as the mixture ratio is one of the most important factors that determine whether this substance is suitable for use or not.

Also need to know a chemical formula for gasoline to determine the air-fuel ratio after added the chemical detection material and before adding it, by using the combustion equation for gasoline (2.2a), the actual chemical formula of gasoline which is

[$C_{7.93}H_{14.9291}$][3].

Calculates the air-fuel ratio for gasoline when: excessive air ratio (ʎ) = 100%

$$C_{7.93}H_{14.9291\,(l)} + Z(O_{2\,(g)} + 3.76N_{2\,(g)}) \underset{high\ temp\ at\ ɑ}{\overset{spark\ at\ SI}{\rightarrow}} XCO_{2\,(g)} + YH_2O_{(g)} + KN_{2\,(g)} \quad (2.2a)$$

C balanced: X=7.93

H balanced: 14.9291=2Y

Y=7.4145

a_{th} = z ; because ʎ=1

2Z= 2X + Y

a_{th} = 11.63725

After calculating the number of mole for each chemical element, the chemical equation will be:

$$C_{7.93}H_{14.92\,(l)} + 11.63(O_{2\,(g)} + 3.76N_{2\,(g)}) \underset{high\ temp\ at\ ɑ}{\overset{spark\ at\ SI}{\rightarrow}} 7.93CO_{2(g)} + 7.41H_2O_{(g)} + 43.756N_{2\,(g)} \quad (2.2b)$$

Air-fuel ratio (A/F ratio) = (number of mole for air) [mole]/ (number of mole for fuel) [mole]

A/F ratio= (11.63725)*(16*2+3.76*2*14) [mole]/ (12*7.93+14.9291*1) [mole] =14.511.

2.4 Diesel combustion calculation

We need to calculate the air-fuel ratio for diesel combustion, before adding the detection material and after adding it to clarify its effect on this ratio as the mixture ratio is one of the most important factors that determine whether this substance is suitable for use or not.

Also need a chemical formula for diesel to determine the air-fuel ratio after added chemical detection material and before added it, by using the combustion equation of diesel (2.3a), the actual chemical formula of diesel which is [$C_{12.381}$ $H_{22.1739}$][3].

Calculates the air-fuel ratio for gasoline when: excessive air ratio (ʎ) = 100%

$$C_{12.381}H_{22.174\,(l)} + a_{th}(O_{2\,(g)} + 3.76N_{2\,(g)}) \underset{high\ temp\ at\ CI}{\overset{spark\ at\ SI}{\rightarrow}} XCO_{2\,(g)} + YH_2O_{(g)} + a_{th}3.76N_{2\,(g)} \quad (2.3a)$$

C balanced:

X=12.381

H balanced:

22.1739=2Y ⟶ Y=11.08695

O balanced:

$2a_{th}$=2X+Y ⟶ a_{th}= (2X+Y)/2

a_{th}= (2*12.381+11.08695)/2 =17.924475

$$C_{12.381}H_{22.174\,(l)} + 17.924(O_{2\,(g)} + 3.76N_{2\,(g)}) \underset{high\ temp\ at\ CI}{\overset{spark\ at\ SI}{\rightarrow}} 12.381CO_{2\,(g)} + 11.087H_2O_{(g)} + 67.4N_{2\,(g)} \quad (2.3b)$$

Air-fuel ratio (A/F ratio) = (number of mole for air) [mole]/ (number of mole for fuel) [mole].

A/F ratio= (17.924) (32+3.76*28) [mole]/ (12*12.381+22.1739*1.008) [mole] = 14.39.

2.5 First Chemical compound (hydroiodic acid)

The first compound selected is hydroiodic acid ($HI_{(aq)}$), based on the characteristics that distinguish it from other compounds to be mentioned later.

The compounds that are likely to appear will be clarified, beginning with the entry of acid and its interaction with the water in the radiator until it comes out of the exhaust or exits through the leaking in the pipes.

The methods of detecting compounds that are maybe produced after added acid and their effects will be clarified, whether on the human, the environment and the engine.

2.5.1 Reaction between acid and water in the radiator:

Safety standards must be followed and acid is added to water, not vice versa[7].

Hydronium ($H3O^{+}{}_{(aq)}$) and iodide ($I^{-}{}_{(aq)}$) is produced from the reaction of water and acid.

The reaction between acid and water is explained by the following equation (2.4a) [5]:

$$HI_{(aq)} + H_2O_{(l)} \rightarrow H_3O_{(aq)} + I^{-}{}_{)(aq} \qquad (2.4a)$$

2.5.2 Properties of chemical compound

First: hydroiodic acid ($HI_{(aq)}$)

Colorless liquid when newly prepared, but soon tends to yellow or brown when exposed to light or air. The chemical formula of HI, with a molecular weight of 127.9, a density of 1.70 g / cm3, and a boiling point of 127 degrees Celsius. And away from light, air, and heat. This acid is soluble in water and alcohol and is a strong caustic acid and skin and surfactant and reacts with rubber[9].

Risk:

Iodic acid is a static compound under normal conditions. Being a strong acid (High concentration), it is very dangerous in case of skin contact (erosion and irritant) and the case of ingestion. also, it is very dangerous in case of inhalation[9].

Second: iodide ($I^-_{(aq)}$)

An iodide ion is the ion I^-. Compounds with iodine in formal oxidation state I^- are called iodides[10].

Third hydronium ($H_3O^+_{(aq)}$)

In chemistry, hydronium is the common name for the aqueous cation H_3O^+, the type of oxonium ion produced by protonation of water. It is the positive ion present when an acid is dissolved in water, as acid molecules in solution give up a proton (a positive hydrogen ion, H^+) to the surrounding water molecules (H_2O), Molar mass for hydronium is 19.02 g/mole[11].

2.5.3 The products behavior in one of the three consumption routes

First: at the combustion chamber inside the engine

The hydronium and iodide ion acted in the combustion chamber

1. **iodide ($I^-_{(aq)}$)**

   It does not act as a reactant in the combustion chamber, because it is an element that has reached a stable state (iodine is present in the seventh group and needs an electron to reach a stable state, iodide represents the stable isotope of the iodine), its properties will be as noble elements (does not react)[10].

