Absorption of CO_2 from Exhaust Gas to Reduce NO_X and HC

By

Haytham Sbaih ***Mohammad Jahalien***

Yahia Abu Zir

Supervisor: Dr. Zuhdi Salhab

Submitted to the College of Engineering

in partial fulfillment of the requirements for the degree of

Bachelor degree in Automobile Engineering

Palestine Polytechnic University

May 2015

Project Name

Absorption CO2 from exhaust gases to reduce NO_X & HC

Project Team:

Mohammad Jahalien ***Yahia abu Zir*** ***Haytham Sbaih***

بناء على نظام كلية الهندسة و التكنولوجيا وإشراف و متابعة المشرف المباشر على المشروع و موافقة أعضاء اللجنة الممتحنة تم تقديم هذا المشروع إلى دائرة الهندسة الميكانيكية ، و ذلك للوفاء بمتطلبات درجة البكالوريس في الهندسة الميكانيكية تخصص هندسة السيارات .

توقيع المشرف

..

توقيع اللجنة الممتحنة

.. **.......................................**

توقيع رئيس الدائرة

....

Dedication

To our Families, for their support

To our Teachers, for help us until the end

To our friends, who give us Positive Sentiment?

To oppressed people throughout the world and their struggle for social justice and egalitarianism

To our great Palestine

To our supervisor Dr .Zuhdi Salhab

To all who made this work possible?

Mohammad Jahalein ***Yahia Abu Zir*** ***Haytham Sbaih***

Acknowledgement

We would like to express our gratitude for everyone who helps us during the graduation project, starting with endless thanks for our supervisor Dr Zuhdi salhab who didn't keep any effort in encouraging us to do a great job, providing our team with valuable information and advices to be better each time. Thanks for the continuous support and kind communication which great effect regarding to feel interesting about what we are working on. Thanks are extended to the "automotive engineering" for the beneficial lecture provided, many thanks for Eng Hussien amer , Eng Mosa zalloum , and Eng Mohammad al-Qwasmi Who helped us in useful lectures, which support our work . Also our thanks are extended to all instructors and engineers who helped us during the first and final stages of our graduation project. Finally, our ultimate thanks go to great edifice of science (Palestine Polytechnic University) for their endless support and their huge effort in providing us with all what we need to build this project.

Abstract

The emission problem is one of the most interesting challenges in automotive technology and it is reached at alarming level. Because exhaust pollutants emitted to atmosphere by automobiles are the serious higienis and environmental risk and the main source of air pollution, particularly in developing countries, the greatest interest and attention was devoted to use an effective technique to reduce the level of these pollutants. So research on improving the engine fuel economy and reducing exhaust emissions has become imperative in combustion and engine development. In internal combustion engines, NO_X formation is temperature dependent phenomenon and takes place when the temperature of the charge in the engine so, to reduce the NO_X emission levels in the exhaust, it is necessary to keep the combustion temperature under control.

As a team of project we are going to design a system to absorb CO_2 from exhaust gases into caustic solution (NaOH) by scrubber tank and try to reduce NO_X by reduce the amount of O_2 and reduce the exhaust gas temperature, and the system could be reduced HC due to reduce the amount of carbon through EGR and Catalysts Converter.

الملخص

تعد مشكلة الانبعاثات الضارة والسامة من التحديات الممتعة في تكنولوجيا السيارات والتي تصل لحد القلق , لان انبعاثات العادم الى الجو والبيئة من السيارات هو خطر جدي ومصدر رئيسي لتلوث الهواء , خاصة في الدول المتقدمة .

كان من الحلول الفعالة هو الاتجاه الى حل هذه المشكلة عن طريق تقليل انبعاثات ونسب هذه الغازات الى اللبيئة , لذا اتجه العلماء والخبراء الى تطوير استهلاك الوقود وتقليل انبعاثات العادم .

في محركات الاحتراق الداخلي تعد اكاسيد النيتروجين من النواتج الرئيسية لعملية الاحتراق والتي تتكون على درجات حرارة عالية وغاز الهيدروكربون غير المحترق الذي يتكون عند حدوث خلل في نظام الاشتعال .

لذا للتحكم بنسبة كل من اكاسيد النيتروجين والهيدروكربون غير المحترق يجب التحكم بدرجة الحرارة والمحافظة على ظروف اشتعال ملائمة للاحتراق .

نحن كفريق مشروع اقترحنا امتصاص غاز ثاني اكسيد الكربون عن غازات العادم من شانه تقليل نسبة انبعاثات غاز الهيدروكربون واكاسيد النيتروجين واول اكسيد الكربون كما سيتم ايضاحه في فصل النتائج والقراءات العملية للمشروع , وان عملية الامتصاص ستتم من خلال مذيب هيدروكسيد الصوديوم المائي خلال نظام حراري كيميائي يعمل على فصل غاز ثاني اكسيد الكربون من النظام وتوثيق ما يحدثه هذا الفصل من تاثير على ابنعاث باقي الغازات .

Table of Contents

List of Figures

list of Tables

CHAPTER ONE

Introduction

1.1Importance of the study.

1.2 Study objectives.

1.3 Methodology of the study.

1.4 Project characteristics.

1.1 Importance of the study:

Motor vehicle are considered as a significant source of pollution that can damage the environment and human health, air pollution from engine vehicle is the result of fuel burning in engine. Harmful chemicals are produced during combustion process and released as exhaust gases, these chemicals causes a variety for human health and environmental problems.

So to treat and deal with these problems the researchers tends to develop systems to reduce the exhaust gases that emits from engine combustion chamber such as EGR system and catalyst converter.

The project team suggests that , the absorption of $CO_2$from exhaust gases could be improved the performance of EGR and catalyst converter.

1.2 Study objectives:

1. Absorb CO_2 from exhaust gases by liquid solvent caustic sodium "NAOH"
2. Improve performance of EGR system and catalyst converter.
3. Use CO_2 in useful application as a recommendation.
4. Don't effect on engine performance.

1.3 Methodology of the study:

1. Select the engine type, fuel and EGR to use in project.
2. Determine and knowing all the exhaust gases that emits from the engine and determine the percentage of each gas.
3. Calculate the temperature inside the exhaust and intake manifold.
4. Using exhaust gas analyzer to evaluate the emission.
5. Design the system to absorb $CO_2$from exhaust gases.

1.4 Project characteristics:

In this project , the procedure depends on absorb CO_2 in aqueous hydroxide sodium in water ,then use CO_2 in useful application such as storage it and fill up and sell it , and recirculation the rest gases in exhaust by EGR , so we will use in this project:

1. Spark ignition engine (gasoline fuel).
2. EGR system.
3. Catalytic Converter.
4. System for absorption CO_2.

1.4.1 Spark ignition engine (gasoline fuel):

A four-stroke spark-ignition engine is an Otto cycle engine. It consists of four strokes: suction or intake stroke, compression stroke, expansion or power stroke, exhaust stroke. Each stroke consists of 180 degree rotation of crankshaft rotation and hence a four-stroke cycle is completed through 720 degree of crank rotation. Thus for one complete cycle there is only one power stroke while the crankshaft turns by two revolutions.[1]

Gasoline or petrol is a transparent, petroleum-derived liquid that is used primarily as a fuel in internal combustion engines. It consists mostly of organic compounds obtained by the fractional distillation of petroleum, enhanced with a variety of additives; a 42 gallon barrel of crude oil yields about 19 gallons of gasoline, when processed in an oil refinery.[1]

Inhaled (huffed) gasoline vapor is a common intoxicant that has become epidemic in some poorer communities and indigenous groups in Australia, Canada, New Zealand, and some Pacific Islands.[1] In response, Opal fuel has been developed by the BP Kwinana Refinery in Australia, and contains only 5% aromatics (unlike the usual 25%), which weakens the effects of inhalation.

Spark-ignition engines are commonly referred to as "gasoline engines" in America, and "petrol engines" in Britain and the rest of the world. However, these terms are not preferred, since spark-ignition engines can (and increasingly are) run on fuels other than petrol/gasoline, such as LPG gas, methanol, ethanol, bioethanol, compressed natural gas, hydrogen, and(in drag racing) nitro methane.

The main concern with gasoline on the environment, aside from the complications of its extraction and refining, is the potential effect on the climate. The chief risks of leaks come not from vehicles, but from gasoline delivery truck accidents and leaks from storage tanks. Because of this risk, most (underground) storage tanks now have extensive measures in place to detect and prevent any such leaks, such as monitoring systems. The material safety data sheet for unleaded gasoline shows at least 15 hazardous chemicals occurring in various amounts. Benzene and many ant knocking additives are carcinogenic.

The quality of gasoline as a fuel in internal combustion engines is measured by its octane rating. Gasoline is produced in several grades of octane rating. Lead compounds are no longer used in most areas for octane improvement, but many other additives are put into gasoline to improve its stability and performance. Some gasoline also contains ethanol as an alternative fuel.

The term spark-ignition engine refers to internal combustion engines, usually petrol engines, where the combustion process of the air-fuel mixture is ignited by a spark from a spark plug. This is in contrast to compression-ignition engines, typically diesel engines, where the heat generated from compression is enough to initiate the combustion process, without needing any external spark. The working cycle of both spark-ignition and compression-ignition engines may be either two-stroke or four-stroke.[2]

1.4.2 EGR System:

The exhaust gas, added to the fuel, oxygen, and combustion products, increases the specific heat capacity of the cylinder contents, which lowers the adiabatic flame temperature.

In a typical automotive spark-ignited (SI) engine, 5% to 15% of the exhaust gas is routed back to the intake as EGR. The maximum quantity is limited by the need of the mixture to sustain a continuous flame front during the combustion event; excessive EGR in poorly set up applications can cause misfires and partial burns. Although EGR does measurably slow combustion, this can largely be compensated for by advancing spark timing. The impact of EGR on engine efficiency largely depends on the specific engine design, and sometimes leads to a compromise between efficiency and NO_X emissions. A properly operating EGR can theoretically increase the efficiency of gasoline engines via several mechanisms:

- Reduced throttling losses. The addition of inert exhaust gas into the intake system means that for a given power output, the throttle plate must be opened further, resulting in increased inlet manifold pressure and reduced throttling losses.
- Reduced heat rejection. Lowered peak combustion temperatures not only reduce NO_X formation, it also reduces the loss of thermal energy to combustion chamber surfaces, leaving more available for conversion to mechanical work during the expansion stroke.
- Reduced chemical dissociation. The lower peak temperatures result in more of the released energy remaining as sensible energy near TDC (Top Dead-Center), rather than being bound up (early in the expansion stroke) in the dissociation of combustion products. This effect is minor compared to the first two.[3]

It also decreases the efficiency of gasoline engines via at least one more mechanism:

- Reduced specific heat ratio. A lean intake charge has a higher specific heat ratio than an EGR mixture. A reduction of specific heat ratio reduces the amount of energy that can be extracted by the piston.

EGR is typically not employed at high loads because it would reduce peak power output. This is because it reduces the intake charge density. EGR is also omitted at idle (low-speed, zero load) because it would cause unstable combustion, resulting in rough idle. The EGR valve also cools the exhaust valves and makes them last far longer (a very important benefit under light cruise conditions).

Since the EGR system recirculates a portion of exhaust gases, over time the valve can become clogged with carbon deposits that prevent it from operating properly. Clogged EGR valves can sometimes be cleaned, but replacement is necessary if the valve is faulty.[4]

1.4.3 Catalytic Converter:

A catalytic converter is a vehicle emissions control device that converts toxic pollutants in exhaust gas to less toxic pollutants by catalyzing a redox reaction (oxidation or reduction). Catalytic converters are used with internal combustion engines fueled by either petrol (gasoline) or diesel—including lean-burn engines.

The first widespread introduction of catalytic converters was in the United States automobile market. Manufacturers of 1975 model year equipped gasoline-powered vehicles with catalytic converters to comply with the U.S. Environmental Protection Agency's stricter regulation of exhaust emissions. These “two-way” converters combined carbon monoxide (CO) with unburned (HC) to produce carbon dioxide (CO_2) and water (H_2O).In 1981, two-way catalytic converters were rendered obsolete by “three-way” converters that also reduce oxides (NO_X); however, two-way converters are still used for lean burn engines.[5]

Although catalytic converters are most commonly applied to exhaust systems in automobiles, they are also used on electrical generators, forklifts, mining equipment, trucks, buses, locomotives and motorcycles. They are also used on some wood stoves to control emissions.[5] This is usually in response to government regulation, either through direct environmental regulation or through health and safety regulations.

1.4.4 System to Absorb CO_2 from Exhaust Gases:

We are going to use in our project to separate CO_2 from exhaust gases this system which include these component:

1. Heat exchanger.
2. Two pumps.
3. Scrubber tank.
4. Radiator or condenser.
5. Pipes.
6. Metal stand.

This system for absorption CO_2 from exhaust gases by using NaOH solution, through thermo chemical process.

Table 1.1: Time table for 1st semester

Tasks weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Selecting project title	🟥	🟥	🟥	🟥												
Planning and setting project concepts and goals					🟥	🟥	🟥									
Studying the project characteristic						🟥	🟥	🟥	🟥	🟥	🟥					
Design and block diagram for packed bed system										🟥	🟥	🟥	🟥	🟥		
Writing report												🟥	🟥	🟥	🟥	
Presentation																🟥

Table 1.2: Time table for 2nd semester

Tasks / weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Selecting project title	🟥	🟥	🟥	🟥												
Planning and setting project concepts and goals					🟥	🟥	🟥									
Studying the project characteristic						🟥	🟥	🟥	🟥	🟥	🟥					
Design and block diagram for packed bed system										🟥	🟥	🟥	🟥	🟥		
Writing report												🟥	🟥	🟥	🟥	
Presentation																🟥

Table 1.3: Cost table for 1st & 2nd semester

NO.	**PIECE NAME**	**PRICE (NIS)**
1.	HEAT EXCHANGER	**1500**
2.	SCRUBBER TANK	**600**
3.	NaOH solution	**400**
4.	pumps	**3000**
5.	pipes	**250**
6.	radiator	**300**
7.	Manufacturing process	**1400**
8.	Total cost	**7450**

CHAPTER TWO

Exhaust Emissions and EGR system

2.1 EGR “Introduction”

2.2 Exhaust and harmful emissions

2.3 Composition of exhaust gases

2.4 Exhaust Emissions

2.5 Exhaust Gas Recirculation (EGR)

2.6 Catalytic Converter

2.1 EGR “Introduction”:

The emission problem is one of the most interesting challenges in automotive technology and it is reached at alarming level. Because exhaust pollutants emitted to atmosphere by automobiles are the serious hygienis and environmental risk and the main source of air pollution, particularly in developing countries, the greatest interest and attention was devoted to use an effective technique to reduce the level of these pollutants. So research on improving the engine fuel economy and reducing exhaust emissions has become imperative in combustion and engine development.

The emissions increase in use of the fossil energy sources in world, in particular, has caused increased pollution of the air, the vehicle exhaust emissions is one of the most important sources of pollution .

2.2Exhaust and harmful emissions:

Exhaust emissions are the non-useable gaseous waste products produced during the combustion process. “Exhaust gas” is the standard term used to describe the waste gas from internal combustion engines.

Harmless products such as Water vapor, Carbon dioxide and Nitrogen, engine exhaust also contain pollutants which are harmful to man and the environment: Carbon monoxide (CO), Hydrocarbons (HC) and Nitrogen oxide (NOx).

Harmful emissions only represent a very small share of the overall emissions of a modern engine. Only 1.1 % for the petrol engine (shows in fig 2.1) and 0.2 % for the diesel engine (shows fig. 2.2). The majority of exhaust consists of nitrogen, water and carbon dioxide.

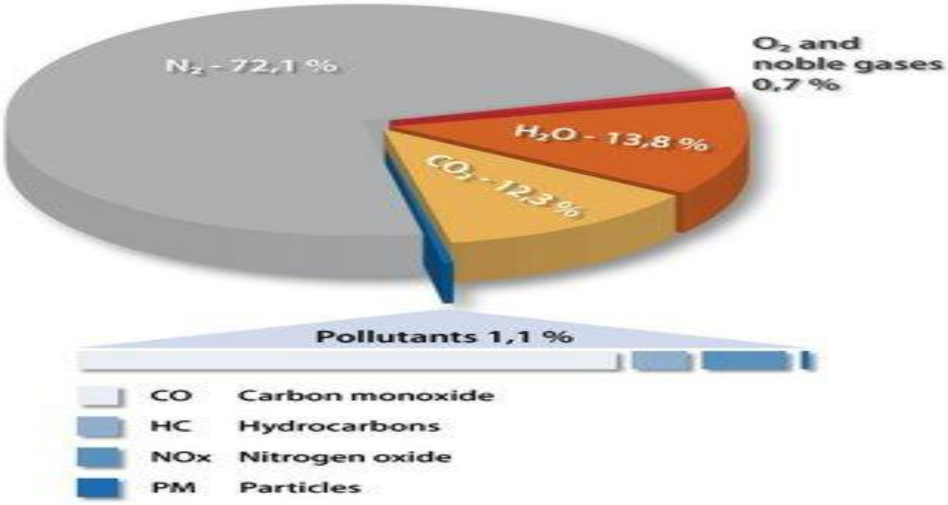


Figure 2.1: % of exhaust gas form petrol engine. [8]

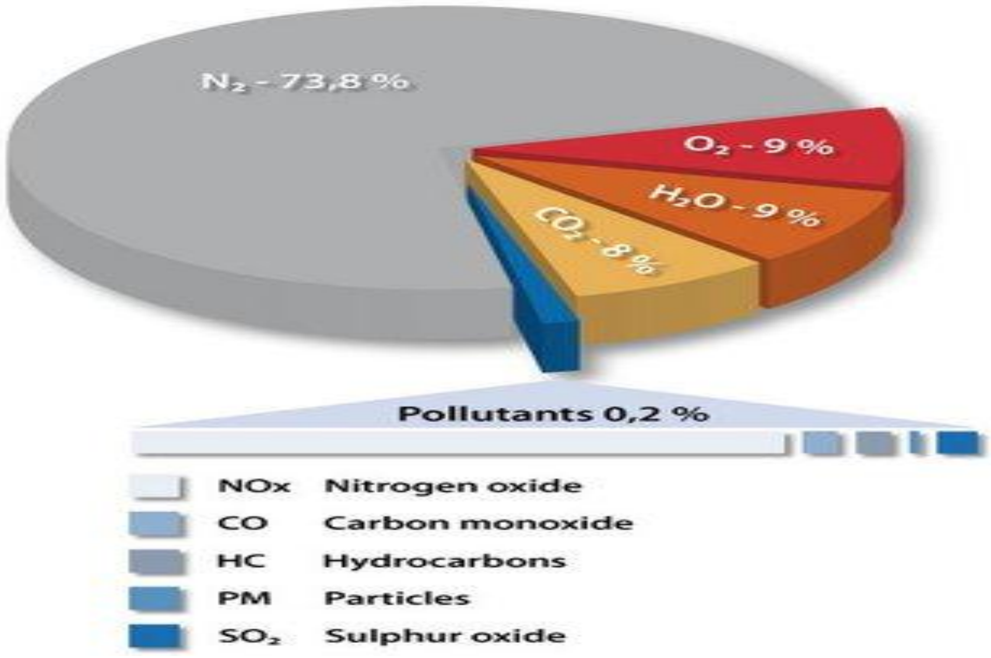


Figure 2.2: % of exhaust gas form diesel engine. [8]

However, it is important that the comparatively small quantity of harmful emissions is also rendered harmless. In order to significantly reduce these harmful emissions, the three-way catalytic converter was introduced.