2. **hydronium ($H_3O^+_{(aq)}$)**

As explained earlier, the hydronium ion consists of a positive proton added to the water[11].
Hydronium will dissociate to water and positive proton which reacts with iodide to produced iodine.

The iodide reaction with hydronium

The iodide (I^-) interacts with the proton positive for hydronium (H_3O^+) in the presence of high temperature according to the following equation (2.4b) [12]

$$4H^+_{(g)} + 4I^-_{(g)} + O_{2\,(g)} \rightarrow 2I_{2\,(g)} + 2H_2O_{(g)} \qquad (2.4b)$$

As shown by equation (2.4b), iodide interacts with the positive proton in the presence of

Oxygen to produce iodine and water vapor.

General combustion equation

The general Gasoline combustion equation (2.5a):

$$LC_{7.93}H_{14.92\,(l)} + a_{th}(O_{2\,(g)} + 3.76N_{2\,(g)}) + H_3O^+_{(l)} + 2I^-_{(l)} \xrightarrow[high\ temp\ at\ C]{spark\ at\ SI} XCO_{2\,(g)} + YH_2O_{(g)} + a_{th} * 3.76N_{2\,(g)} + I_{2\,(g)} \qquad (2.5a)$$

C balanced

7.93L=X ⟶ equation (1)

H: balanced

14.9291L+3 = 2 Y ⟶ equation (2)

O: balanced

$2a_{th}$+1=2X ⟶ equation (3)

X= (24.274-Y)/2

Sub value of X on equation (1)

16L= 24.274 –Y

2Y= 48.548-32L

By equation (2): value of 2Y= 16L+2

16L+2= 48.548-32L

48L= 46.548 $\longrightarrow$ L= 0.978

X= 8*0.978= 7.824

Y=8.835

$$0.98C_{7.93}H_{14.92} + 11.637(O_2 + 3.76N_2) + 2I^- + H_3O \xrightarrow[high\ temp\ at\ CI]{spark\ at\ SI} 7.757CO_2 + 8.758H_2O + 43.76N_2 + I_2 \quad (2.5b)$$

A/F ratio = 11.637(28*3.76+32)/(0.96975*(7.93*12+14.9293*1.008))

= (1597.523)/110.20 = 14.49655

The addition of acid led to a slight change in the air-fuel ratio.

As noted in the above equation, iodide is converted to iodine after combustion.

Iodine (I_2)

Iodine is a nonmetallic, nearly black solid at room temperature and has a glittering crystalline appearance. The molecular lattice contains discrete diatomic molecules, which are also present in the molten and the gaseous states. Above 700 °C (1,300 °F), dissociation into iodine atoms becomes appreciable Iodine has a moderate vapor pressure at room temperature and in an open vessel slowly sublimes to a deep violet vapor that is irritating to the eyes, nose, and throat. (Highly concentrated iodine is poisonous and may cause serious damage to skin and tissue)[13].

So when iodine vapor comes out from combustion, appears violet color can be observed by the eye, iodine is one of the colorful elements that can be observed, and this is the main reason for the selection of this element.

Second: at exhaust pipe

Iodide and hydronium, with high temperature at the exhaust state of solution, will change from aqueous to gas form.

The equation formula turns iodine into iodine (2.6a):

$$4H^{+}_{(g)} + 4I^{-}_{(g)} + O_{2\,(g)} \rightarrow 2I_{2\,(g)} + 2H_2O_{(g)} \qquad (2.6a)$$

Note that from the equation (2.6a) the elements needed for the conversion of iodide to iodine are (H+) and (O2).

1. at lean combustion (λ> 1):

Chemical component that produced from lean combustion is (H_2O, O_2, CO_2, and N_2).

Hydronium contains (H^+) and because the mixture is poor, there is O_2, so at these condition iodide its convert to be iodine.

2. at rich combustion (ʎ< 1):

Chemical component that produced from rich combustion is (H_2O, CO, CO_2, and N_2).

In this case, iodide does not turn into iodine, because there is no oxygen which is an important component of the reaction, so with hydrogen ion H^+ and iodide, Hydrogen iodide will produce as shown at (2.6b) reaction [14].

$$H^{+}_{(g)} + I^{-}_{(g)} \rightarrow HI_{(g)} \tag{2.6b}$$

Third at cooling pipe:

In this case, checking the water consumption to the exhaust directly or to the engine, if engine leakage is checked, the cooling pipes are good.

If it does not leak into the engine, the problem lies in the cooling pipes and should be checked for engine safety.

2.5.4 Calculate the volume of acid needed to add at the water in the radiator.

The acid should be diluted if its concentration is high and its concentration reduced to reduce the damage caused by dealing with it, this is done by defining the concentration to be reached and the amount of the diluted solution to be reached, according to the following formula (2.7a)[15].

Number of acid before added = Number of acid after added

$$C_1V_1=C_2V_2 \tag{2.7a}$$

C1= concentration of acid before adding to water [mole/L].

C2=concentration of acid after added to water [mole/L].

V1= volume of acid before adding to water [L].

V2=volume of acid after added to water [L].

2.5.5 PH of acid after and before adding:

PH it's a scale used to specify how acidic or basic at the water-based solution. Acidic solutions have a lower pH, while basic solutions have a higher pH.

The pH scale is logarithmic and inversely indicates the concentration of hydrogen ions in the solution (a lower pH indicates a higher concentration of hydrogen ions). This is because the formula used to calculate pH approximates the negative of the base 10 logarithm of the molar concentration [a] of hydrogen ions in the solution[14].

$$PH = -\log [H_3O^+] \qquad (2.7b)$$

Because hydroiodic is strong acid, so $[H_3O^+] = [acid]$.

For 57%wt concentration of $HI_{(aq)}$ = 0.57 of $[H_3O^+]$ concentration.