2.3 Composition of exhaust gases:

The largest part of most combustion gas is Nitrogen (N_2), Water vapor (H_2O) (except with pure-carbon fuels), and Carbon dioxide (CO_2) (except for fuels without carbon); these are not toxic or noxious (although carbon dioxide is generally recognized as a greenhouse gas that contributes to global warming). A relatively small part of combustion gas is undesirable Noxious or toxic substances, such as Carbon monoxide (CO) from incomplete combustion, Hydrocarbons (properly indicated as C_XH_Y, but typically shown simply as "HC" on emissions-test slips) from un burnt fuel, nitrogen oxides (NO_X) from excessive combustion temperatures, Ozone (O_3), and Particulate matter(mostly soot).[4,5]

2.3.1 Sources of Vehicle Emissions:

The power to move a motor vehicle comes from burning fuel in an engine, pollution from vehicles comes from the by-products of this combustion process.

There are many sources lead to vehicles emission such as:

1) The combustion process: this process results in emissions of oxides of nitrogen (NO_X), particulate matter (PM), and carbon monoxide (CO), which are released from the tailpipe while a vehicle is operating.

2) Fuel Tank : The fuel tank emits fuel vapors into the atmosphere. As the temperature inside the engine rises, the fuel tank heats up. The air inside the fuel tank expands, part of which goes out through the tank vent tube or leaves through the vent of the cap in the tank. This air are mixed with gasoline vapors .

The general equation for combustion process:

$$C_mH_nO_qS_p + \delta_{O2}\,O_2 + \delta_{N2}\,N_2 \rightarrow \delta_{CO2}\,CO_2 + \delta_{CO}\,CO + \delta_C\,C + \delta_{H2O}\,H_2O +$$

$$\delta_{H2}\,H_2 + \delta_{NO}\,NO + \delta_{NO2}\,NO_2 + \delta_{SO2}\,SO_2 + \delta_{CH}C_xH_yO_z + \delta_{O2}\,O_2 + \delta_{N2}\,N_2 .$$

δ: mole fraction.
m: number of atom for Carbon.
n: number of atom for Hydrogen.
q: number of atom for Oxygen.
p: number of atom for Sulfur.
x: number of atom for Carbon after burn.
y: number of atom for Hydrogen after burn.
z: number of atom for Oxygen after burn.

2.4 Exhaust Emissions:

The Major and Minor exhaust emission in SI engine is: [8]

1) CO_2-Carbon dioxide.
2) CO - Carbon monoxide.
3) NO_X -Nitrogen oxides.
4) PM - Particulate matter.
5) HC – Hydrocarbons.
6) SO_2 - Sulphur dioxide.

2.4.1 Carbon monoxide (CO):

Carbon monoxide is a colorless, odorless and tasteless gas. The compound, consisting of carbon and oxygen, is formed during incomplete combustion of carbon-containing substances and is very poisonous to the respiratory system. As soon as it is inhaled and enters the bloodstream it prevents the bonding of oxygen to the red corpuscles. A concentration of 1.28 percent carbon monoxide in the air will cause death from suffocation within 1 to 2 minutes.

Since carbon monoxide is heavier than air, it accumulates especially near the ground. In addition, higher concentrations can occur in parking garages. They are usually equipped with special sensors.

Cold-like symptoms can result from small concentrations of 70 to 100 ppm (parts per million) in the air.150 to 300 ppm cause nausea, dizziness and vomiting. Concentrations of 400 ppm or more result in unconsciousness, brain damage and even death. Healthy adults can withstand up to 50 ppm over an extended period; however, children and people with poor health can already experience problems at this concentration.

The eq. (2.1) describe how the carbon monoxide formation.

$$CO_2 \rightarrow CO + \tfrac{1}{2} O_2 \qquad (2.1)$$

2.4.2 Hydrocarbon (HC):

Hydrocarbons are chemical compounds which consist only of carbon (C) and hydrogen (H). They can be found in large quantities in crude oil, natural gas and coal, where they are the actual “fuel”. Some hydrocarbon compounds cause cancer.

When exposed to sunlight, hydrocarbons and nitrogen oxide react to form ozone. In the lower layers of the atmosphere this is a hazardous substance, which irritates the mucous membranes and causes headaches and nausea. Since 1995, ozone is also considered to be a “proven cancer-causing agent”. In addition, increased concentrations of ozone in the air can damage vegetation severely.

2.4.3 Nitrogen oxides (NO_X):

Nitrogen oxides are the gaseous oxides of nitrogen (N). They are abbreviated NO_X because of the various possible compounds with different numbers of atoms: N_2O, NO, N_2O_3, NO_2, etc.

If they come into contact with water (also in the form of fog), acids are formed, which irritate the mucous membranes and can even cause lung damage. There is one exception: Nitrogen monoxide (N_2O), also known as “laughing gas”. However, this is a greenhouse gas, which damages the protective ozone layer in the upper atmosphere.

There are a number of possible reactions that form NO shown in equations below:

$O + N_2 \rightarrow NO + N$ (2.2)
$N + O_2 \rightarrow NO + O$ (2.3)
$N + OH \rightarrow NO + H$ (2.4)

NO can further react to form NO_2 by various means, shown in equations below:

$NO + H_2O \rightarrow NO_2 + H_2$ (2.5)

$NO + O_2 \rightarrow NO_2 + O$ (2.6)

2.4.4 Carbon dioxide(CO_2):

Carbon dioxide (chemical formula CO_2) is a colorless, odorless gas vital to life on Earth. This naturally occurring chemical compound is composed of a carbon atom covalently double bonded to two oxygen atoms. Carbon dioxide exists in the Earth's atmosphere as a trace gas at a concentration of about 0.04 percent (400 ppm) by volume. It is emitted from vehicles, Industrials, volcanoes, springs and geysers and is freed from carbonate rocks by dissolution in water and acids. Since carbon dioxide is soluble in water, it occurs naturally in ground water, rivers and lakes, in ice caps and glaciers and in seawater. It is present in deposits of petroleum oil and natural gas.

Atmospheric carbon dioxide is the primary source of carbon in life on Earth and its concentration in Earth's pre-industrial atmosphere since late in the Precambrian eon was regulated by photosynthetic organisms.

This equation shown react of CO with O_2:
$CO + \frac{1}{2} O_2 \rightarrow CO_2 + heat$ (2.7)
$n\,(CH_2O) + nO_2 \rightarrow nCO_2 + nH_2O$ (2.8)

2.4.5 Particulate matter (PM):

Particulate matter, also known as particle pollution or PM, is a complex mixture of extremely small particles and liquid droplets. Particle pollution is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles.

2.4.6 Sulphur dioxide (SO_2):

Sulphur dioxide is a colorless, pungent and non-flammable gas. Sulphur dioxide causes respiratory illness, but only occurs in very low concentrations in exhaust gases. Sulphur dioxide emission can be curbed by reducing the sulphur content in the fuel. Table 2.1 shows amount for gases related to year.

Component	Emission Rate	Annual pollution emitted
Hydrocarbons	2.80 grams/mile (1.75 g/Km)	77.1 pounds (35.0 kg)
Carbon monoxide	20.9 grams/mile (13.06 g/Km)	575 pounds (261 kg)
NO_x	1.39 grams/mile (0.87 g/Km)	38.2 pounds (17.3 kg)
Carbon dioxide - greenhouse gas	0.916 pounds per mile (258 g/km)	11,450 pounds (5,190 kg)

Table 2.1: Passenger car emissions summary

Exhaust gases related to Air/Fuel Ratio and the relationship between gases as shown in fig 2.3.

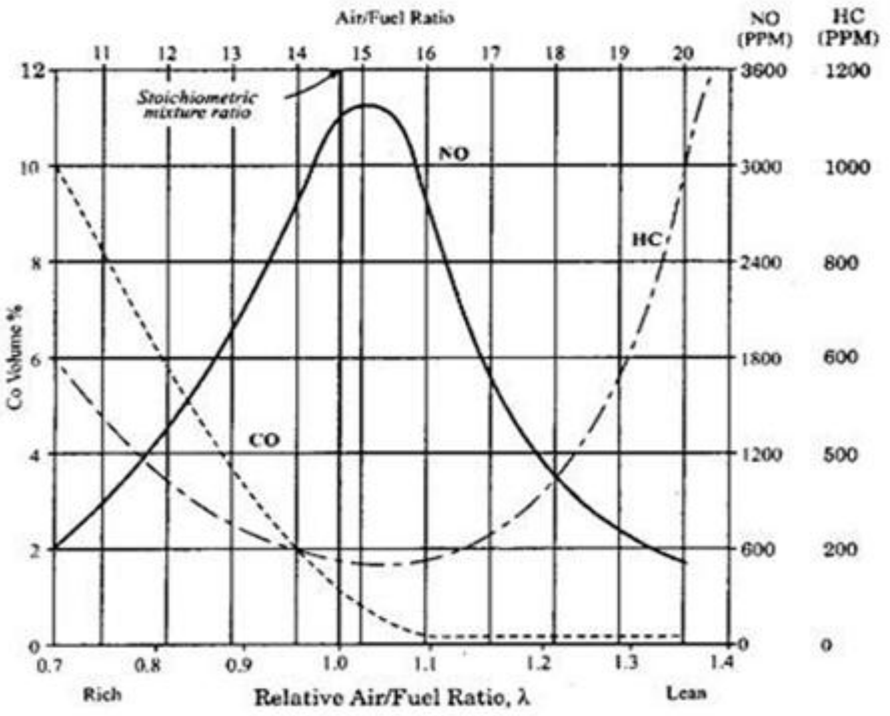


Figure (2.3): Relation between Air/Fuel ratio and exhaust gases.

2.5 Exhaust Gas Recirculation (EGR):

In internal combustion engines, Exhaust Gas Recirculation (EGR) is a Nitrogen oxide (NO_X) emissions reduction technique used in petrol/gasoline and diesel engines. EGR works by recirculation a portion of an engine's exhaust gas back to the engine cylinders. Exhaust gas is routed back into the combustion chamber because the exhausted air is much hotter than the intake air. EGR works by diluting the N_2 and providing inert gases to combustion (CO_2 primarily) to act as an absorbent of combustion heat to reduce peak in cylinder temperatures. NO_X is produced in a narrow band of high cylinder temperatures and pressures.

A gasoline engine, this inert exhaust displaces the amount of combustible matter in the cylinder Because NO_X forms primarily when a mixture of Nitrogen and Oxygen is subjected to high temperature, the lower combustion chamber temperatures caused by EGR reduces the amount of NO_X the combustion generates (though at some loss of engine efficiency).Gasses re-introduced from EGR systems will also contain near equilibrium concentrations of NO_X and CO; the small fraction initially within the combustion chamber inhibits the total net production of these and other pollutants when sampled on a time average. Most modern engines now require exhaust gas recirculation to meet emissions standards; (Fig. 2.4) shows the relationship between EGR system and % of NO_X& HC. [6]

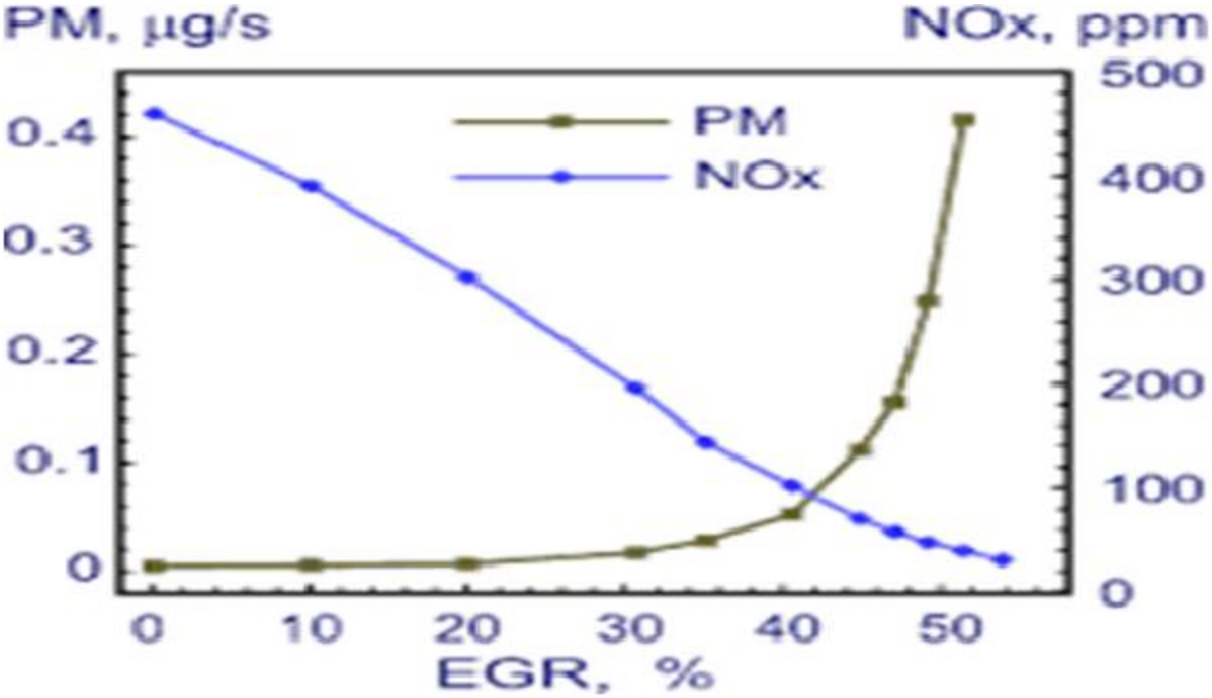


Figure 2.4: Relationship between EGR system and % of NO_X and PM.

2.5.1 Advantages of EGR:

1. The main objective of EGR system lowering NO_X.
2. The EGR system also helps control detonation (knock)**.** Occurs high-pressure and heat cause the air fuel mixture to ignite.
3. Using the EGR system allows for greater ignition timing advance and for the advance to occur sooner without detonation problems, which increases power and efficiency.

2.5.2 Disadvantages and difficulties of EGR:

1. Since EGR reduces available Oxygen in the cylinder, the production of particulates. Is increased when EGR is applied.
2. The deliberate reduction of the Oxygen available in the cylinder will reduce the peak power available from the engine.
3. The EGR valve cannot respond instantly to changes in demand, the exhaust gas takes time to flow around the EGR circuit.
4. The recalculated gas is normally introduced into the intake system before the intakes divide in a multi-cylinder engine.

2.6 Catalytic Converter:

An automotive catalytic converter is one of the several elements of an exhaust system that reduces the emission of harmful pollutants, such as Carbon monoxide (CO), Hydrocarbons (HC) and Nitrogen oxides (NO_X). The catalytic function of the converter will activate certain oxidation and/or reduction reactions, which transform these harmful pollutants into Carbon dioxide (CO_2), Water (H_2O) and Nitrogen (N_2).

A converter typically consists of one or more honeycomb bricks. The term honeycomb describes a structure containing many fine channels. As such, it closely resembles a honeycomb, as we know them from bees in nature. The cross-section of such a honeycomb is most commonly little squares or, alternatively, triangles. Fig. 2.5 shows the working principles of Catalytic Converter. [5]

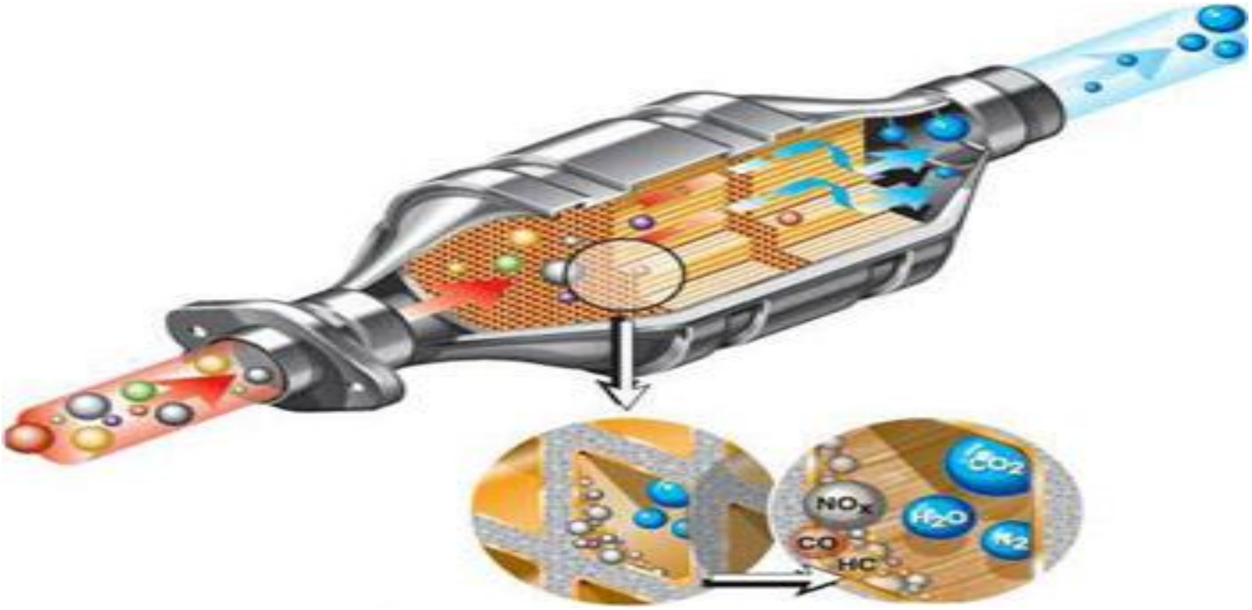


Figure 2.5: Catalytic Converter.