Before added to water

Concentration of acid=0.57 [mole/litter]

Volume of acid=250ml

PH= -log [H3O+] = -log [0.57] =0.24

After added to water:

Concentration of acid will be 0.04

PH = -log $[H3O^+]$ = -log [0.04] =1.4

2.6 Second chemical compound Ethanolamine (C_2H_7NO)

Ethanolamine is an organic chemical compound with the formula (C_2H_7NO). The molecule is functional, containing both a primary amine and a primary alcohol. Ethanolamine is a colorless, viscous liquid with an odor reminiscent of ammonia. Its derivatives are widespread; e.g., lipids, as a precursor of a variety of N-acylethanolamines, that modulate several animals and plant physiological processes such as seed germination, plant-pathogen interactions, chloroplast development, and flowering, as well as precursor, combined with arachidonic acid ($C_{20}H_{32}O_2$)[16].

2.6.1 Reaction ethanolamine with water:

Ethanolamine reacts with water to produce hydroxide (OH^-) and aminoethyloxidanium ($C_2H_8NO^+$)(2.8a)[17]:

$$C_2H_7NO_{(aq)} + H_2O_{(l)} \rightarrow C_2H_6NOH^+{}_{(aq)} + OH^-{}_{(aq)} \quad (2.8a)$$

2.6.2 The products behavior in one of the three consumption route

First: at the combustion chamber inside the engine

A. Effect of ethanolamine on diesel fuel

1. Before added ethanolamine into gasoline:

At stoichiometric (ʎ=1):

$$C_{7.93}H_{14.92(l)} + 11.75(\,O_{2\,(g)} + 3.76N_{2\,(g)}) \xrightarrow[high\ temp\ at\ CI]{spark\ at\ SI} 7.93CO_{2\,(g)} + 7.5H_2O_{(g)} + 88.36N_{2\,(g)} \quad (2.8b)$$

Number mole of nitrogen= 88.36.

Mass of nitrogen = 88.36*28 = 2481.64 gr

Air-fuel ratio = 14.53.

2. **After Added ethanolamine to gasoline:**

Reaction between ethanolamine with gasoline (2.8c):

$$ZC_{7.93}H_{14.92} + C_2H_8NO^{+} + OH^{-} + a_{th}(O_2 + 3.76N_2) \xrightarrow[\text{high temp at C}]{\text{spark at SI}} XCO_2 + XH_2O + ZN_2 \quad (2.8c)$$

C balanced:

7.93Z+2 =X ⟶ equation (1)

H balanced:

14.9291 Z+9=2Y ⟶ equation (2)

O balanced:

2+2*11.75=2X+Y ⟶ equation (3)

After sub equation (1) to equation (2)

Z= 0.728

By sub value of Z on equation (1) ⟶ X=7.773

By sub value of Z on equation (2) ⟶ Y=9.934

Number mole of nitrogen =89.36

Mass of nitrogen=89.36*28= 2509.64 gr

Mass of nitrogen is changed by (1.2%) from the standard value.

B. Effect of ethanolamine on diesel fuel

1. Before added ethanolamine into diesel fuel

$$C_{12.381}H_{22.174} + 18(O_2 + 3.76N_2) \underset{high\ temp\ at\ CI}{\overset{spark\ at\ SI}{\rightarrow}} 12.4CO_2 + 11.1H_2O + 135.3N_2 \quad (2.9a)$$

Several moles of nitrogen= 135.36. Air-fuel ratio = 14.4.

Mass of nitrogen = 135.36*28 = 3790.08 gr

2. After added ethanolamine into diesel fuel

$$ZC_{12.38}H_{22.17} + C_2H_8NO^{+} + OH^{-} + a_{th}(O_2 + 3.76N_2) \underset{high\ temp\ at\ CI}{\overset{spark\ at\ SI}{\rightarrow}} XCO_2 + XH_2O + ZN_2 \quad (2.9b)$$

C balanced

12.381 Z +2 = X ⟶ equation (1)

H balanced

22.174Z+9=2Y ⟶ equation (2)

O balanced

2*18+2=2X+Y ⟶ equation (3)

By deletion and compensation

Z=0.53.

Air-fuel ratio =15.88.

Several moles for N_2=136.66.

Second: at exhaust pipe

The temperature of the exhaust is (300-500) C^{o}[18].

2-aminoethyloxidanium ($C_2H_8NO^+$) dissociation temperature is = 200C^{o}.

Because the exhaust temperature is higher than the dissociation temperature of the compound ($C_2H_8NO^+$), the compound will be dissociated after the temperature has been exceeded (200C^{o}) since the compound will break down to (C, H, N, O).

The compounds resulting from the dissociation process are compounds of nitrogen monoxide (CO) and nitrogen dioxide (CO_2).

Third at cooling pipe:

In this case, checking the water consumption to the exhaust directly or to the engine, if engine leakage is checked, the cooling pipes are good.

If it does not leak into the engine, the problem lies in the cooling pipes and should be checked for engine safety.

2.7 A comparison of the two chemical elements

Table 2.1: comparison between Ethanolamine and Hydroiodic acid

Variances\Chemical element	Hydroiodic acid ($HI_{(aq)}$)	Ethanolamine (C_2H_7NO)
Classification	Acid	Base
Solubility	Good	Good
Products that may be produced	Iodine ($I_{2\,(g)}$) or $HI_{(g)}$	Increased concentration of (NO_x)
Detect these products	Using starch or color of smoke	Using an ethanol sensor
Price/250ml	361$	66$

CHAPTER THREE

TESTING EXPERREMENT

3.1 Introduction

In this chapter, the selected chemical detection material will be mentioned based on its ease of disclosure and the information obtained through studies and calculations that have been mentioned in the previous chapter.

3.2 selected Chemical Detection Material

The chemical compound hydroiodic acid ($HI_{(aq)}$) was chosen based on its chemical properties, ease of predicting its products, and ease of discovering possible chemical compounds.

The reason for choosing this chemical compound, not other chemical compounds is the little influence on internal combustion engines and Ease of discovering its compounds.

3.2.1 Method for detection of chemical detection material

At combustion chamber:

When the products of this substance iodide (I^-) and hydronium (H_3O^+) entering into the combustion chamber, it becomes iodine (I_2) according to an equation (2.4b) in the previous chapter.