The substrate is protected from vibration and shock by a mineral or metallic 'mat' and then packaged into a stainless steel can. The use of a mat is only applicable to ceramic converters. Positioned between the ceramic substrate and the steel mantle, the mat helps to absorb temperature and mechanical shocks.

Current generation automotive catalyst material consists of a ceramic or metallic substrate coated by an aluminum oxide (Al_2O_3)-based wash coat. The most commonly found converters contain a ceramic substrate (cordierite: $2Al_2O_3.2SiO_2.5MgO$) coated with a precious metal containing wash coat. For certain applications (reducing light-off, reducing back-pressure, etc), a metallic substrate is preferred over a ceramic substrate, typically a specially rolled-up thin stainless steel foil coated with a thin wash coat. Most of these converters are easily recognizable by the circular/swirl movement, as can be seen in a cross section. However, other metallic substrate techniques exist as well. It is a commonly known fact that converters on a ceramic substrate cover about 95% of the total market. [7]

This wash coat contains a combination of platinum group metals (Pt, Pd, Rh) with other rare earth oxides such as CeO_2, ZrO_2, etc. and provide for the catalytic function. PGM is a commonly used denominator for the precious metals Platinum (Pt), Palladium (Pd), Rhodium (Rh), Iridium (Ir), Ruthenium (Ru) and Osmium (Os).

CHAPTER THREE

Project main components (construction)
Project hardware

3.1 Introduction

3.2 Heat Exchanger

3.3 Scrubber tank

3.4 Centrifugal pump

3.5 Radiator

3.6 Sodium hydroxide

3.7 Pipes

3.1 Introduction:

We are going in the project to absorb CO_2 from exhaust gases by NaOH solution in a system include these components:

1. Heat Exchanger.
2. Scrubber tank.
3. Centrifugal Pumps.
4. Radiator or Condenser.
5. Pipes.
6. NaOH solution.

3.2 Heat Exchanger:

A heat exchanger is a piece of equipment built for efficient transfer from one medium to another. The media may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air.

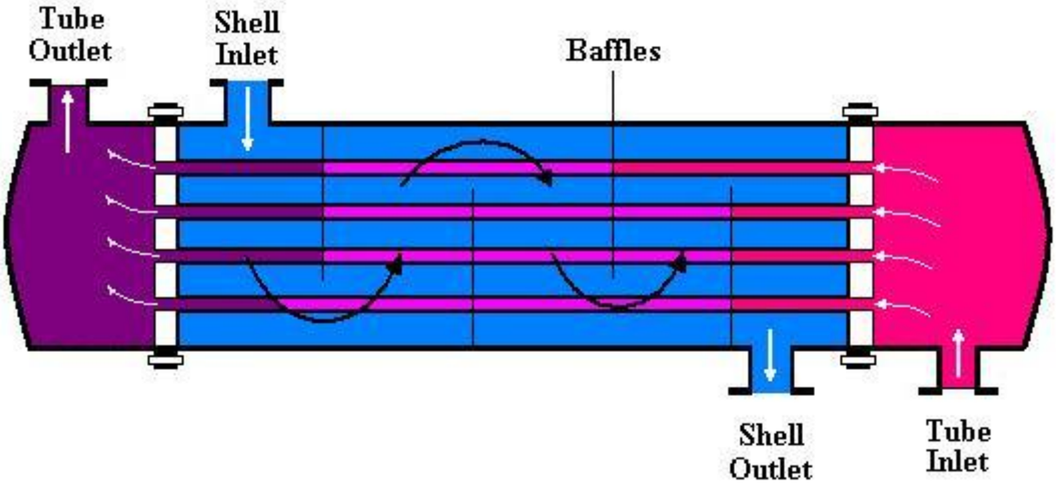


Figure 3.1: Heat Exchanger.

3.2.1 Classifications of Heat Exchangers:

According to their flow arrangement. In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In counter-flow heat exchangers the fluids enter the exchanger from opposite ends. The counter current design is the most efficient, in that it can transfer the most heat from the heat (transfer) medium per unit mass due to the fact that the average temperature difference along any unit length is higher. See countercurrent exchange. In a cross-flow heat exchanger, the fluids travel roughly perpendicular to one another through the exchanger.

For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger. The exchanger's performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence.

3.2.2 Types of Heat Exchanger:

1. Shell and tube heat exchanger.
2. Plate heat exchanger.
3. Plate and shell heat exchanger.
4. Adiabatic wheel heat exchanger.

3.3 Scrubber tank:

Scrubber for cleaning of exhaust gases, absorption technology with NaOH solution Scrubber systems are a diverse group of air pollution control devices that can be used to remove some particulates and/or gases from industrial exhaust streams as shows in fig. 3.2. The first air scrubber was designed to remove carbon dioxide from the air of an early submarine. Traditionally, the term "scrubber" has referred to pollution control devices that use liquid to wash unwanted pollutants from a gas stream. Recently, the term is also used to describe systems that inject a dry reagent or slurry into a dirty exhaust stream to "wash out" acid gases. Scrubbers are one of the primary devices that control gaseous emissions, especially acid gases. Scrubbers can also be used for heat recovery from hot gases by flue-gas condensation. [14]

There are several methods to remove toxic or corrosive compounds from exhaust gas and neutralize it.

Combustion is sometimes the cause for harmful exhaust gas, but, in many cases, combustion may also be used for exhaust gas cleaning if the temperature is high enough and enough oxygen is available.

3.3.1 Scrubber tank components:

1. Cylinder tank
2. Radial PVC palates
3. Injector.

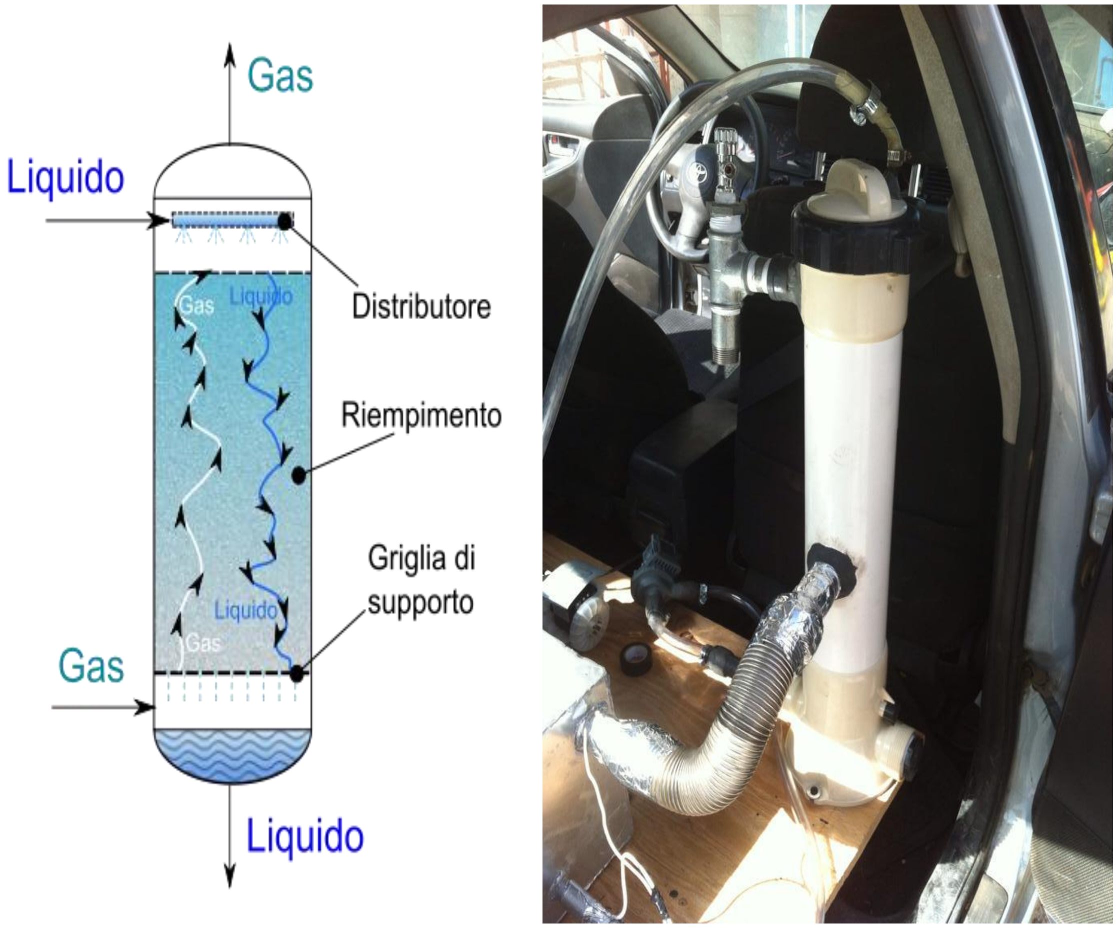


Figure 3.2: Scrubber tank designed (sketch & real).

3.4Centrifugal pump:

Centrifugal pumps are a sub-class of dynamic asymmetric work-absorbing turbo machinery as shows in fig. 3.3. Centrifugal pumps are used to transport fluids by the conversion of rotational kinetic energy to the hydrodynamic energy of the fluid flow. The rotational energy typically comes from an engine or electric motor.

Figure 3.3: Centrifugal pumps (Drain pumps)

The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radially outward into a diffuser or volute chamber (casing), from where it exits.

Common uses include water, sewage, petroleum and petrochemical pumping. The reverse function of the centrifugal pump is a water turbine converting potential energy of water pressure into mechanical rotational energy as shows fig 3.3.[12,13]

How it works:

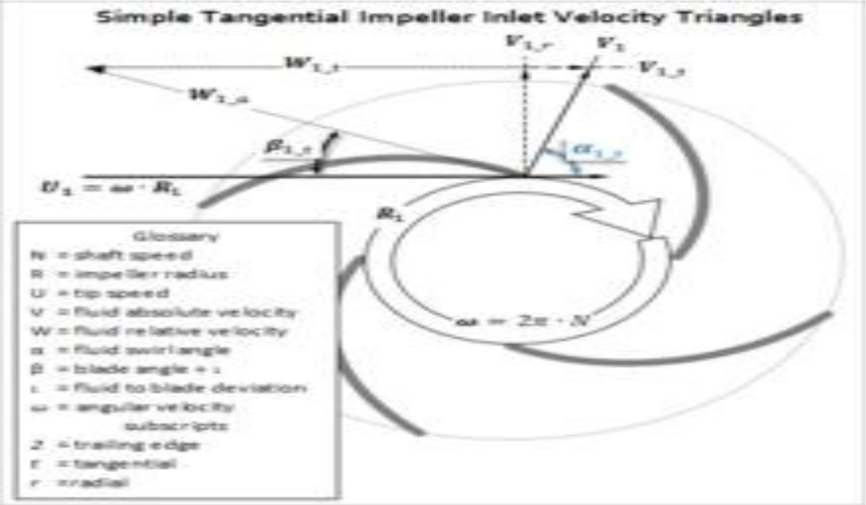


Figure 3.4: the relation between Inlet velocity and Exit velocity. [12,13]

General explanation: Like most pumps, a centrifugal pump converts rotational energy, often from a motor, to energy in a moving fluid. A portion of the energy goes into kinetic energy of the fluid. Fluid enters axially through eye of the casing, is caught up in the impeller blades, and is whirled tangentially and radially outward until it leaves through all circumferential parts of the impeller into the diffuser part of the casing. The fluid gains both velocity and pressure while passing through the impeller. The doughnut-shaped diffuser, or scroll, section of the casing decelerates the flow and further increase the pressure. [13]

3.5 Radiator:

Radiators are heat exchangers used to transfer thermal energy from one medium to another for the purpose of cooling and heating. The majority of radiators are constructed to function in automobiles, buildings, and electronics. The radiator is always a source of heat to its environment, although this may be for either the purpose of heating this environment, or for cooling the fluid or coolant supplied to it, as for engine cooling. Despite the name, radiators generally transfer the bulk of their heat via convection, not by thermal radiation, though the term "convector" is used more narrowly; shows fig. 3.6. [11]

Figure 3.5: Radiator with fan.

The Roman hypocaust, a type of radiator for building space heating, was described in 15 AD. The heating radiator was invented by Franz San Galle, a Polish-born Russian businessman living in St. Petersburg, between 1855 and 1857.

Radiators are used for cooling internal combustion engines, mainly in automobiles but also in piston-engine aircraft, locomotives, motorcycles, stationary generating plants and other places where such engines are used.

To cool down the engine, a coolant is passed through the engine block, where it absorbs heat from the engine. The hot coolant is then fed into the inlet tank of the radiator (located either on the top of the radiator, or along one side), from which it is distributed across the radiator core through tubes to another tank on the opposite end of the radiator. As the coolant passes through the radiator tubes on its way to the opposite tank, it transfers much of its heat to the tubes which, in turn, transfer the heat to the fins that are lodged between each row of tubes. The fins then release the heat to the ambient air. Fins are used to greatly increase the contact surface of the tubes to the air, thus increasing the exchange efficiency. The cooled coolant is fed back to the engine, and the cycle repeats. Normally, the radiator does not reduce the temperature of the coolant back to ambient air temperature, but it is still sufficiently cooled to keep the engine from overheating.

This coolant is usually water-based, with the addition of glycols to prevent freezing and other additives to limit corrosion, erosion and cavitation. However, the coolant may also be oil. The first engines used thermo to circulate the coolant; today, however, all but the smallest engines use pumps. [11]

Figure 3.6: Radiator Form.

3.6Sodium hydroxide:

Sodium hydroxide (NaOH), also known as lye and caustic soda, is a caustic metallic base. It is used in many industries, mostly as a strong chemical base in the manufacture of pulp and paper, textiles, drinking water, soaps and detergents and as a drain cleaner.

Sodium hydroxide is soluble in water, ethanol and methanol. This alkali is deliquescent and readily absorbs moisture and carbon dioxide in air.

Pure sodium hydroxide is a white solid available in pellets, flakes, granules, and as a 50% saturated solution. It is hygroscopic and readily absorbs water from the air, so it should be stored in an airtight container. It is very soluble in water with liberation of heat. It also dissolves in ethanol and methanol, though it exhibits lower solubility in these solvents than does potassium hydroxide. Molten sodium hydroxide is also a strong base, but the high temperature required limits applications. It is insoluble in ether and other non-polar solvents. A sodium hydroxide solution will leave a yellow stain on fabric and paper.[14]

How to absorb CO_2 from exhaust gases by NaOH solution:

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O \quad (3.1)$$

$$Na_2CO_3(s) \rightarrow Na_2O(s) + CO_2(g) \quad (3.2)$$

$Na_2O + H_2O \rightarrow 2NaOH + O_2$ (3.3)

3.6.1 Physical Properties:

Caustic soda is also known as sodium hydroxide, caustic, and lye. Anhydrous (100%, solid) sodium hydroxide has a chemical formula of NaOH and a molecular weight of 40.00. [14]

Basic Properties of Caustic Soda Solution 50%	
Vapor pressure	1.5 mmHg @ 68°F (0.20 kPa @ 20°C)
Boiling point	Approximately 293°F (145°C)
Freezing point	Approximately 58°F (14°C)
pH	14
Specific gravity	1.52 g/ml @ 68°F (20°C)*

Table 3.1: Basic Properties of Caustic Soda.

3.6.2 Stability and Storage Life:

Caustic soda solution is a stable product but its storage life is dependent upon the storage conditions. If the caustic is exposed to air, a change in the product quality will be seen over time, since the caustic soda solution will pick up carbon dioxide to form sodium carbonate (Na_2CO_3) solids. In addition, iron pick up is common in carbon steel storage vessels or in lined carbon steel storage vessels where the liner has been damaged. Therefore, minimizing its exposure to air and its direct contact with iron containing metals will extend the storage life of caustic soda solution.

3.7 Pipes:

A pipe is a tubular section or hollow cylinder, usually but not necessarily of circular cross-section, used mainly to convey substances which can flow — liquids and gases (fluids), slurries, powders and masses of small solids. It can also be used for structural applications; hollow pipe is far stiffer per unit weight than solid members.

CHAPTER FOUR

The CO_2 Absorption System

4.1The procedure of project

4.2 Detailed Description of Project

4.1 The procedure of project:

The system uses a scrubber tank containing a carbon dioxide absorbent fluid to capture CO_2 in the exhaust, the system includes an internal combustion engine, a heat exchanger, a scrubber tank, a pump, metal stand.

The internal combustion engine is configured to emit exhaust gas when operating. The exhaust gas is characterized as having an elevated temperature and comprises carbon dioxide. The heat exchanger is configured to cool the exhaust gas emitted by the internal combustion engine. The scrubber tank contains a carbon dioxide absorbent fluid and is configured to bubble exhaust gas from the heat exchanger through the carbon dioxide absorbent fluid. By this process carbon dioxide gas is absorbed by the carbon dioxide absorbent fluid. The pump is configured to urge the carbon dioxide absorbent fluid through the heat exchanger so that the carbon dioxide absorbent fluid is heated as the exhaust gas is cooled. Heating the carbon dioxide absorbent fluid releases stored carbon dioxide, Fig 4.1 shows design for project.

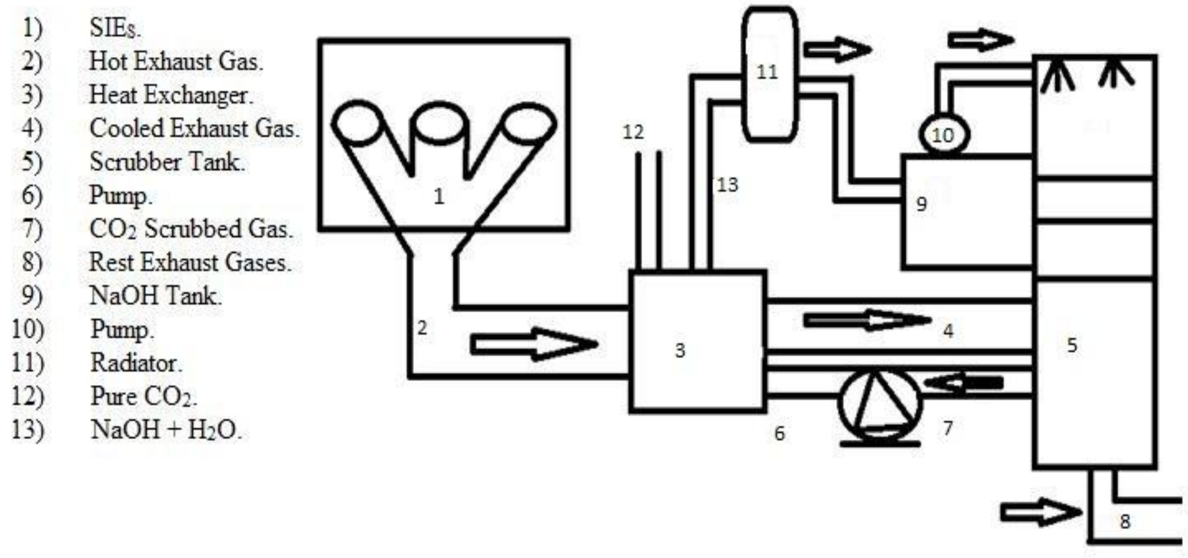


Figure 4.1: The System for Absorption CO_2 and Design of Project.

4.2 Detailed Description of Project:

The exhaust gases exit from engine **1** into exhaust manifold at high temperature **2**, these hot gases entre to the heat exchanger **3** the hot gas cooled by lose heat to other solution water or Na_2CO_3, then the gases exit from heat exchanger **3** as cooled exhaust gases **4** to the scrubber tank **5** which include CO_2 absorbent (NaOH solution) and sprayer nozzle to inject the solution on the stream gas to pass through three plates which increase contact surface between NaOH solution and stream gas to absorb CO_2, then the pump **6** pumps the scrubbed gas **7** to return it to the heat exchanger **3** to release CO_2 from solution by heated the solution **7** with hot exhaust gases **2**, the CO_2 that released **12** from solution will exit from heat exchanger **3** to use in other applications, the hot fluid into heat exchanger **3** will pass through into a thermostat to regulate the temperature inside heat exchanger **3** to the radiator **11**that configured to receive fluid **7** from heat exhachanger**3** and cool the fluid **7** as it flows into the NaOH solution tank **9** the cooling by a radiator **11** may be assisted by a fan it is desirable to cool fluid **7** as much as possible since the fluid

7 generally is able to absorb more CO_2 at lower temperature ,the pump **10** pumps the solution to the sprayers nozzle inside the scrubber tank **5**, other gases after separate CO_2 **8** will go outside the system .

Inside the heat exchanger **3** the CO_2 generally rises out of the fluid **7** to the top of the heat exchanger **3** and accumulates around a CO_2 gas outlet **12**, the heat exchanger **3** may include a thermostat to help regulate the temperature of the fluid **7** exiting the heat exchanger **3** so that the amount of CO_2 removed from the fluid **7** is maximized. It is noted that the heat exchanger **3** is generally configured to keep the exhaust gas **2** and the cooled exhaust gas **4** separated from the fluid **7**, but does facilitate heat transfer from the exhaust gas **2** to the fluid **7**.

The absorption CO_2 could reduce NO_X and HC. The exhaust gases will cool after system applied and will be without CO_2, When a small amount of exhaust gases after scrubbed CO_2 return to the intake manifold with less O_2 and at lower temperature with the same amount of N_2 that could reduce NO_X, also due to the amount of Carbon reduces after scrubbed gases that may be reduce the amount of HC.

CHAPTER FIVE

Theories and Basics for System Design

5.1 The Heat Exchanger Design Equation

5.2 Main principles of pumps selection

5.3 Scrubber Tank Design

5.1 The Heat Exchanger Design Equation:

Heat exchanger theory leads to the basic heat exchanger design equation:

$$Q = U\ A\ \Delta T_{lm} \tag{5.1}$$

Where:

Q is the rate of heat transfer between the two fluids in the heat exchanger in Btu/hr.

U is the overall heat transfer coefficient in Btu/hr-ft^2-^{o}F,

A is the heat transfer surface area in ft^2,

ΔT_{lm} is the log mean temperature difference in ^{o}F, calculated from the inlet and outlet temperatures of both fluids.

5.1.1 Heat Transfer Rate, Q:

Heat exchanger calculations with the heat exchanger design equation require a value for the heat transfer rate, Q, which can be calculated from the known flow rate of one of the fluids, its heat capacity, and the required temperature change. Following is the equation to be used:

$$Q = \dot{m}_H\ C_{pH}\ (T_{Hin} - T_{Hout}) = \dot{m}_C\ C_{pC}\ (T_{Cout} - T_{Cin}) \tag{5.2}$$

Where:

$\dot{m}_H$ = mass flow rate of hot fluid, slugs/hr,

C_{pH} = heat capacity of the hot fluid, Btu/slug-^{o}F

$\dot{m}_C$ = mass flow rate of cold fluid, slugs/hr,

Cp_C = heat capacity of the cold fluid, Btu/slug-^{o}F,

5.1.2 Overall Heat Transfer Coefficient, U:

The overall heat transfer coefficient, U, depends on the conductivity through the heat transfer wall separating the two fluid and the convection coefficients on both sides of the heat transfer wall. [15,16]

5.2 Main principles of pumps selection:

Centrifugal pumps are one of the most numerous representatives of non-positive displacement pumps that are widely used. The working member of centrifugal pumps is put on shaft impeller provided with blades enclosed between disks and mounted inside spiral-shaped body.

Impeller rotation creates centrifugal force affecting the mass of pumped media inside the impeller, and imparts to it part of kinetic energy passing then into potential energy of head. When this happens the vacuum created in the impeller provides continuous delivery of pumped medium from suction pipe. It is important to note that before starting operation the centrifugal pump should be first filled with the pumped medium, as otherwise suction force will not be sufficient for proper pump operation.
Centrifugal pump may have not one working mechanism, but several.

In this case the pump is called multistage. In terms of design it is distinguished by having several impellers on the shaft at a time, and fluid successively passes through each of them. Having one and the same performance capacity the multistage pump will create greater head as against single-stage pump analogous to it. [17]

5.2.1 Calculation of pumps:

Centrifugal pump performance capacity can be calculated in the following way:

$$Q = b_1 \cdot (\pi \cdot D_1 - \delta \cdot Z) \cdot c_1 = b_2 \cdot (\pi \cdot D_2 - \delta \cdot Z) \cdot c_2. \qquad (5.3)$$

Q – Centrifugal pump performance capacity, m^3/s.

$b_{1,2}$ – widths of impeller pass through diameters D_1 and D_2,m.

$D_{1,2}$ – inlet external diameter (1) and impeller external diameter(2), m.

δ –thickness of blades, m.

Z – Number of blades.

$C_{1,2}$ – radial components of absolute velocities at impeller inlet (1) and its outlet (2), m/s.

5.2.2 Extreme suction head (for centrifugal pump):

Geometric suction head can be determined by the formula: [17]

$$h_г = (P_0 - P_1)/(\rho \cdot g) - h_{св} - w^2/(2 \cdot g) - \sigma \cdot H \qquad (5.4)$$

$h_Г$ – geometric suction head, m.

P_0 – Intake tank pressure, Pa.

P_1 – pressure of the impeller blades, Pa.

ρ – Pumped medium density, kg/m^3.

g – Gravity acceleration, m/s^2.

$h_{св}$ – losses due to overcoming suction pipeline hydraulic resistance, m.

$w^2/(2\cdot g)$ – suction pipeline velocity head, m.

σ*H – added resistance losses proportional to head, m.

where: σ – cavitations factor, H – head created by pump.

Cavitations factor can be calculated by the empirical formula:[17]

$$\sigma = [(n\cdot\sqrt{Q}) / (126H^{4/3})]^{4/3} \tag{5.5}$$

σ – Cavitations factor.

n – Impeller rotation speed, s^{-1}.

Q – Pump performance capacity, m^3/s.

H – Created head, m.

There is also formula for centrifugal pumps for calculation of head margin providing absence of cavitations:

$$H_{кв} = 0{,}3\cdot(Q\cdot n^2)^{2/3} \tag{5.6}$$

$H_{кв}$ – head margin, m.

Q – centrifugal pump performance capacity, m^3/s.

n – impeller rotation speed, s^{-1}.

5.3 Scrubber Tank Design:

The theoretical equations for design scrubber tank:

(EX. Temp.(F) + 460 /540) * INTAKE air flow = exhaust flow (5.7)

(Engine size (CID) * RPM /3456) * Volumetric efficiency = intake air flow (5.8)

A stoichiometric air-fuel ratio, the exhaust gas temperature is different from that in a lean or rich air-fuel ratio. At rich air-fuel ratio, the exhaust gas temperature decreases due to the cooling effect of the fuel. High temperatures (typically above 1,600 °F or 900 °C) can be an indicator of dangerous conditions that can lead to catastrophic engine failure.[18]

$NaOH_{(s)} + CO_{2\,(G)} + H_2O_{(L)} \rightarrow Na_2CO_{3(S)} + H_2O_{(G)}$ (5.9)

$Na_2CO_{3(S)} \rightarrow CO_{2\,(g)} + Na_2O_3$ (5.10)

Calculate the concentration of NaOH in term of molarities:

Molarity = moles of solute / liters of solution (5.11)

Moles of solute = mass of solute / molar mass of solute (5.12)

Molarity = (mass of solute / molar mass of solute) / liters of solution (5.13)

Atomic weight:

Na=23;
O=16;
H=1;

pH = 12-13

CHAPTER SIX

The Experimental work

6.1 Describe of the system

6.2 Components of the system

6.1 Describe of the system:

The design depends on temperature of exhaust gases that exit from combustion process of engine, the percentage of CO_2 in the total of exhaust gases 21%, the amount caustic solution using in system 6kgand percentage of NaOH concentration about 25%, it depended on the amount of caustic injects inside scrubber tank to absorb most efficient amount of carbon dioxide and rate of heat transfer between two fluids inside heat exchanger.

6.2 Components of the system:

6.2.1 Heat Exchanger:

The heat exchanger was design to basically decrease the temperature of hot exhaust gases that emits from engine cylinder, to allow these gases entre to the scrubber tank at required T, since T must not increase above 145 C◦, and to gain temperature to the bicarbonate Na_2CO_3 to release CO_2 that scrubbed inside scrubber tank.

So to calculate the total volume of heat exchanger we use the actual gas equation:

$$P\,V = m\,R\,T \qquad (6.1)$$

Where:
P: the total abs. pressure inside exhaust system.
V: the total volume of gas "constant volume".
m: the actual mass add to the system contained in *V*.
R: gas constant.
T: required Temperature in K.
Where: p = atm. pressure, constant volume, T in range between (400-500) C◦, m = 6kg amount of NaOH.
* Note: our working on 25% concentration from NaOH.

So we can calculate R from this equation:

$$R_{specific} = \frac{R}{M} \qquad (6.2)$$

R: The gas constant value.

$$R = 8.3144621(75)\,\frac{J}{mol.K^{[2]}} \qquad (6.3)$$

$$^{M}{}_{Naoh} = 23 + 16 + 1 = 40 \text{ g/mol.} \qquad (6.4)$$

$$R_{NaOH} = 8.314 / 40 = 0.20785 \text{ J/mol.K} \qquad (6.5)$$

The heat exchanger volume that needed to contain 6 kg soda solution at T between (550 - 600) K at constant pressure equal as shown in fig. 6.1:

$P\,V = m\,R\,T$, P = 1 Atm.
$V = 6 * 0.20785 * 560 = 698.4\ cm^3$. (6.6)

Figure 6.1: The Heat exchanger design and describe.

Information about Heat exchanger as shown in fig. 6.1:

Total volume = 70 L.
Length = 70 cm, width = 40 cm, highest = 25 cm, inlet = 2 in, outlet = 2 in.
Cylinder radius = 15 cm, length = 50, volume = 0.035 m^3, inlet = 0.5 in, outlet = 0.5 in.

6.2.2. Scrubber tank:

The scrubber tank as shown in fig.6.2 designed to Absorb CO_2 with respect to these conditions:

1. PVC material which is corrosion resistance, which due to the soda solution is a strong base that cause corrosion and wear the usual Iron.
2. Injectors at the top of tank to inject soda solution inside tank at 7 gal\hr at 60◦.
3. PVC plates to increase touching area between soda solutions and exhaust gases.
4. The dimension of scrubber tank was determined experimentally to achieve the idea of project.

Figure 6.2: Scrubber tank.

Information about Scrubber tank as shown in fig. 6.2:

Highest =75, radius = 20 cm, inlet = 1.5 in, outlet = 1 in.
Three plates: radius = 19 cm , PVC material.
Injector: flow = 7 gal \ hr at 60◦.

6.2.3 Soda solution Tank:

We use a tank that enough to store 15L of hydroxide sodium solution which use to absorb CO_2 by inject through a scrubber tank my pump that pumps the soda solution from tank as shown in fig. 6.3 to the injectors at the top of scrubber tank .

Figure 6.3: Soda Solution Tank

Information about Soda Solution Tank:

Volume = 15 L, inlet = 0.5 in, outlet = 0.5 in, pressure gauge.

6.2.4 Two drain pumps:

We use in our project two drain pumps to make fluid cycle into a system, the first drain pump as shown in fig. 6.4 used to pumps the fluid from soda tank to the injectors at the top of scrubber tank with power of 35 W, the other one used to pump fluid from scrubber tank to heat exchanger as shown in fig. 6.4, this fluid scrubbed with CO_2 also with power of 35 W.

Figure 6.4: Drain Pumps.

Data sheet for drain pumps:

Model No.	PX2-35-1
Electrical Properties	Phase: single phase
Rated voltage	110~240 V
Rated frequency	50/60 Hz
Power	35 W
Starting voltage	85% of rated voltage
Voltage-proof insulation	Resistance between live part and iron core ≥ 100MΩ, when AC 1500V was put between winding and iron core for 1 minute.
Insulation	Class F.
Temperature rise	Winding temperature rise ≤ 115K, under 1.06 times rated voltage and rated head.
Idle	currency0.2A, power10W.
Under load	currency0.2A, power35W.
Physical Property	Noise: 55db.
Rotor rotation	3000 rpm / 3600 rpm.
Water proof	No leakage under 0.03Mpa hydraulic pressure.
Drain volume	21 L/min.
Head	up to 1.2 M.
Life test	≥ 15000 cycles (1 cycle names 7.5 minutes' on & 2.5 minutes' off).

Table 6.1: Data Sheet for pump.

6.2.5 Condenser and Fan:

We use condenser with fan to cool the fluid that exit from heat exchanger after heated to release CO_2 to return to the soda tank as shown fig. 6.5.

Figure 6.5: Condenser and Fan.

6.2.6 Thermo watch:

We use to determine the temperature at the inlets and exits of the system by thermo watch such as :
At the hot gas inlet, cool gas outlet, cool fluid, and hot fluid as shown in fig. 6.6.

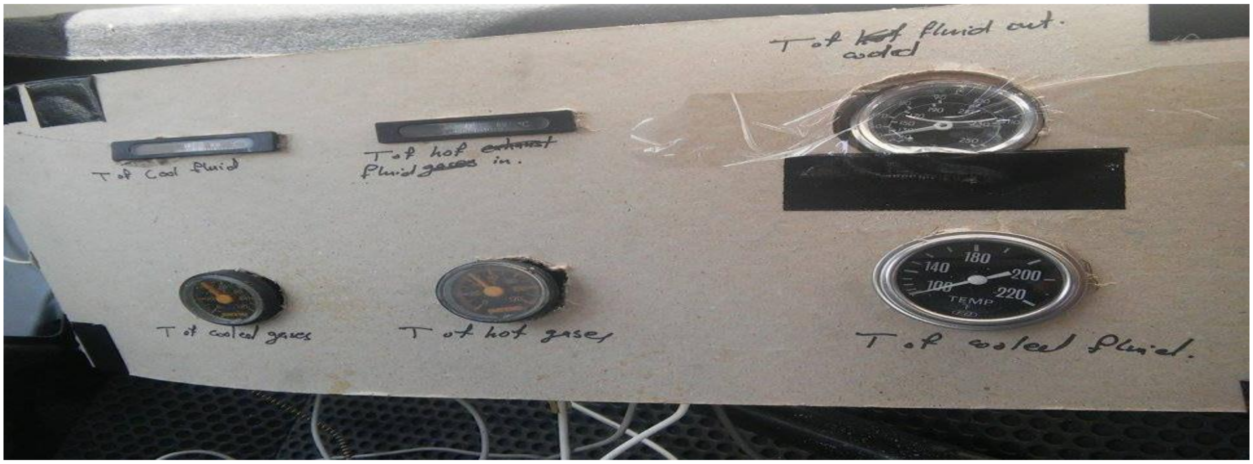


Figure 6.6: The Board for Thermo watches.