The presence of iodine is detected through the starch paper, where it adheres to it with the help of water vapor in the exhaust, where the color of the starch paper changes to blue in the event of iodine as shown in Figure (3.1), or it can be monitored by the special purple color of the iodine gas [19].

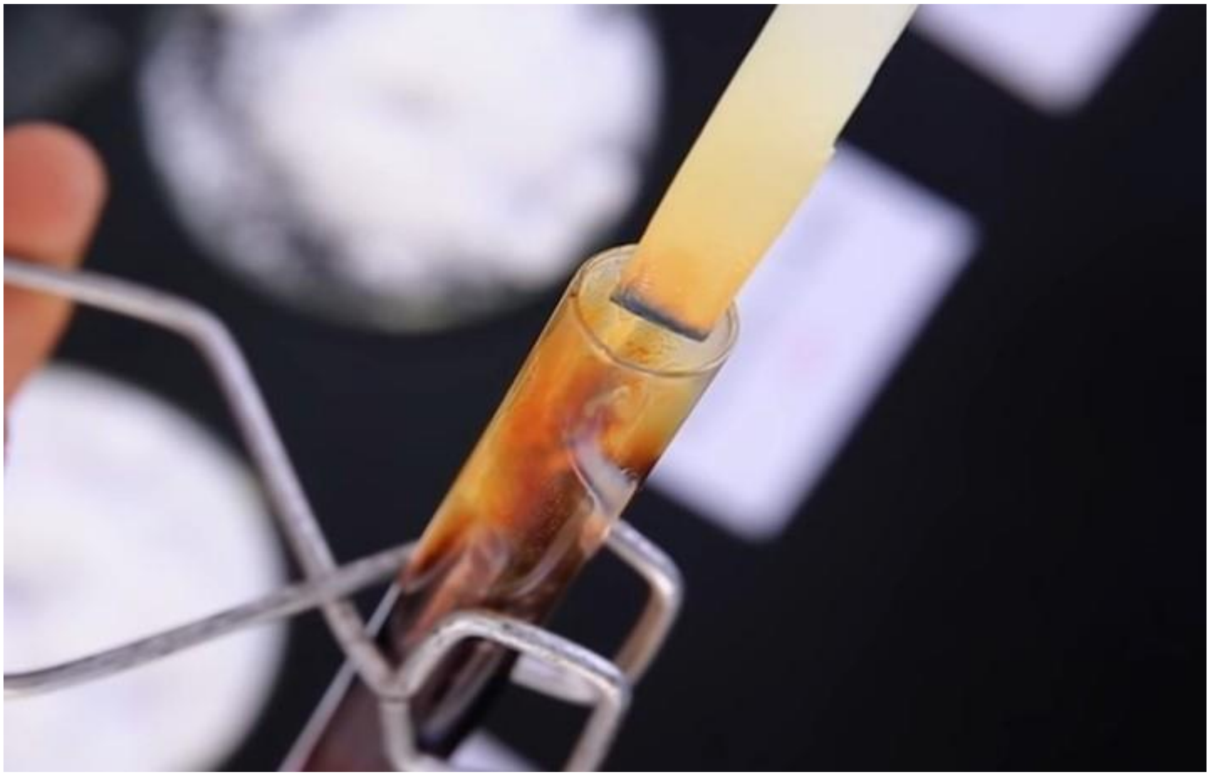

Figure 3.1: paper changes to blue in the event of iodine

At exhaust pipe:

1. **When chemical detection material enter the exhaust at lean combustion:**

In the presence of oxygen, these products are converted into iodine, which can be detected by using starch paper (Fig 3.1) or through the purple color of the iodine.

2. **When chemical detection material enter the exhaust at rich combustion:**

Oxygen is not available in this case, as the products react to form hydrogen iodide, which can be discovered using sulfuric acid that helps it to oxidize a portion of it according to the equation [20].Reaction between hydriodic acid with sulfuric acid (3.1):

$$2HI_{(g)} + H_2SO_{4_{(l)}} \rightarrow 2H_2O_{(l)} + SO_{4_{(g)}} + I_{2_{(g)}} \qquad (3.1)$$

The resulting iodine can be observed with starch paper.

In the cooling pipes:

If no leaks are detected in the exhaust or the combustion chamber, the last option is the tubes.

3.3 Virtual experiment

1. Determine the volume of the compound based on the concentration before and after the addition, as the size of the compound, will be determined later.
2. Purchase the chemical compounds ($HI_{(aq)}$, $H_2SO_{4\,(l)}$) and their reagents (starch).
3. Bring a vehicle, remove its engine head, and fabricate artificial leaking between the waterway and the combustion chamber (as a simulation of what actually happens).
4. The artificial leaking test of the engine for several days. If the test is successful, we will move to the next step. If the test fails, the engine head will be checked again.
5. Added the chemical compound to the cooling water while the engine running and reach at running temperature, to ensure a higher solubility between a chemical compound and cooling water because the water cycle is moving.
6. Using starch paper to check the presence of iodine as one of the exhaust gases. If the iodine is a presence in the exhaust gases, the starch color will change to blue color, then the reason for water consumption is the combustion chamber. If the color of the starch paper does not change, check for the presence of hydrogen iodide in the exhaust gases using sulfuric acid and starch paper if the color changes to blue, then the leak will be from the exhaust.

CHAPTER four

Theoretical Aspects of the Detection Materials

4.1 Introduction

In this chapter, the effect of the chemical detection material which was selected on the vehicle cooling cycle, the effect on the pressure inside the combustion chamber and the effect on the density of gases produced and theoretical amount iodine gas produced.

4.2 The Effect of the detection materials on the vehicle cooling cycle parts materials

First: On cooling pipe

Cooling tubes are considered as one of the most important parts of the cooling system, it produced from the materials that resist the pressure of the cooling cycle, these tubes are made from carbon steel or ASTM A106[21], that is not affected by the addition.

Second: On the water pump

The water pump is a major part of the cooling system and is responsible for the continuity of the flow of coolant liquid in all parts of the cooling cycle, it is made of stainless steel or aluminum alloy with zinc[22], that is not affected by the addition. Stainless steel is generally resistant to acidic corrosion[23].