CHAPTER SEVEN

Rustles and Conclusion

7.1 Introduction

7.2 Experimental Results and Carves

7.3 Conclusions

7.4 Recommendations

7.1 Introduction:

There are some consideration when deal with gases. The following are a few general facts and tips to keep in mind when deal with exhaust emissions:

1) Carbon Monoxide (CO) is, arguably, an indicator of combustion inefficiency as it represents partly burned fuel. Such as:

1. High CO readings usually indicate a fuel mixture richer than ideal.
2. Rich mixture - air fuel ratio below 14.7:1 or below Lambda 1.
3. High CO levels result from insufficient oxygen supply required for complete combustion.
4. This indicates a rich mixture, (either too much fuel or not enough air).

- Note: This is a gas that is treated in the catalyst, if fitted; therefore high readings may be attributed to catalyst efficiency.

2) Carbon Dioxide (CO_2) gives us a direct measure of combustion efficiency. The higher the value the more efficient the combustion, therefore the nearer to the ideal air-fuel ratio. Such as: Low readings, (usually below approximately 12%), indicate a combustion fault, an exhaust system leak or a sample dilution.

- Note: This gas is not treated by the catalyst, if fitted, but may be affected by the catalyst process.

3) Hydrocarbon (HC) is, as CO, a measure of combustion inefficiency as it represents unburned fuel. High readings may indicate a lack of ignition or poor compression.

- Note: This is a substance which is treated by the catalyst, if fitted; therefore high readings may be attributed to catalyst efficiency.

4) Oxygen (O_2) readings can also show combustion efficiency, as it shows how much oxygen is left over after combustion has taken place. It starts with the ambient, which is around 20% and may be divided by the number of cylinders the engine runs and should result in as little as possible, although there should always be a little left over. High levels can indicate poor combustion or exhaust system and sample probe leaks. Low levels may indicate a rich mixture.

- Note: This is not a gas directly treated by the catalyst, if fitted, but will be affected by the catalyst process.

- Reminder: The emissions are dependent on the combustion process air-fuel ratio.

7.2 Experimental Results and Curves:

The experimentally values were recorded at two different condition of running engine (Idle speed, Part load):

7.2.1 Experimental values without system at idle speed:

Experimental results without system of absorption CO_2 as shown in table 7.1 on Idle speed.

Time	HC (ppm)	CO_2 (%)	CO (%)
0	**0**	**0**	**0**
5	**465**	**12.7**	**0.361**
10	**495**	**12.9**	**0.375**
15	**520**	**13.1**	**0.37**
20	**531**	**13.3**	**0.372**
25	**576**	**13.25**	**0.378**
30	**630**	**13.35**	**0.367**
35	**649**	**13.4**	**0.371**
40	**678**	**13.5**	**0.39**
45	**695**	**13.42**	**0.412**
50	**702**	**13.71**	**0.426**
55	**724**	**13.91**	**0.46**
60	**710**	**14.15**	**0.44**
65	**702**	**13.97**	**0.472**
70	**750**	**14.3**	**0.384**
75	**732**	**13.98**	**0.434**
80	**706**	**13.73**	**0.487**

Table 7.1: Experimental values without system at idle speed.

7.2.2 Experimental values with system at idle speed:

Experimental results with system of absorption CO2 as shown in table 7.2 on Idle speed.

Time	HC (ppm)	CO_2 (%)	CO (%)
0	**0**	**0**	**0**
5	**702**	**13.72**	**0.41**
10	**712**	**13.61**	**0.459**
15	**722**	**13.3**	**0.441**
20	**730**	**12.95**	**0.43**
25	**736**	**12.73**	**0.46**
30	**739**	**12.8**	**0.462**
35	**742**	**12.75**	**0.46**
40	**733**	**12.4**	**0.463**
45	**728**	**12.09**	**0.431**
50	**720**	**11.92**	**0.45**
55	**715**	**11.85**	**0.471**
60	**725**	**11.74**	**0.487**
65	**730**	**11.69**	**0.412**
70	**741**	**11.63**	**0.432**
75	**744**	**11.33**	**0.398**
80	**747**	**11.05**	**0.412**

Table 7.2: Experimental values with system at Idle speed.

The Curves in Fig 7.1, 7.2 and 7.3 shows experimental results without and with system of absorption CO_2 at 780 rpm.

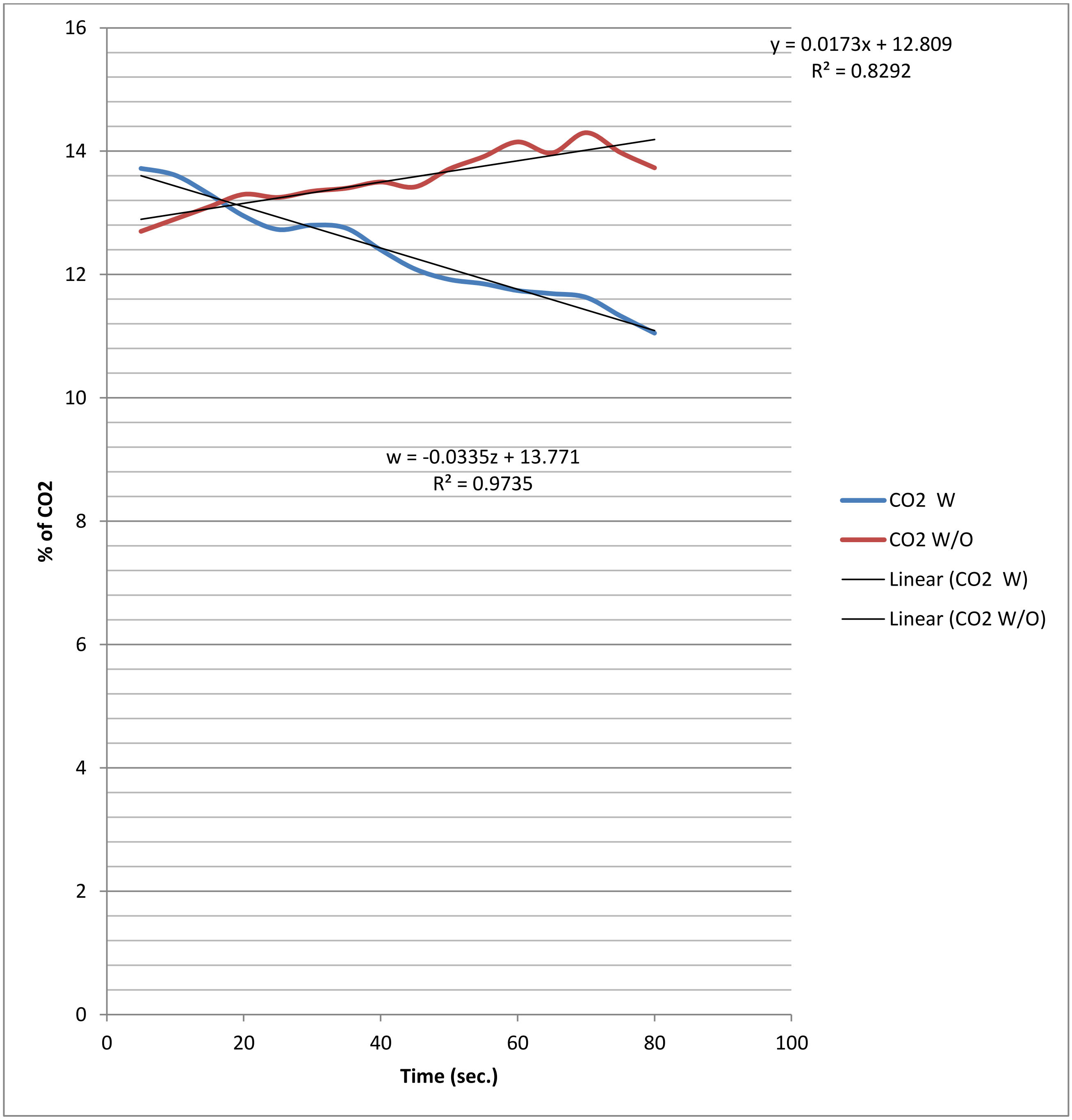


Figure 7.1: % of CO_2 related to Time with and without system at idle.

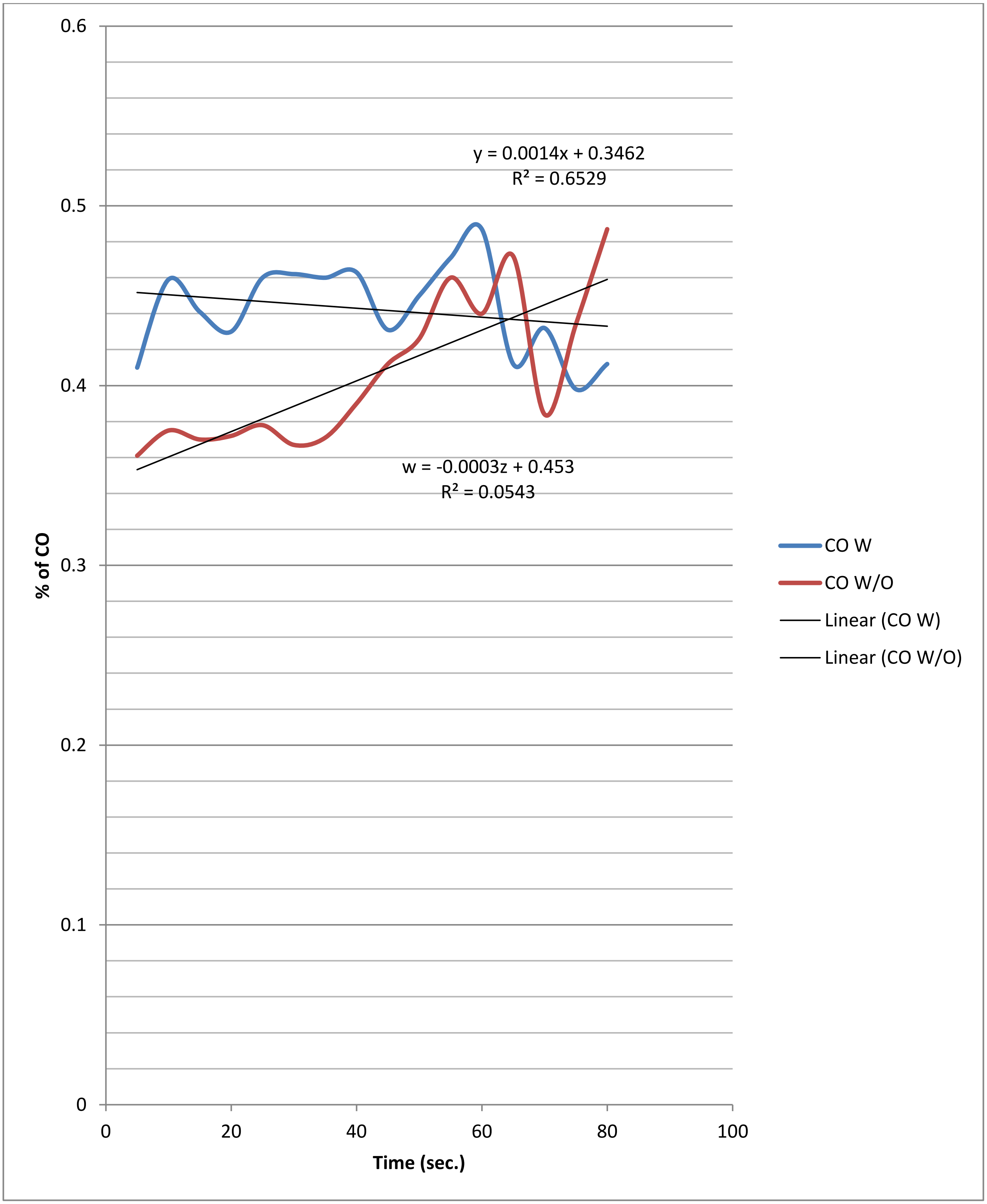


Figure 7.2: % of CO related to Time with and without system at idle.

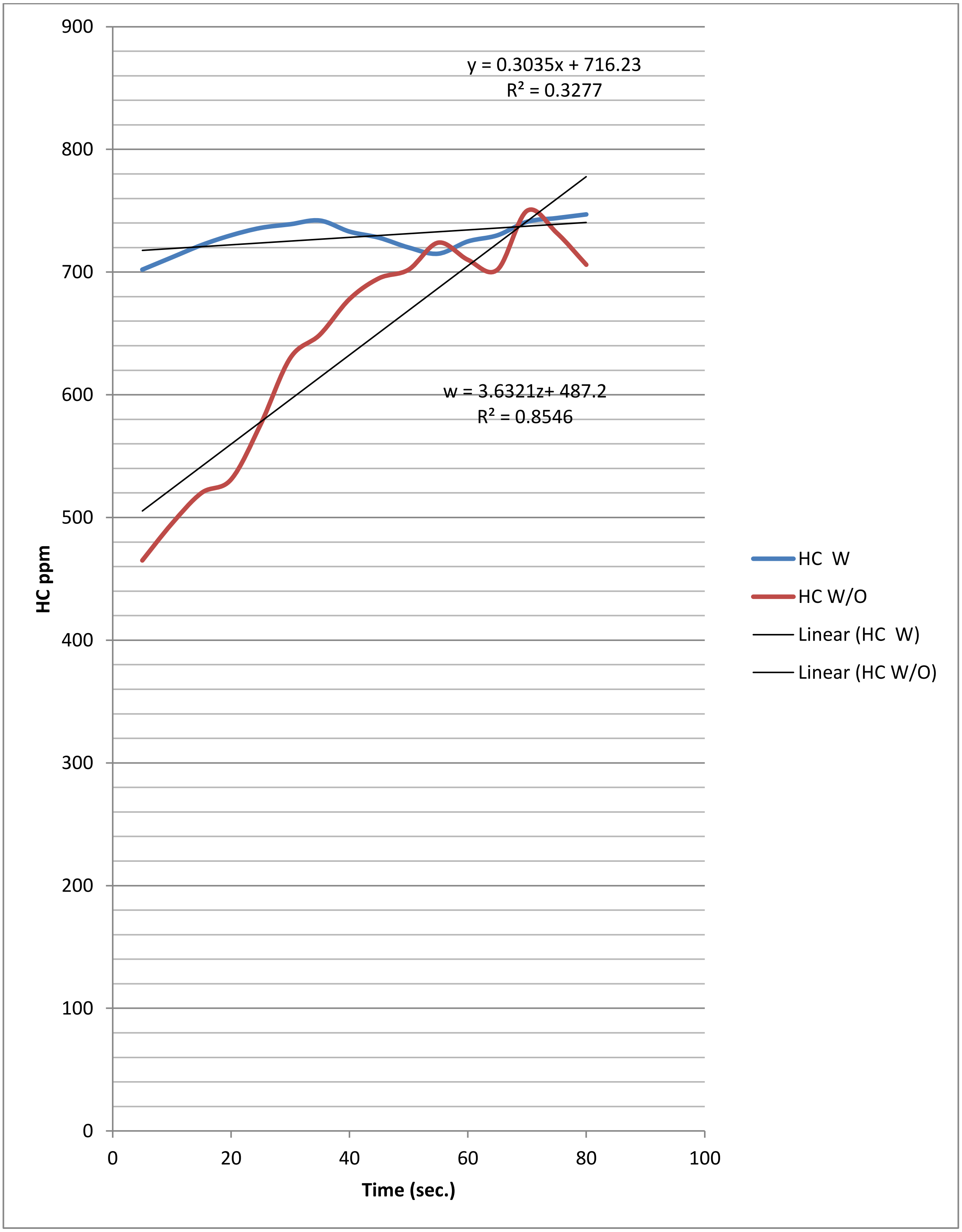


Figure 7.3: HC ppm related to Time with and without system at idle.

7.2.3 Experimental values without system at Part load:

Experimental results without system of absorption CO_2 as shown in table 7.3 on part load.

Time	HC (ppm)	CO_2 (%)	CO (%)
0	**0**	**0**	**0**
5	**756**	**13.71**	**0.45**
10	**748**	**13.85**	**0.44**
15	**744**	**13.94**	**0.42**
20	**740**	**14.01**	**0.392**
25	**732**	**14.11**	**0.37**
30	**715**	**14.32**	**0.375**
35	**660**	**14.5**	**0.381**
40	**622**	**14.57**	**0.381**
45	**540**	**14.7**	**0.392**
50	**451**	**14.85**	**0.37**
55	**392**	**14.83**	**0.361**
60	**362**	**14.79**	**0.344**
65	**322**	**14.87**	**0.356**
70	**294**	**14.95**	**0.333**
75	**274**	**15.07**	**0.32**
80	**256**	**15.27**	**0.316**

Table 7.3: Experimental values without system at part load.

7.2.4 Experimental values with system at part load:

Experimental results with system of absorption CO_2 as shown in table 7.4 on part load.

Time	HC (ppm)	CO_2 (%)	CO (%)
0	0	0	0
5	743	12.09	0.41
10	712	12.31	0.459
15	685	12.41	0.463
20	605	12.5	0.472
25	576	12.2	0.507
30	556	12.7	0.462
35	509	12.96	0.442
40	470	13.2	0.406
45	442	13.35	0.378
50	412	13.74	0.351
55	381	13.25	0.341
60	330	13.12	0.334
65	270	12.85	0.321
70	233	12.75	0.296
75	160	12.91	0.282
80	96	12.67	0.274

Table 7.4: Experimental values with system at part load.

The Curves in Fig 7.4, 7.5 and 7.6 shows experimental results without and with system of absorption CO_2 at part load (2000rpm).

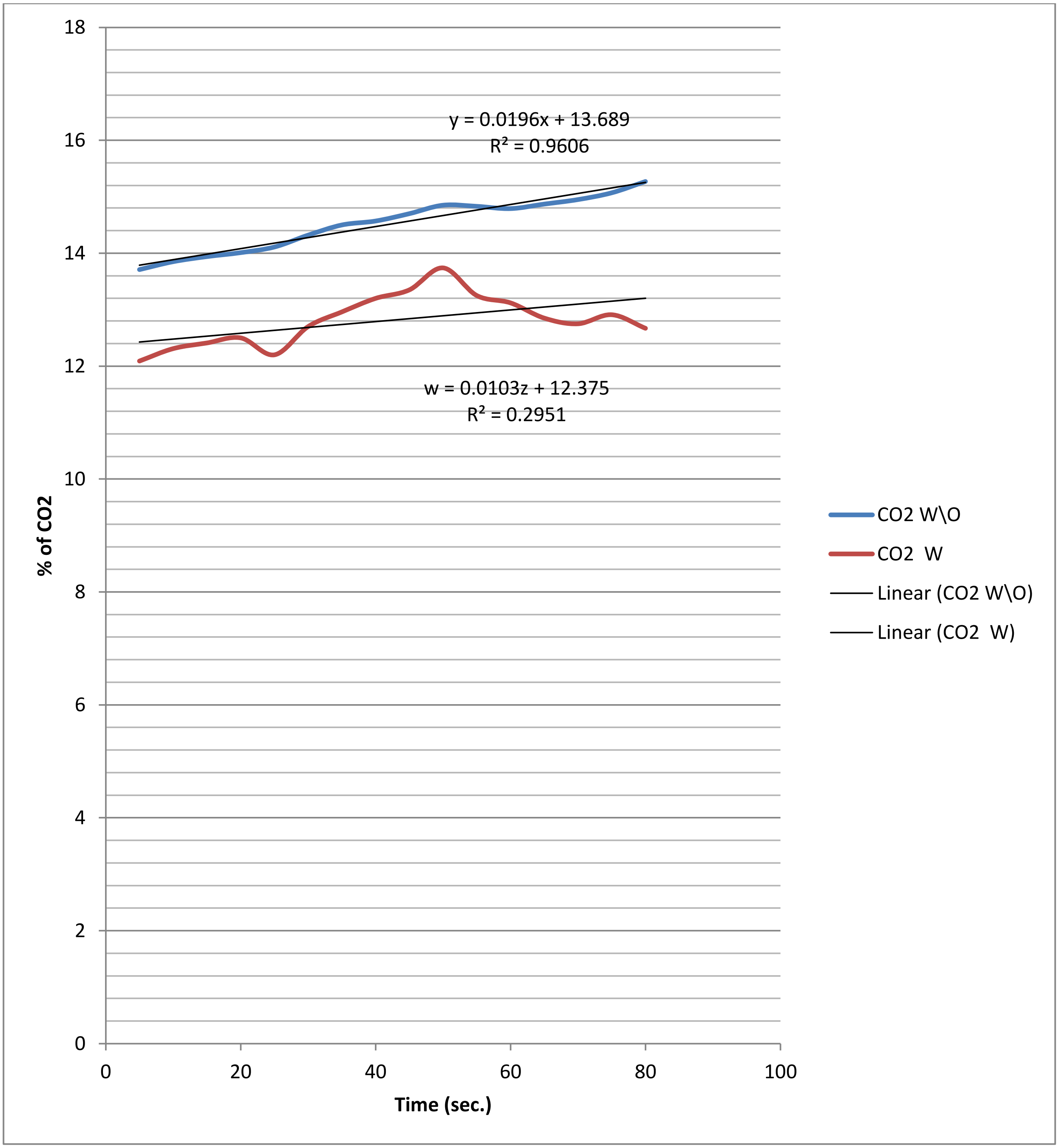


Figure 7.4: % of CO_2 related to Time with and without system at part load.

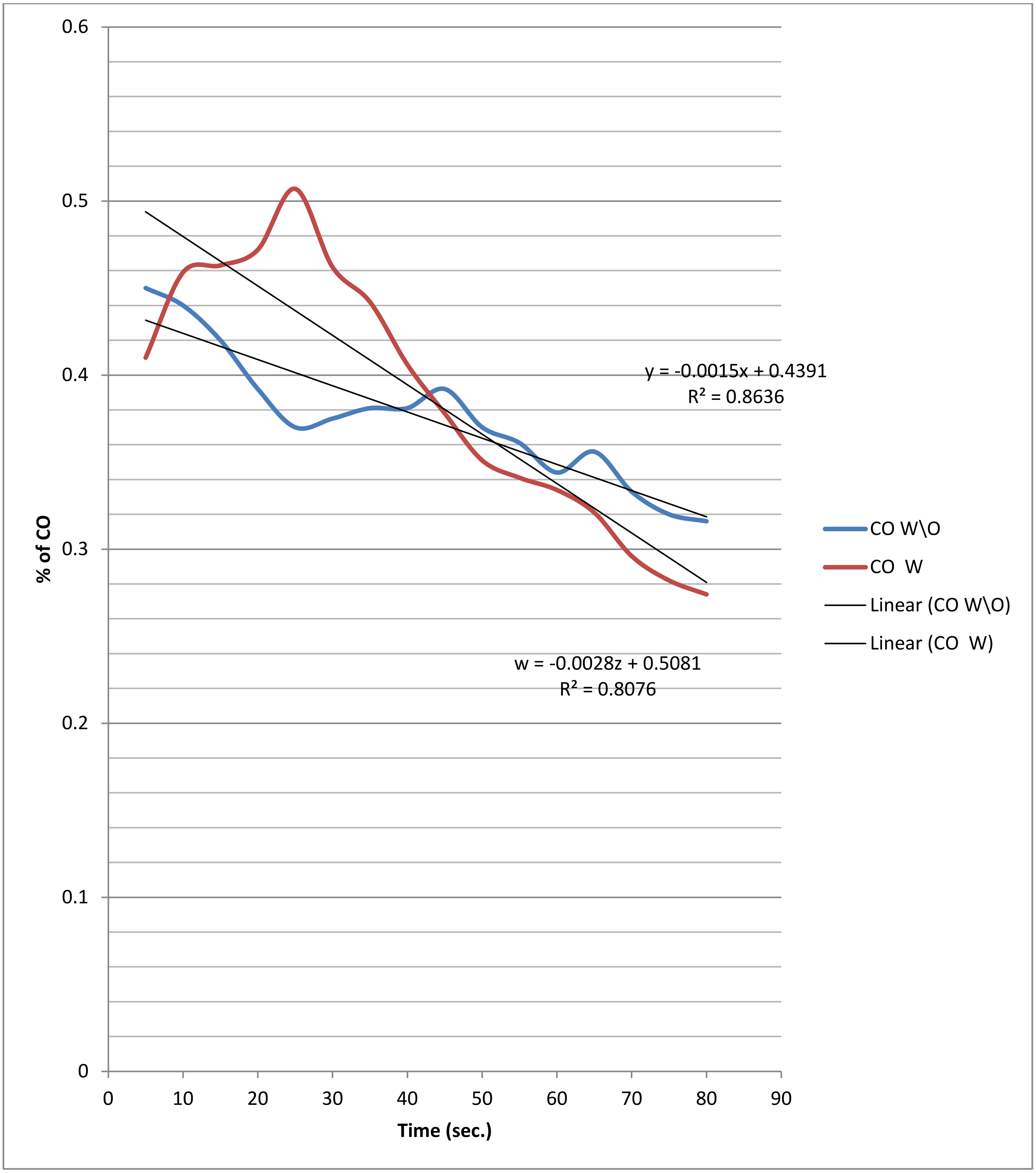


Figure 7.5: % of CO related to Time with and without system at part load.

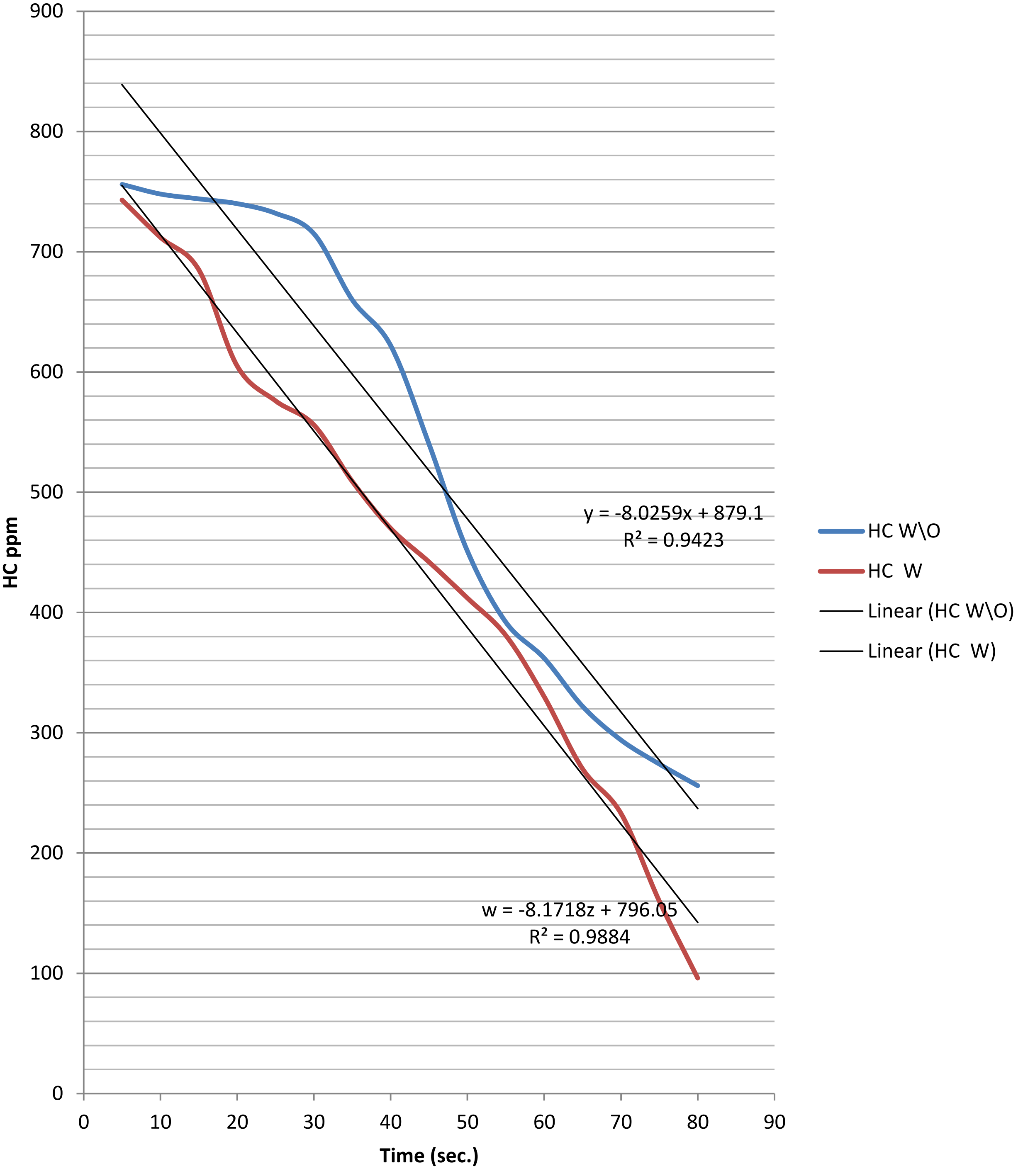


Figure 7.6: HC ppm related to Time with and without system at part load.

7.3 Conclusions:

1. The amount of CO_2 and HC at idle speed 780 rpm were affected by the system to absorb CO_2 from exhaust gases, they decreases with respect to the time as shown in fig. 7.4 -7.6.
2. At part load the amount of CO_2 return to be stable at range (11- 14) %.
3. The amount of CO decreases at part load due to the mixture is rich and more oxygen entre to the engine at part so will react to produce CO_2 which absorbed in a system used in a project.
4. The amount of HC improved after system used in project, as shown in fig. 7.6 the amount of HC decreases linearly with respect to the time.
5. The system used in a project improved the performance of emissions test and reduce toxic emission from engine.
6. The success percentage of project was at idle speed about 16.52% and for part load about 32.43%

7.4 Recommendations:

We conclude many recommendations to improve the efficiency of project, as follow:

1. Store CO_2 by storage system to use the gas in other application such as Electronics, Steel Manufacture and ….. Etc.
2. Replace some tools in project with others with more efficiency such as heat ex., pumps, pipes, scrubbed solution … Etc.
3. It would prefer to use this project after cat. Converter that due to the converter turn the HC and H_2O to CO_2.
4. If the system has a formal design with all possibilities, it can design the system in a small volume that could connect at the exhaust manifold directly.
5. Use another types to absorb CO_2 and there are better than NaOH and faster such as monoethanolamine (MEA), diethanolamine (DEA), methyldiethanolamine (MDEA), diisopropanolamine (DIPA), diglycolamine (DGA) and potassium carbonate ($K2CO_3$). In general, most solvents are either primary or secondary amines, with tertiary amines occasionally used. Besides being used in single component solutions, many of these amines are combined into multicomponent mixtures.

References

References:

[1] Pulkrabek, Willard W. (1997). Engineering Fundamentals of the Internal Combustion Engine. Prentice Hall. p. 2. ISBN 9780135708545.

[2] Naijar, Yousef S.H. (2009). "Alternative Fuels for Spark Ignition Engines". The Open Fuels & Energy Science Journal (2): 1 –9.

[3] Rosen (Ed.), Erwin M. (1975). The Peterson automotive troubleshooting & repair manual. Grosset & Dunlap, Inc. ISBN 978-0-448-11946-5.

[4] Fogler, H. Scott (2006). Elements of Chemical Reaction Engineering (4th Edition ed.). Prentice Hall. ISBN 0-13-047394-4.

[5] Zumdahl, Steven S. (2009). Chemical Principles 6th Ed. Houghton Mifflin Company. p. A23. ISBN 0-618-94690-X.

[6] Toyota Motor Sales. Emission Sub Systems, Exhaust Gas Recirculation, USA, 2006.

[7] Salhab Z. Termodynamic and emission parameters of spark-ignition engines powered by gaseous fuels. Doctroral work, 2001, CZ.

[8] G. H. Abd-Alla, H. A. Soliman, O. A. Badr, M.F. Rabbo, "Effects of diluents and intake air temperature in exhaust gas recirculation of an indirect injection dual fuel engine". Energy Conversion Management, Vol.42, 2001, 1033-1045.

[9] Eran Sher. Hand Book of Air Pollution from Internal Combustion Engines- Pollutant Formation and Control. ISBN: 0-10-639855-08. Library of Congress Cataloging. McGraw-Hill Inc. 1998.

[10] Hu, E., Huang, Z., Liu, B., Zheng, J., Gu, X., Huang, B., 2009, "Experimental investigation on performance and emissions of a spark-ignition engine fuelled with natural gas–hydrogen blends combined with EGR", International Journal of hydrogen Energy, 34:528-539.

[11] S.Y.E. Mohamed, "Effect of exhaust gas recirculation on some combustion characteristics of duel fuel engine". Energy Conversion Management, Vol.44, 2003,707-721.

[12] Agarwal, D., Singh, S. K., Agarwal, A. K., 2011, "Effect of Exhaust Gas Recirculation (EGR) on performance, emissions, deposits and durability of a constant speed compression ignition engine", Applied Energy, 88:2900–2907.

[13] Kirk-Othmer Encyclopedia of Chemical Technology 5th edition (online, account needed), John Wiley & Sons. Accessed November 21, 2005.

[14] Cetin Kurt, Jürgen Bittner (2005), "Sodium Hydroxide", Ullmann's Encyclopedia of Industrial Chemistry, Weinheim: Wiley-VCH,doi:10.1002/14356007.a24_345.pub2.

[15] Ayres, Chris (27 February 2010) Clean green finish that sends a loved one down the drain Times Online. Retrieved 2013-02-20.

[16] Seader, J.D. and Henley, Ernest J. (2006). Separation Process Principles (2nd Edition ed.). John Wiley & Sonstahm. ISBN 0-471-46480-5.

[17] Arastoopour, H. (Ed.). (1998). Fluidization and Fluid Particle Systems: Recent Research and Development. New York, NY: American Institute of Chemical Engineers.

[18] Welty, James R.; Wicks, Charles E.; Wilson, Robert Elliott (1976). Fundamentals of momentum, heat, and mass transfer (2 ed.). Wiley.

[19] Ö. Akgiray and A. M. Saatçı, Water Science and Technology: Water Supply, Vol:1, Issue:2, pp. 65–72, 2001.

[20] Harwood, Laurence M.; Moody, Christopher J. (1989). Experimental organic chemistry: Principles and Practice (Illustrated ed.). Oxford: Blackwell Scientific Publications. pp. 141–143. ISBN 978-0-632-02017-1.

[21] Kravchenko, A. I. (2014). "Design of advanced processes of zone distillation". Perspectivnye materialy (in Russian) (7): 68–72.

[22] Perry, Robert H. and Green, Don W. (1984). Perry's Chemical Engineers' Handbook (6th Edition ed.). McGraw-Hill. ISBN 0-07-049479-7.

[23] Gavin Towler and R K Sinnott (2007). Chemical Engineering Design: Principles, Practice and Economics of Plant and Process Design. Butterworth-Heinemann. ISBN 0-7506-8423-2.

[24] Theodore, Louis; Ricci, Francesco (2011). Mass Transfer Operations for the Practicing Engineer. John Wiley and Sons. ISBN 0470602589.