Third: On the radiator

It is the largest part on the cooling cycle in size and its importance is cooling the coolant liquid which comes from the engine, it is made of copper/brass, aluminum gains or plastic[24], a slow reaction may occur between hydriodic acid and aluminum gains.

Reaction between aluminum gain and hydriodic acid (4.1a) [25]:

$$Al_2O_{3_{(s)}} + HI_{(l)} \rightarrow 2AlI_{3_{(s)}} + 3H_2O_{(l)} \quad (4.1a)$$

Forth: On gasket

A shell of layer steel located between the upper and lower part of the engine, its importance is to maintain the cooling cycle and protect it from the surrounding influences like the combustion process, oil cycle and exhaust that affect it[26] ,stainless steel is generally resistant to acidic corrosion[23].

Fifth: On the head engine

It is the part responsible for entering the mixture (fuel and air) into the combustion chamber at the appropriate time, it is made of cast iron or aluminum alloy[27], a slow reaction may occur between hydriodic acid and aluminum alloy:

Reaction equation between Hi acid with aluminum gain (2.4a).

Sixth: On thermostats

It is placed between the engine and the radiator to make sure that the coolant stays above a certain preset temperature. If the coolant temperature falls below this temperature, the thermostat blocks the coolant flow to the radiator, forcing the fluid instead of a bypass directly back to the engine[28], a slow reaction may occur between hydriodic acid and aluminum[25].

Seventh: On the cooling jacket

It is part of the engine, its allow cooling water to arrive combustion chamber to reduce the temperature and ensure that no problem results due to the high temperature, it's made of cast iron or steel[29].

4.3 The effect of the detection materials on the pressure inside the combustion chamber.

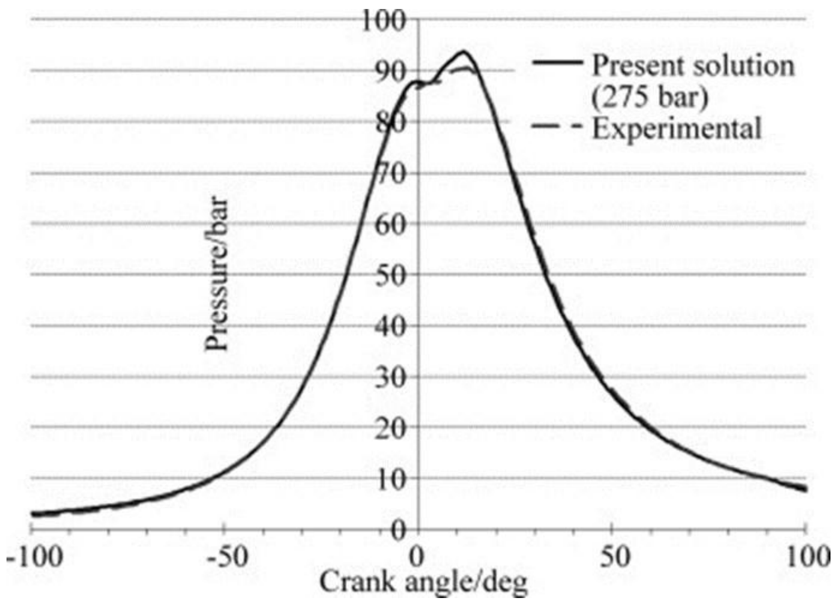

Figure 4.1: variable pressure inside combustion chamber

Figure (4.1) shows the variable pressure inside the combustion chamber of a four-stroke engine, the value of pressure is variable from 0.1 to 90 [bar][30].

Partial pressure of gases inside combustion chamber

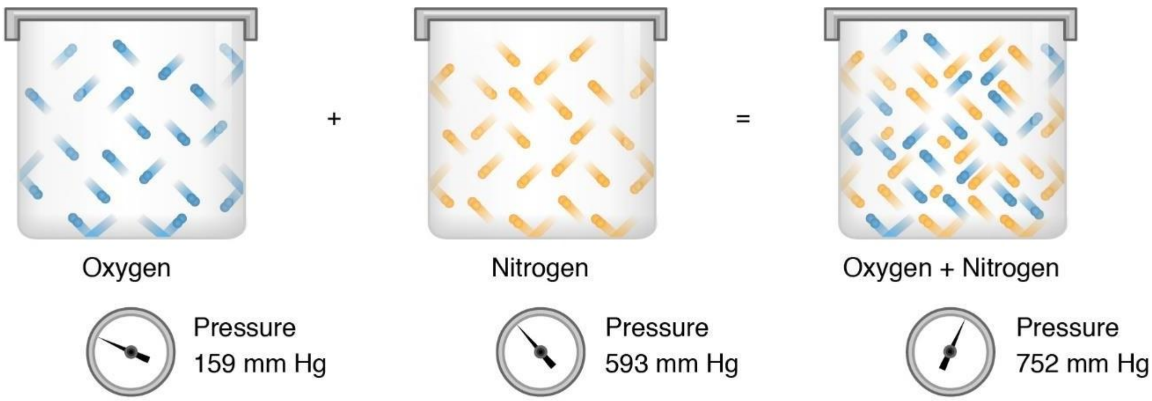

Figure (4.2) partial pressures gives the total pressure of the gas mixture.

Dalton's law of partial pressures states that the total pressure of a mixture of gases is equal to the sum of the partial pressures of the component gases[31]:

P_{Total}=$P_{gas\ 1}$+$P_{gas\ 2}$+$P_{gas\ 3}$ . . . etc. (4.1b)

Dalton's law can also be expressed using the mole fraction of a gas[31], [Xi]

$$P_{gas1} = Xi * P_{total} \quad (4.2a)$$

First: before adding detection material

From combustion gasoline equation (2.2b), we have 7.93 mole (CO_2), 7.41 mole (H_2O), 43.756 mole (N_2).

Total mole of gases = 7.93+7.41+43.756 = 59.096 [mole].

Xi (CO_2) = 7.93[mole]/ 59.096[mole] = 0.134188.

Xi (H_2O) = 7.41[mole]/ 59.096[mole] = 0.125389.

Xi (N_2) = 43.756[mole]/ 59.096[mole] = 0.740422.

P (CO_2) = total pressure * Xi (CO_2) = 0.134188*20.7[bar] =2.77769 [bar].

P (H_2O) = total pressure * Xi (H_2O) = 0.125389*20.7[bar] =2.59555 [bar].

P (N_2) = total pressure * Xi (N_2) = 0.740422*20.7[bar] =15.32673 [bar].

Percentage partial pressure of (N_2) is 74%.

Percentage partial pressure of (H_2O) is 12.6%.

Percentage partial pressure (CO_2) is 13.48%.

Second: after adding detection material

From combustion gasoline equation (2.5a), we have 7.757 mole (CO_2), 8.758 mole (H_2O), 43.76 mole (N_2) and 1 mole (I_2).

Total mole of gases = 7.757+8.758+43.76+1 = 61.275 [mole].

Xi (CO_2) = 7.757[mole]/ 61.275[mole] = 0.1266.

Xi (H_2O) = 8.758[mole]/ 61.275 [mole] = 0.1430.

Xi (N_2) = 43.76[mole]/ 61.275 [mole] = 0.7145.

Xi (I_2) = 1[mole]/ 61.275 [mole] = 0.0163.

P (CO_2) = total pressure * Xi (CO_2) = 0.1266*20.7[bar] =2.65 [bar].

P (H_2O) = total pressure * Xi (H_2O) = 0.1430*20.7[bar] =2.96 [bar].

P (N_2) = total pressure * Xi (N_2) = 0.7145*20.7[bar] =14.8 [bar].

P (I_2) = total pressure * Xi (I_2) = 0.0163*20.7[bar] =0.326 [bar].

Percentage partial pressure of (N_2) is 71.8%.

Percentage partial pressure of (H_2O) is 14.3689%.

Percentage partial pressure (CO_2) is 12.8640%.

Percentage partial pressure of (I_2) is 1.582%.

Table (4.1): Comparison of partial pressures before and after adding the substance

Gas / Partial pressure [bar]	I_2	H_2O	CO_2	N_2
Before adding material	0	2.5955	2.77769	15.3267
After adding material	0.326	2.96	2.65	14.8

Table (4.1): shows the partial pressures of gases before and after adding material, as iodine exerts partial pressure after adding the material (0.326 [bar]), and does not exist before adding it, as the partial pressure ratio has very little compared to other gases.

It is noted that all the partial pressures of gases decrease with a percentage (4%) Except for water, the partial pressure increases by (12%) from the previous pressure.

4.4 Theoretical amount of iodine gas produced.

Let we have 1.6 liter engine at Temperature [T] =1073.15[kelvin] and Pressure [P] =20.7[bar].

Volume for single cylinder [V] =1.6/4=0.4 [litter].

By using ideal gas equation[32]:

PV=nRT (4.2b)

N: number of mole.

R: The gas constant = 8.31441 J K^{-1} mol^{-1}.

N= (PV/RT) = (20.7*0.4)/ (0.0821*1073.15) = 0.0939 [mole] air.

1 mole of air have (1 mole [O_2] and 3.76 mole [N_2])

Mole of [O_2] = (1/4.76)*0.0939 = 0.01972[mole]

Mole of [N_2] = (3.76/4.76)*0.0939 =0.074[mole]

4.4.1 Adding the detection material into gasoline engine

From gasoline equation (2.2b) at stoichiometry

1 mole gasoline $\longrightarrow$ 11.63 mole air

X mole gasoline $\longrightarrow$ 0.0939 mole air

X=0.0080737 [mole] gasoline

At combustion chamber we have 0.01972 [mole] O_2

From convert iodine equation (2.4b), we need 1 mole O_2 to convert iodide I^-

1 mole gasoline $\longrightarrow$ 11.63 mole O_2

Convert iodide into iodine $\longrightarrow$ 1 mole O_2

1:11.63

O_2 Needed to convert iodide = (1/12.63)*0.01972 =1.561*10^{-3}[mole]

O_2 Needed to burn gasoline = (11.63/12.63)*0.01972 =0.018158[mole]

6.184*$10^{-3}$$H^+$ +6.184*$10^{-3}$$I^-$ + 1.561*10^{-3} O_2 $\longrightarrow$ 3.1*10^{-3} I_2+3.1*10^{-3} H_2O (4.1)

Mass of I_2 produced = [mole]*[molecule] =3.1*10^3*(126.9*2) =0.7847 gram

Mole of gases which produced by burned gasoline

We have 0.018158 [mole]O_2, then number of mole for product will be

0.01199 mole [CO_2], 0.0135 mole [H_2O] and 0.067 mole [N_2]

The mass of produced gases:

Mass= [mole]*[molecule]

CO_2= 0.527 gram H_2O= 0.243 gram N_2= 1.876 gram

I_2= 0.7847 gram

4.4.2 Adding the detection material into diesel engine

From gasoline equation (2.3b) at stoichiometry

1 mole diesel $\longrightarrow$ 17.924 mole air

X mole diesel $\longrightarrow$ 0.0939 mole air

X=0.0052387 [mole] gasoline

At combustion chamber we have 0.01972 [mole] O_2

From convert iodine equation (2.4b), we need 1 mole O_2 to convert iodide I^-

1 mole diesel $\longrightarrow$ 17.924 mole O_2

Convert iodide into iodine $\longrightarrow$ 1 mole O_2

1:17.924

O_2 Needed to convert iodide = (1/12.63)*0.01972 =1.561*10^{-3}[mole]

O_2 Needed to burn diesel = (11.63/12.63)*0.01972 =0.018158[mole]

4.168*10^{-3}H^{+} +4.168*$10^{-3}I^{-}$ + 1.042*10^{-3} O_2 $\longrightarrow$ 2.08*10^{-3} I_2+2.08*10^{-3} H_2O (4.2)

Mass of I_2 produced = [mole]*[molecule] =2.0844*10^{3}*(126.9*2) =0.5279 gram

Mole of gases which produced by burned diesel

We have 0.018158 [mole]O_2, then number of mole for product will be

0.0129 mole [CO_2], 0.011553 mole [H_2O] and 0.070 mole [N_2]