Appendixes

Appendixes A

PRIMARY HAZARD PLACARD

MATERIAL SAFETY DATA SHEET
SODIUM HYDROXIDE

ELABORATION DATE: MAY 98 REVIEW DATE: ENERO 2010

I. GENERAL DATA OF THE RESPONSIBLE FOR THE SUBSTANCE

Mexichem	***NAMEOFTHE MARKER OR SUPPLIER : Mexichem Derivados, S.A. de C.V., Planta Coatzacoalcos***
	COMPLETE ADDRESS: Complejo Industrial Pajaritos, Coatzacoalcos, Veracruz C.P. 96400
	IN EMERGENCIES TO COMMUNICATE TO THE TELEPHONE: 01152 800 71 21275, Fax: 01152 921 2180036

II. IDENTIFICATION OF THE SUBSTANCE

CHEMICAL NAME: SODIUM HYDROXIDE	**MARKET NAME: Caustic Soda, 48.5% by weight**	**SINONYMS: Bleach, Caustic Bleach, Sodium hydrate, Lye solution**
CHEMICAL FORMULA: NaOH	MOLECULAR FORMULA: NaOH	DEVELOPED FORMULA: NaOHI
CHEMICAL GROUP, FAMILY: Strong Alkali	MOLECULAR WEIGHT: 40.00 lb /lb mol	IDENTIFICATION: UN 1824, CAS 1310-73-2 DOT EMERGENCY GUIDE NO: 154

III. IDENTIFICATION OF DANGEROUS COMPONENTS

COMPOUND NAME	% WEIGHT	UN	CAS	CPT	CCT	P	IDLH	RISK OF LEVEL				
				mg/m^3	mg/m^3	mg/m^3	mg/m^3	H	F	R	ESP	PERSONAL PROTECTION EQUIPMENT
Sodium Hydroxide	48.5	1824	1310-73-2		2	2	10	3	0	1	alk	

IV. PHYSICAL AND CHEMICAL PROPERTIES

1. PHYSICAL APPEARANCE	Viscous liquid	13. HEAT CAPACITY	Irrelevant
2. COLOR	Colorless to slightly colored	14. DENSITY OF VAPOR (air = 1)	Do not apply
3. ODOR	Odorless	15. RELATIVE DENSITY (water = 1)	1.53 (15.6°C, 50% by wt)
4. BOILING POINT	145°C (50%)	16. DRY GAS DENSITY	Do not apply
5. FREEZING POINT	12.1°C	17. DENSITY OF LIQUID	1.53 (15.6°C, 50% by wt)
6. FLASH POINT	Non-flammable	18. GAS / LIQUID RELATION	Do not apply
7. SELF IGNITION TEMPERATURE	Non-flammable	19. COEFFICIENT OF EXPANSION	Do not apply
8. UPPER EXPLOSIVE LIMIT	Non-flammable	20. SOLUBILITY IN WATER	100%
9. LOWER EXPLOSIVE LIMIT	Non-flammable	21. VAPOR PRESSURE (mm Hg)	6.3 mmHg (50%, 40°C)
10. HEAT OF COMBUSTION	Do not apply	22. % OF VOLATILITY	Do not apply
11. HEAT OF VAPORIZATION	Do not apply	23. VEL. OF EVAPORATION	Do not apply
12. HEAT OF FUSION	Irrelevant	24. TEMPERATURE OF DECOMPOSITION	Do not apply

V. FIRE FIGHTING MEASURES

A. EXTINGUISHING MEDIA: CO_2: **X** WATER SPRAY: **X** FOAM: **X** DRY CHEMICAL: **X** OTHER (specify):

B. PERSONAL PROTECTIVE EQUIPMENT: Wear self-contained breathing apparatus and full protective clothing.

C. PROCEDURE AND SPECIAL CAUTIONS IN THE COMBAT FIRES: Move container from fire area if it can be done without risk. Cool container with water spray until well after the fire is out. Stay away from the ends of tanks. Use extinguishing agents appropriate for surrounding fire. Do not get water directly on material . For large fires, flood with fine water spray. Reduce vapors with water spray. Apply water from a protected location or from a safe distance. Avoid body contact or inhalation of material or combustion by-products. Stay upwind and keep out of low areas.

D. CONDITION THAT THEY DRIVE TO ANOTHER SPECIAL RISK: This material will react with some metals and cause liberation of oxygen. May ignite or explode on contact with combustible materials.

E. PRODUCTS OF THE COMBUSTION TOXICS OR NOXIOUS FOR THE HEALT: Toxic fumes can be liberated by contact with acid or heat.

VI. STABILITY AND REACTIVITY

A. SUBSTANCE: STABLE: **X** UNSTABLE: EXTREMELY UNSTABLE:

B. CONDITION TO AVOID: Avoid heat, flames, sparks and others sources of ignition. Dangerous gases may accumulate in confines spaces. Under normal conditions caustic soda solution is stable.

C. INCOMPATIBILITY (substances to avoid): Avoid contact with water. These products may be added slowly to water or acids with dilution and constant stirring to avoid a violent exothermic reaction. When handling this product, avoid contact with aluminum, tin, zinc, and alloys containing these metals. The reaction with these metal may generate flammable hydrogen gas. The reaction with aluminum is particularly vigorous. Caustic soda is strongly alkaline and may react violently with acidic materials such as hydrochloric or sulfuric acids. These reactions will generate heat and could cause splattering of the liquid. Avoid contact with leather, wool, organic halogen compounds and organic nitro compounds.

D. HAZARDOUS DECOMPOSITION: None known.

E. Decompositions Products: None known.

SPONTANEOUS POLYMERIZATION: IT CAN HAPPEN: **NO**

VII. RISK FOR THE HEALT (TOXICITY)

VII.1 Exposure Level and their Health Effects

Exposure Limits	ppm	mg/m^3	Type of Organisms that underwent the chemical agent's exhibition
TLV: CPT or TWA	Not Available		Exhibition 8-hour time weighted average without adverse effects to the health
TLV: CCT or STEL	Not Available		Exhibition at short time (15 min) in 8-hour time weighted average without adverse effects to the health.
TLV: P or C		2	Instantaneous maximum Exhibition that it should not be surpassed for human beings.
IDLH: CT_{Baja} or TC_{LO}		10	Low toxic concentration for inhalation reported for human beings in a hour of exhibition.
IDLH: DT_{Baja} ó TD_{LO}	Not Available		
$LC_{LO\ INNL}$	Not Available		Low lethal concentration for inhalation reported for human beings in 30 exhibition min.
$LD_{LO\ oral}$	500 mg/kg		Lethal dose but it lowers reported in rats or rabbits
LC_{50}	Not Available		Lethal concentration for inhalation for 50% of the rats in a hour of exhibition.
LD_{50}	Not Available		

Potential Route of Ingress to the Organism

A. INHALATION:

SHORT TERM EXPOSURE: Dust or mists may cause severe irritation to respiratory tract. May have same as effect reported in other routes of exposure, burns, pulmonary edema.

LONG TERM EXPOSURE: To our knowledge, no effects are known.

B. INGESTION:

SHORT TERM EXPOSURE: May cause gastrointestinal irritation or ulceration and severe burns of the mouth and throat, nausea,vomiting.

LONG TERM EXPOSURE: Same as effects reported in the short term exposure

C. EYES CONTAC:

SHORT TERM EXPOSURE: May cause severe irritation with corneal injury and result in permanent impairment of vision, even blindness. Dusts may irritate eyes.

LONG TERM EXPOSURE: Same as effects reported in short term exposure.

D. SKIN CONTAC:

SHORT TERM EXPOSURE: Short single exposure may cause severe skin burns.

LONG TERM EXPOSURE: Liquid caustic soda solutions are corrosive to tissues and may produce severe burns, depending upon the severity of exposure (dermatitis).

VII.2 Effects to the health for chronic exposure

CHEMICAL RATED AS: CARCINOGEN: **NO** TERATOGEN: **NO** MUTAGEN: **NO** OTHER: **Toxic, irritant, Corrosive**
FOR THE DEPENDENCE OR ORGANISM: STPS (NOM-010-STPS-1999): **X** OSHA: **X** NIOSH: **X** ACGIH: **X** OTHER: **EPA**

VII.3 Complementary Information

CARCINOGEN STATUS:

The repeated contact with this substance and to low concentrations it can cause chronic dermatitis.

Other long term effects are not known on the live organisms.

VII.4 First Aids Measures

A. INHALATION: Remove from exposure and get fresh air. If an exposed person has stopped breathing, begin cardiopulmonary resuscitation immediately. If an exposed person is still breathing, trained personnel should administer humidified oxygen as soon as possible. Keep the person warm and at rest. Call a physician as soon as possible.

B. INGESTION: If an exposed person is conscious, gives to drink water to dilute. Don't induce the vomit, but if this happens wash and give to drink but it dilutes. Keep the person warm and at rest. Call a physician as soon as possible.

C. EYE CONTACT: Wash eyes immediately with large amount of water, occasionally lifting upper and lower lids, until no evidence of chemical remains (at least 15 minutes). Continue irrigating with water until ready to transport to physician. Cover with sterile bandages. Get medical attention immediately.

D. SKIN CONTACT: Remove contaminated clothing, and shoes. Flush affected area with large amounts of water, preferably a safety shower. Use large amounts of water until no evidence of chemical remains (at least 15-30 minutes). For burns, cover affected area securely with sterile, dry, loose fitting dressing. Do not attempt neutralization or apply any salves or ointments to damaged skin. Call a physician as soon as possible.

E. OTHER RISK FOR THE HEALT: Not certain.

F. ANTIDOTE: There is no known specific antidote for acute sodium hydroxide exposure. Milk of magnesia may be helpful. Do not use acidic antidotes such as sodium bicarbonate. However, prompt medical assessment and supportive measures are necessary to obtain good therapeutic results.

G. DATA FOR THE PHYSICIAN: For inhalation, consider oxygen. For ingestion, avoid gastric lavage, emesis, sodium bicarbonate and acids solutions. Consider the use of antacids

VIII.- EXPOSURE CONTROLS AND PERSONNEL PROTECTION

A. RESPIRATOR: Under conditions of frequent use or heavy exposure, respiratory protection may be needed. Respiratory protection is ranked in order from minimum to maximum. Consider warning properties before use. Any chemical cartridge respirator with a full facepiece and organic vapor cartridges. Any air –purifying respirator with full facepiece and organic vapor canister. Any self-contained breathing apparatus with a full facepiece (Use for High Concentrations or those which are immediately Dangerous to Life or Healt).

B. SKIN PROTECTION: It is recommended to wear appropriate chemical resistant gloves and to wear appropriate chemical resistant clothing to avoid body contact such : chemical protective suit and boots for footwear.

C. EYES PROTECTION: Splash goggles are preferred to a faceshield. Another option is to wear splash resistant safety goggles with a faceshield. Provide an emergency eye wash fountain and quick drench shower in the immediate wok area.

D. HYGIENE: Avoid the contact with the skin or the eyes as web as to breathe the vapors. Not to eat, to drink or to smoke in the work areas. Wash your hands before eating, to drink or to go to the bathroom.

E. VENTILATION: Provide local exhaust ventilation system. Ensure compliance with applicable exposure limits.

F. OTHER MEASURES OF CONTROL AND PROTECTION: Under conditions of frequent use or heavy exposure, respiratory protection may be needed. Consider warning properties before use.

IX.- ACCIDENTAL RELEASE MEASURES

A. Do not touch spilled material.

B. Stop leak if possible without personal risk. For small spills, collect spilled material in appropriate container for disposal and consider absorbing with sand or other non-combustible material.

C. Be advised, however, that the use of absorbing material is creating hazardous waste and this absorbing material must now be disposed of properly.

D. Collect spilled material in appropriate container for disposal. For small dry spills. Move containers away from spill to a safe area. For large spills, dike for later disposal.

E. If possible, do not allow material to enter sewers, streams, ponds or storm conduits as concentrated solutions will seriously injure aquatic life.

F. Keep unnecessary people away, isolate hazard area and deny entry. Contain in as small an area as possible, such as a holding area for dilution and neutralization. Contain spill in plastic drums when available. Dispose of in accordance with Federal, state, and local regulations.

G. Personal engaged in cleanup operations must be equipped with NIOSH approved respirator protection, rubber boots, gloves, and clothing to avoid body contact. Notify Local Emergency Planning Committee and State Emergency Response Commission for release greater than or equal to RQ (U.S SARA Section 304). If release occurs in the U.S. and is reportable under CECLA Section 103, notify the National Response Center at (800) 424-8802(USA) or (202) 426-2675 (USA).

X.- TRANSPORT INFORMATION

A. CAUTIONS FOR TRANSPORTATION: Use single units authorized for the transportation of hazardous materials that complete with the regulation of the Official Mexican Standards, support the Mexican Hazardous Materials Land Transportation Regulation. For transportation-related incident in the U.S, one should utilize SETIQ. SETIQ operates around-the-clock, 24 hours-a-day, seven days-a-week to receive direct dial, calls from any point in the U.S at 011 52 5559-1588.

B. U.S.DOT 49 CFR 172.101	C. BOTTLING OR PACKAGING MARKS:	D. PLACARD WHIT IDENTIFICATION NUMBER: **UN 1824**	E. PLACARD TO SISTEM OF HAZARD COMMUNICATION
Shipping Name: Sodium Hydroxide **Hazard Class or Division: 8** **Packing Group: II** **Labeling Requirements: 8** **DOT Hazardous Substance(s):** **Sodium Hydroxide 1000lb(s)**			

XI.- ECOLOGY AND DISPOSITIONS WASTE

A. The Normas Oficiales Mexicanas (Official Mexican Standards) often referred to as Normas or NOMs, support the Mexican Hazardous Materials Land Transportation Regulation. The Mexican Secretariat for Communications and Transport is responsible for publishing and applying the NOMs. The Mexican NOMs are fairly consistent with those of the United Nations Recommendations on the Transport of Dangerous Goods (UN Recommendations) and TC and DOT regulations. In addition to federal requirements, state provincial or local requirements might affect these operations.

B. Reuse or reprocess if possible. Dispose in accordance with all applicable regulations. Subject to disposal regulation: U.S. EPA 40 CFR 262.

Hazardous Waste Number (s): D002.

C. Their handling and final disposition should be in agreement to the General Law of the Ecological Balance and Protection to the Atmosphere, Regulation of the LGEEPA, in matter of Dangerous Residuals, the NOMs, NOM-052-ECOL/93 and NOM-053-ECOL/93, other legal technical classifications federal, state or municipal applicable.

XII.-HANDLING AND STORAGE

Prevent eye and skin contact. Do not breathe dusts or mists.
Store and handle in accordance with all current regulations and standards. Keep container tightly closed and properly labeled.
Do not store in aluminum container or use fittings or transfer lines, as flammable hydrogen gas may be generated.
Keep separated from incompatible substances.

Do not get in eyes, or on clothing. Wash thoroughly after handling. When mixing, slowly add to water to minimize heat generation and spattering.

Store and handle in accordance with all current regulations and standards including NFPA 430 Code for the Storage of Liquid Corrosive Materials.

XIII.- OTHER INFORMATION

EMERGENCY OVERVIEW:
MAJOR HEALTH HAZARDS: Corrosive. Causes burns to the respiratory tract, skin, eyes and gastrointestinal tract. Causes permanent eye damage.
PHYSICAL HAZARD: Mixing with water, acid or incompatible materials may cause splattering and release of heat.
SIGNAL WORD: Danger.
HEALT EFFECTS:
INHALATION : ACUTE EXPOSURE: May cause severe bronchial irritation, sore throat with possible blistering, coughing, nausea, labored breathing, Short Terms Exposure: Irritation (possibly severe) burns, pulmonary edema.
Long Terms Exposure: To our knowledge, no effects are known.
The classification in Mexico is the same as that in the U.S. The United Nations identification number for Sodium Hydroxide is U.N 1824.

Appendixes B

TATA
TATA CHEMICALS (SODA ASH) PARTNERS

Safety Data Sheet – Sodium Carbonate, Anhydrous

Date Reviewed: February 2015 Supersedes: January 2015

This document has been prepared to meet the requirements of the U.S. OSHA Hazard Communication Standard, 29 CFR 1910.1200; the Canada's Workplace Hazards Materials Information System (WHMIS) and, the EC Directive, 2001/58/EC.

1. Product and Company Identification

Product Name	Sodium Carbonate, Anhydrous
Alternate Product Name(s)	Soda Ash, Disodium Carbonate Also: Dense Soda Ash, Soda Ash Light, Synthetic Light Soda Ash, Soda Ash Liquid, Natural Light Soda Ash, Natural Light HA Soda Ash
Chemical Formula	Na_2CO_3
Product Use	Glass manufacture, detergent manufacture, sodium chemicals and carbonate chemicals manufacture, pulp and paper, brine treatment, water hardness removal, pH adjustment in water or wastewater, flue gas desulphurization, coal treatment, ion exchange resin regeneration.
This chemical is certified to ANSI/NSF Standard 60, Drinking Water Chemicals – Health Effects (as packaged in the original, unopened container). Concentration not to exceed 100 ppm when used for corrosion control or scale control pH adjustment.	
Manufacturer	Tata Chemicals (Soda Ash) Partners 100 Enterprise Drive Rockaway, NJ 07866
Emergency Telephone Numbers	(800) 424-9300 (CHEMTREC – US) (613) 996-6666 (CANUTEC – Canada) (307) 872- 3431 (Plant – Green River, WY)

2. Hazards Identification

Emergency Overview: White, odorless, granular solid. Product is non-combustible. Reacts with acids to release carbon dioxide gas and heat. May irritate skin and eyes. Dusts may irritate respiratory tract. Not expected to be toxic to the environment, nor to aquatic organisms. Avoid simultaneous exposure to soda ash and lime dust. In the presence of moisture (i.e. perspiration) the two materials combine to form caustic soda (NaOH), which may cause burns.

Hazard Classification:

Class	Category	Hazard Statement

Eye Irritant	Category 2	H319 Causes serious eye irritation

EC Labeling

Name of substance to appear on label.	Sodium Carbonate
Symbol(s)	 Xi – irritating
Label Phrases	R36: Irritating to eyes. S2: Keep out of reach of children. S22: Do not breathe dust. S26: In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.

Potential Health Effects:

Skin	Prolonged contact may cause skin irritation (red, dry, cracked skin).
Eyes	Irritating to the eyes.
Ingestions	Although low in toxicity, ingestion may cause nausea, vomiting, stomach ache, and diarrhea.
Inhalation	Prolonged inhalation of product dusts may irritate nose, throat, and lungs.
Chronic Effects	Excessive, long term contact may produce “soda ulcers” on hands and perforation of the nasal septum. Sensitivity reactions may occur from prolonged and repeated exposure. This product does not contain any ingredient designated by IARC, NTP, ACGIH or OSHA as probable or suspected human carcinogens.