The mass of produced gases:

Mass= [mole]*[molecule]

CO_2= 0.5676 gram H_2O= 0.207 gram N_2= 1.96 gram

I_2= 0.5289 gram

Percentage of gases in engine:

% Gas = (mass of gas)/ (total mass of gases)

Table (4.2): Percentage of gases produced at internal combustion engines (ICEs)

Type of engine\Gas	CO_2	H_2O	N_2	I_2
Gasoline engine	15.36%	7.08%	54.68%	22.81%
Diesel engine	17.39%	6.30%	60%	16.20%

4.5 Density of combustion gases after adding detection material.

A material's density is defined as its mass per unit volume. Put another way, density is the ratio between mass and volume or mass per unit volume. It is a measure of how much "stuff" an object has in a unit volume (cubic meter or cubic centimeter). Density is essentially a measurement of how tightly matter is crammed together. The principle of density was discovered by the Greek scientist Archimedes, and it is easy to calculate if you know the formula and understand its related units[33].

$$\rho = m / v. \qquad (4.3a)$$

P: Density of gas.

M: mass of gas [kg].

V: volume of gas [m^3].

First: At gasoline engine

Density of [CO_2] = (0.527)/ (0.0016) =329.375[gram/m^3]

Density of [H_2O] = (0.243)/ (0.0016) =151.875[gram/m^3]

Density of [N_2] = (1.876)/ (0.0016) =1172.5[gram/m^3]

Density of [I_2] = (0.7847)/ (0.0016) =490.4375[gram/m^3]

Second: At diesel engine

Density of [CO_2] = (0.5676)/ (0.0016) =354.75 [gram/m^3]

Density of [H_2O] = (0.207)/ (0.0016) =129.375 [gram/m^3]

Density of [N_2] = (1.96)/ (0.0016) =1225 [gram/m^3]

Density of [I_2] = (0.5289)/ (0.0016) =330.5625 [gram/m^3]

4.6 The effect of the detection material on the cooling cycle and how to dispose of it.

There is no doubt that the detection material has negative effects on the cooling cycle if it remains for a long time in it due to the acidic property of the detection material.

The detection material can be disposed of by using a water pump made of stainless steel due to its anti-corrosive properties[23], and what remains of the substance, its effect can be neglected by reducing its concentration, so as not to effects on cooling cycle by using the concentration formula (2.7a).

From concentration equation (2.7a):

The concentration of detection material = 4.5Wt, $\%H_2O$.

Let we have 200ml of detection material, remains of the substance after extraction by using the pump, and the total capacity of radiator is 4 litter.

$C_2 = C_1 * V_1/V_2$

C_1: The concentration of detection material before extraction.

C_2: The concentration of detection material after extraction.

V_1: The volume of detection material at radiator.

V_2: The volume of detection material after extraction.

$$C_2 = 0.045 * \frac{200}{4000} = 0.00225[mole/l]$$

By the concentration of remaining detection material, it can be said that the effectiveness of the substance is no longer useful.

CHAPTER *five*

Diagnostic Result

5.1 Introduction.

5.2 Steps of Practical Experiment.

5.3 Result of Diagnosis.

5.4 Conclusion.

5.5 Problems.

5.1 Introduction

This chapter, presents the results of the diagnosis obtained through practical experiment, also presents the results of the diagnosis obtained in different diagnosis and discuss the results obtained, and finally the steps of doing practical experiment.

5.2 Steps of Practical Experiment

The practical steps that were taken are as follows:

1. Produce starch, which detects iodine gas

2. Mixing hydriodic acid with water, (25 ml of acid has been added to 50 ml of water).

3. Dipped the paper in the starch solution.

4. The air filter is removed to facilitate the entry of the diagnosis material into the combustion chamber.

5. Injection the diagnosis material into the combustion chamber.

5.3 Result of Diagnosis

The diagnostic process can’t start until the engine reaches the operation temperature “worm up temperature” which is about 90 ℃ for most vehicles.

Normally, the diagnose material cannot be detected while it is in a liquid state, so to detect it must be in an invasive state by using starch paper. The starch paper will change color from white to blue and purple when diagnose material is detected.

The time taken for detected is 30 seconds when the diagnosis material enters the combustion chamber or the exhaust to exit with gases.

The practical results of the three consumption routes

First: In the cooling pipe

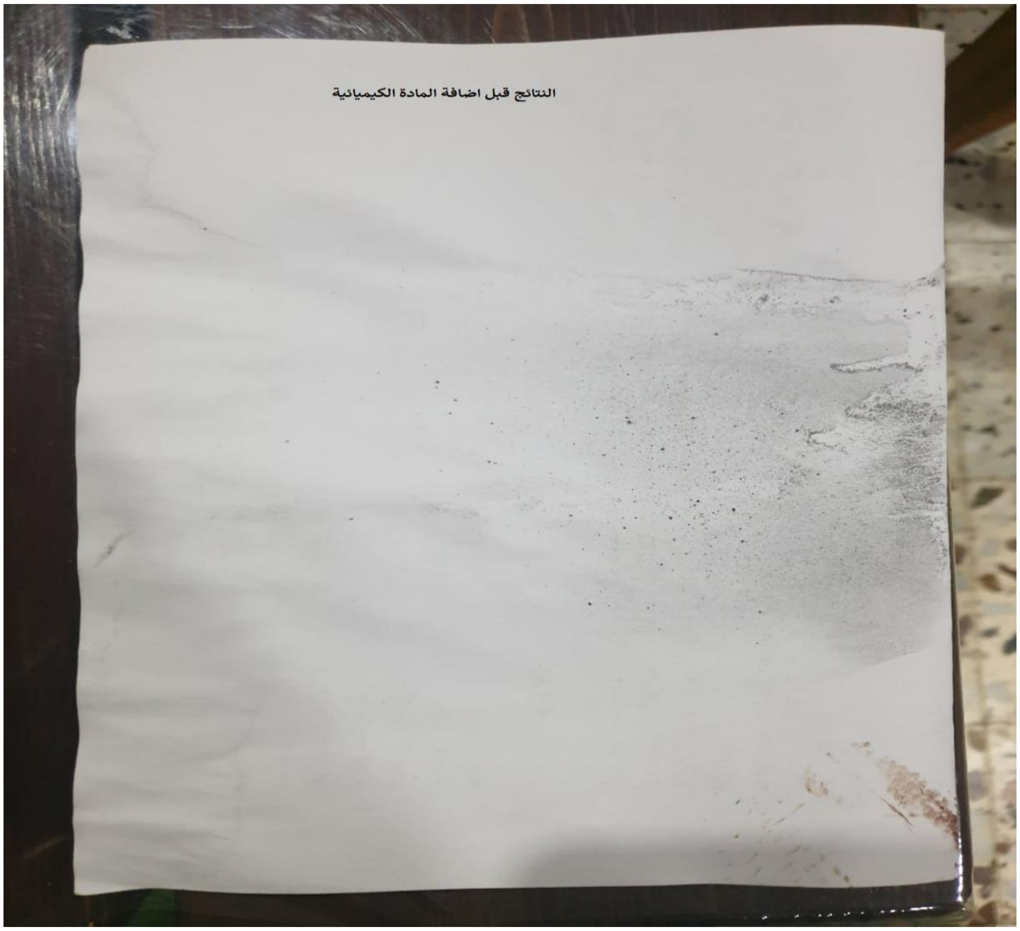

Figure 5.1: the color of starch paper before adding material

In this case, the material does not enter the combustion chamber and does not appear with the exhaust gases.

From figure(5.1), some parts of the paper changed color to black, indicating the presence of particles of unburned fuel in the exhaust gases and there is no detect of the presence of the chemical in the exhaust gases, didn't enter in the combustion chamber. This means that the engine is good and the leakage at the cooling pipe.

Second: At the combustion chamber inside the engine

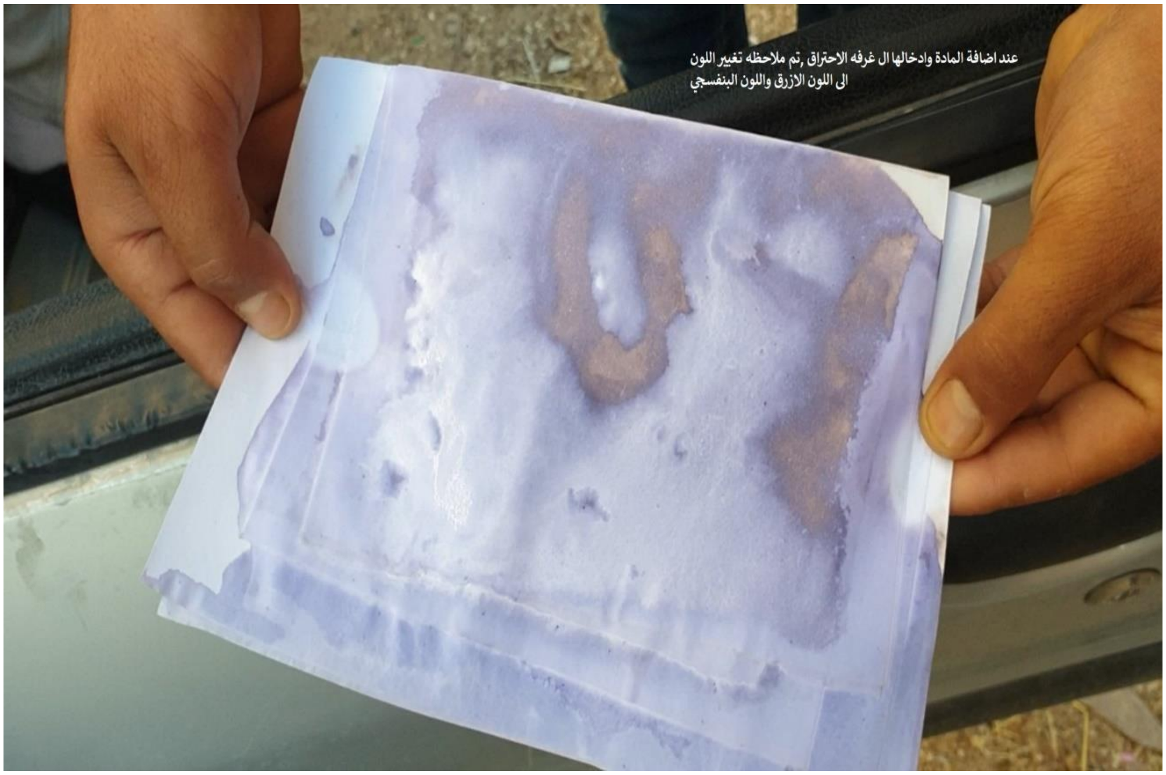

Figure 5.2: The color of starch paper, when the material inside the engine

In this case, the diagnosis material enters the combustion chamber and it will go out the exhaust.

From the figure (5.2), the starch paper has changed color to blue and purple, as the blue color results from the reaction between iodine with starch, and the purple color is the original iodine color. This indicates that the diagnosis material entered the combustion chamber and took the expected behavior and was detected and that it did not react with other gases, which means the engine head needs maintenance.

Third: At exhaust pipe

Figure 5.3: The color of starch paper, when the material inside the engine

In this case, the diagnosis material enters the exhaust and exits with the gases directly.

From figure (5.3), some parts of the starch paper have changed to black and light blue and this indicates that there the diagnosis material in the exhaust, which means the engine head needs maintenance.

5.4 Conclusion

The material was selected based by specific specifications then the detector material was made, the material was injected into the intake manifold, Based on the practical experiment the results obtained was positive and there were no negative results, whether by detecting the presence of the material or damage to the vehicle in general, the practical results were consistent with calculations and theoretical results.

5.5 Problems

The shortage to obtain a sufficient amount of the material to be used in the water cooling system, the major reason of the inability to obtain appropriate quantities of the diagnose material it’s the global pandemic (Covid-19), thus the diagnose material was used by entering it through the air into the combustion chamber as a simulation of the three routes of water consumption.

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