3. Composition / Information on Ingredients

Chemical Name	CAS #	Wt. %	EC No.	EC Class
Sodium Carbonate	497-19-8	99.8	207-838-8	Xi, R36

4. First Aid Measures

Skin	Wash with plenty of soap and water. Get medical attention if irritation occurs and persists. Remove and wash contaminated clothing before re-use.
Eyes	Immediately flush with water for at least 15 minutes lifting the upper and lower eyelids intermittently. See a medical doctor or ophthalmologist as necessary.
Ingestions	Rinse mouth with water. Dilute by giving 1 or 2 glasses of water. Do not induce vomiting. Never give anything by mouth to an unconscious person. If symptoms persist, contact a doctor or poison control center.
Inhalation	Remove to fresh air. If breathing difficulty or discomfort occurs and persists, obtain medical attention.
Advice to Physician	While internal toxicity is low, irritant effects of high concentrations may produce corneal opacities, and vesicular skin reactions in humans with abraded skin only. Treatment is symptomatic and supportive.

5. Fire Fighting Measures

Extinguishing Media:	Not combustible, use extinguishing method suitable for surrounding fire.
Fire/Explosion Hazards:	Not applicable.
Fire Fighting Procedures:	Wear full protective clothing and self-contained breathing apparatus
Flammable Limits:	Not applicable
Auto ignition Temperature:	Not applicable
Hazardous Combustion Products:	Carbon dioxide.
Sensitivity to Impact:	None
Sensitivity to Static Discharge:	None

6. Accidental Release Measures

Personal Precautions:	Refer to Section 8 “Exposure Controls / Personal Protection”
Containment:	Prevent large quantities of this product from contacting vegetation or waterways; large spills could kill vegetation and fish.
Clean Up:	This product, if spilled, can be recovered and re-used if contamination does not present a problem. Vacuum or sweep up the material and collect in a suitable container for disposal If the spilled product is unusable due to contamination, consult state or federal environmental agencies for acceptable disposal procedures and locations. See Section 13
Notification Requirements:	Federal regulations do not require notification for spills of this product. State and local regulations may contain different requirements; consult local authorities.

7. Handling and Storage

Handling:	Use air conveying / mechanical systems for bulk transfer to storage. For manual handling of bulk transfer use mechanical ventilation to remove airborne dust from railcar, ship or truck. Use approved respiratory protection when ventilation systems are not available. Selection of respirators is based on the dust cloud generation. Keep material out of lakes, streams, ponds and sewer drains. Avoid eye contact or prolonged skin contact. Avoid breathing dusts. When dissolving, add to water cautiously and with stirring; solutions can get hot. Use good personal hygiene and housekeeping.
Storage:	Store in a cool dry area, away from incompatible products (acids). Prolonged storage may cause product to cake from atmospheric moisture.

8. Exposure Controls / Personal Protection

Engineering Controls:	Where possible, provide general mechanical and/or local exhaust ventilation to prevent release of airborne dust into the work environment. Eye wash facility should be provided in storage and general work area.

Personal Protective Equipment:

Eyes and Face:	For dusty or misty conditions, or when handling solutions where there is reasonable probability of eye contact, wear chemical safety goggles and hardhat. Under these conditions do not wear contact lenses. Otherwise, appropriate eye and face protection equipment (ANSI Z87 approved) should be selected for the particular use intended for this material. Safety glasses with side shields are recommended.
Respiratory:	Whenever dust in the worker's breathing zone cannot be controlled with ventilation or other engineering means, workers should wear respirators or dust masks approved by NIOSH/MSHA, EU CEN or comparable certification organization to protect them against airborne dust.

Hands, Arms, and Body:	Wear long-sleeve shirt and trousers, and impervious gloves for routine product use. Cotton gloves are sufficient for dry product; wear impervious (e.g., rubber, neoprene, etc.) gloves when handling solutions. Protective shoes or boots.

Exposure Guidelines: Federal guidelines treat the ingredient(s) in this product as a nuisance dust, as no product-specific guidelines have been issued for exposure. As with all nuisance dusts, worker breathing zone concentrations should be measured by validated sampling and analytical methods. The following limits (OSHA and MSHA) apply to this material:

Particulates Not Otherwise Regulated:
OSHA (PEL / TWA): 15 mg/m^3 (total dust); 5 mg/m^3 (rasp fraction)
MSHA (PEL / TWA): 10 mg/m^3 (total dust)

Avoid simultaneous exposure to soda ash and lime dust. In the presence of moisture (i.e. perspiration) the two materials combine to form caustic soda (NaOH), which may cause burns.

The information noted above provides general guidance for handling this product. Specific work environments and material handling practices will dictate the selection and use of personal protective equipment (PPE).

9. Physical and Chemical Properties

Appearance:	White, granular solid
Odor:	Odorless
Formula:	Na_2CO_3
Molecular Weight:	105.99
Bulk Density (g/l)	Dense grades: 0.9 – 1.1 Natural light grade: 0.7 – 0.9 Synthetic light grade: 0.5 – 0.7
Specific Gravity:	2.533 (vs. water)
Boiling Point:	Decomposes
Melting Point:	854°C (1569°F)
Evaporation Rate:	Not applicable
Percent Volatile:	0%
Vapor Density:	Not applicable
Vapor Pressure:	Not applicable
pH (1% solution)	11.3
Flash Point	None

10. Stability and Reactivity

Stability:	Stable
Conditions to Avoid:	Contract with acids will release carbon dioxide, heat. Contract with lime dust in the presence of moisture can produce corrosive sodium hydroxide.
Materials to avoid	May react with aluminum, acids, fluorine, lithium, and 2,4,6-Trinitrotoluene.
Polymerization:	Will not occur.
Hazardous Decomposition	When heated to decomposition, carbon dioxide is released.

Products	
Other Precautions:	When dissolving, add to water cautiously and with stirring; solutions can get hot.

11. Toxicological Information

Eye:	Severe irritant (50 mg, rabbit).
Skin:	Mild irritant (500 mg/24hr, rabbit). Minor irritation may occur on abraded skin. Not a sensitizer (tested at 0.25% solution).
Oral:	LD_{50}, rat: 4,090 mg/kg
Inhalation:	LC_{50}, rat, 2hr 2.3 mg/l 24 – hour LC_{50}: 800 mg/m^3, 20 h exposure (guinea pig) (moderate toxicity)
Chronic:	Excessive, long term contact may produce "soda ulcers" on hands and perforation of the nasal septum. Sensitivity reactions may occur from prolonged and repeated exposure.
Carcinogenicity:	Not designated by IARC, NTP, ACGIH or OSHA as probable or suspected human carcinogens.

12. Ecological Information

Acute ecotoxicity:	96 – hour LC_{50}: 265 – 565 mg/l (daphnia magnia) (low toxicity) 300 – 320 mg/l (blue gill sunfish) (low toxicity) 96 – hour TL_m: 1200 mg/l (mosquito-fish) 48 – hour TL_m: 840 mg/l (mosquito-fish) 48 – hour EC_{50}: 265 mg/l (daphnia magnia) 5 Day EC_{50}: 242 mg/l (Nitszcheria linearis)
Chronic ecotoxicity:	7 Day EC, biomass: 14 mg/l (phytoplankton)
Mobility:	Air: Not Applicable Water: Considerable solubility and mobility. Soil / sediments: Non-significant adsorption
Abiotic degradation:	Water (hydrolysis): degradation's products: carbonate (pH>10) / carbonic acid / carbon dioxide (pH<6). Soil**:** Hydrolysis as a function of pH.
Biotic degradation:	Aerobic / anaerobic: Not applicable (inorganic compound
Potential for bioaccumulation:	Not applicable (ionizable inorganic compound)

Observed effects are related to alkaline properties of the product. Product is not significantly hazardous for the environment.

13. Disposal Considerations

Disposal	When this product is discarded or disposed of, as purchased, it is neither a

Method:	characteristic nor a listed hazardous waste according to US Federal RCRA regulations (40 CFR 261). As a non-hazardous waste the material may be disposed of in a landfill in accordance with government regulations; check local or state regulations for applicable requirements prior to disposal. Any processing, usage, alteration, chemical additions to, or contamination of, the product may alter the disposal requirements. Under Federal regulations, it is the generator's responsibility to determine if a waste is a hazardous waste.

14. Transportation Information

Proper Shipping Name:	Not regulated
Primary Hazard Class / Division:	Not regulated
UN / NA Number:	Not applicable
Label(s), Placard(s), Marking(s):	Not applicable
Reportable Quantity (RQ)	None
49 STCC Number:	Not Applicable
ADR (EU), TDG (Canada)	Not regulated
IMDG (sea) , ICAO (air), IATA (air)	Not regulated

15. Regulatory Information

UNITED STATES:

SARA Title III (Superfund Amendments and Reauthorization Act)

Section 302 Extremely Hazardous Substances: 40CFR355, Appendix A	Not listed
Section 311 Hazard Class 40CFR370	Immediate (acute)
Section 312 Threshold Planning Quantity (TPQ) 40CFR370	No TPQ listed for sodium carbonate.
Section 313 Reportable Ingredients 40CFR372	Not listed

CERCLA (Comprehensive Environmental Response Compensation and Liability Act):
40CFR302.4 –

There is no listed RQ (reportable quantity) for this product.

TSCA (Toxic Substance Control Act)

This product is listed on the TSCA Inventory of Chemical Substances. No other TSCA rules affect this product

State Regulations:

This product does not contain any components that are regulated under California Proposition 65.

Other:

Clean Water Act (CWA) – Section 301/ 311: Not listed
Clean Air Act (CAA) – Section 112: Not regulated

CANADA:

WHMIS Classification:	D2B Toxic Class E Corrosive Symbol: This product has been classified in accordance with hazard criteria of the Controlled Products Regulations and the MSDS contains all the information required by the Controlled Products Regulations.
WHMIS Ingredient Disclosure List	Listed
DSL Status (Domestic substances list)	Listed on DSL

EUROPEAN UNION:

EINECS Inventory	Listed: 207-838-8
Annex I (Substances Directive)	Listed: 011-005-00-2 Xi, R-36 (See label details in Section 16)
Greman Water Classificatin	hazard class 1, low hazard to waters
EU - Food Additives Directive (95/2/EC) - Annex I - Generally Permitted for Use in Foodstuff	E500

INTERNATIONAL:

This product is also found on the chemical inventories of Australia, China, Korea, Japan and the Philippines.

16. Other Information

HMIS (Hazardous Material Identification System)

Health	2
Flammability	0
Physical Hazard	0
Personal Protection (PPE)	B

Protection = B (Safety glasses and gloves)
4 = Severe, 3 = Serious, 2 = Moderate, 1 = Slight, 0 = Minimal

NFPA (National Fire Protection Association System)

Health	2
Flammability	0
Reactivity	0
Special	None

4 = Extreme, 3 = High, 2 = Moderate, 1 = Slight, 0 = Insignificant

Other Information: Soda ash is produced in three principal grades: Dense, natural light and synthetic light soda ash. When these products are mixed in water they may be known as liquid soda ash. These grades differ only in physical characteristics such as bulk density and size and shape of particles, which influence flow characteristics and angle of repose. Other physical properties, as well as chemical as chemical properties of solutions, are common to each grade of soda ash.

Certified to ANSI / NSF 60

Concentration not to exceed 100 ppm when used for corrosion control or scale control pH adjustment.

The information given corresponds to the current state of our knowledge and experience of the product, and is not exhaustive. This applies to product, which conforms to the specification, unless otherwise stated. In this case of combinations and mixtures one must make sure that no new dangers can arise. In any case, the user is not exempt from observing all legal, administrative and regulatory procedures relating to the product, personal hygiene, and protection of human welfare and the environment.
This Material Safety Data Sheet is offered for your information, consideration and investigation as required by Federal Hazardous Products Act and related legislation. The information is believed to be accurate but General Chemical Industrial Products provides no warranties, either expressed or implied.

Appendixes C

Appendixes D

PVC Pipes, PVC Pipe Fittings

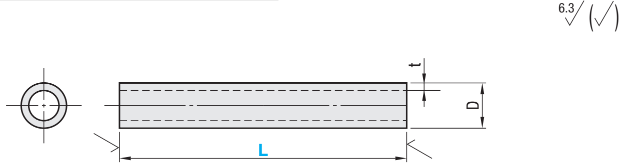
TS Fittings, HI Fittings

For dimension of the junction on fittings, see Dimension Table in Overview on **P.1200** For specifications, application of each material, see Overview in **P.1200**

PVC Pipe

RoHS

Type	Material	Standards	Color
PVCT	PVC	JIS K 6742	Gray
PVCH	Impact Resistance PVC		Blue Gray



Note that pipe O.D. may have some scratches or small flaws on its surface.

Part Number		L	O.D.		Thickness		I.D.	Unit Price						
								PVCT						
Type	No.	1mm Increment	D	D Tolerance	t	t Tolerance	(Reference Value)	L50~200	201~400	401~600	601~800	801~1000	1001~1250	1251~1500
PVCT PVCH	13	50~1500	18	±0.2	2.5	±0.2	13							
	16		22	±0.2	3	±0.3	16							
	20		26	±0.2	3	±0.3	20							
	25		32	±0.2	3.5	±0.3	25							
	30		38	±0.3	3.5	±0.3	31							

The tolerance of L dimension will be +1~3 for 50~1000, +2~5 for 1001~1500.

Ordering Example	Part Number	-	L
	PVCT20	-	1000

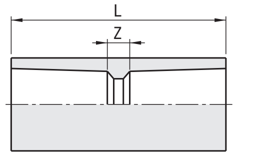
Price Configure Online

Days to Ship Configure Online

Couplings

RoHS

Type	Types	Material
PVCTS	TS Fittings	PVC
PVCHS	HI Fittings	Impact Resistance PVC

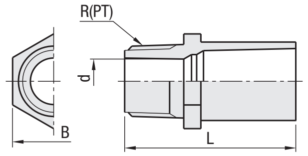


Part Number		Z	L	Standards	Small Order Charge	Unit Price	
						PVCTS	PVCHS
Type	No.				1~19 pc(s).	20~49 pcs.	20~49 pcs.
PVCTS PVCHS	13	5	57	JIS K 6743			
	16	7	67				
	20	7	77				
	25	7	87				
	30	7	95				

Adapters

RoHS

Type	Types	Material
PVCTSB	TS Fittings	PVC
PVCHSB	HI Fittings	Impact Resistance PVC

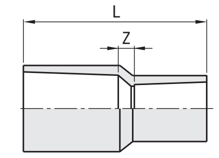


Part Number		R (PT)	d	B	L	Standards	Small Order Charge	Unit Price	
								PVCTSB	PVCHSB
Type	No.						1~19 pc(s).	20~49 pcs.	20~49 pcs.
PVCTSB PVCHSB	13	1/2	13	24	50	JIS K 6743			
	16	1/2	13	29	57				
	20	3/4	18	33	64				
	25	1	23	40	71				
	30	1 1/4	31	46	80				

Reducing Couplings

RoHS

Type	Types	Material
PVCTSD	TS Fittings	PVC
PVCHSD	HI Fittings	Impact Resistance PVC

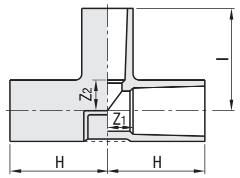


Part Number		Z	L	Standards	Small Order Charge	Unit Price	
						PVCTSD	PVCHSD
Type	No.				1~19 pc(s).	20~49 pcs.	20~49 pcs.
PVCTSD PVCHSD	1613	5	61	JIS K 6743			
	2016	6	71				
	2516	15	85				
	2520	9	84				
	3025	9	93				

Tees

RoHS

Type	Types	Material
PVCTT	TS Fittings	PVC
PVCHT	HI Fittings	Impact Resistance PVC

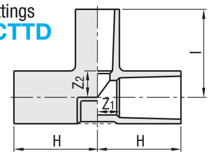


Part Number		Z1	Z2	H	I	Standards	Small Order Charge	Unit Price	
								PVCTT	PVCHT
Type	No.						1~19 pc(s).	20~49 pcs.	20~49 pcs.
PVCTT PVCHT	13	10	10	36	36	JIS K 6743			
	16	13	13	43	43				
	20	15	15	50	50				
	25	18	18	58	58				
	30	21	21	65	65				

Reducing Tees

RoHS

TS Fittings
PVCTTD



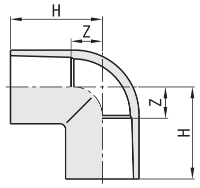
Material: PVC

Part Number		Z1	Z2	H	I	Standards	Small Order Charge	Unit Price
Type	No.						1~19 pc(s).	20~49 pcs.
PVCTTD	1613	11	12	41	38	JIS K 6743		
	2016	13	15	48	45			
	2516	13	18	53	48			
	2520	15	18	55	53			
	3025	18	21	62	61			

90° Elbows

RoHS

Type	Types	Material
PVCTE	TS Fittings	PVC
PVCHE	HI Fittings	Impact Resistance PVC

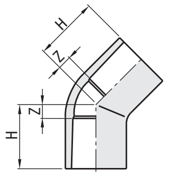


Part Number		Z	H	Standards	Small Order Charge	Unit Price	
						PVCTE	PVCHE
Type	No.				1~19 pc(s).	20~49 pcs.	20~49 pcs.
PVCTE PVCHE	13	10	36	JIS K 6743			
	16	13	43				
	20	15	50				
	25	18	58				
	30	21	65				

45° Elbows

RoHS

HI Fittings
PVCHHE



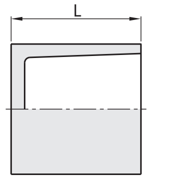
Material: Impact Resistance PVC

Part Number		Z	H	Standards	Small Order Charge	Unit Price
Type	No.				1~19 pc(s).	20~49 pcs.
PVCHHE	13	7	33	JIS K 6743		
	20	9	44			
	25	11	51			

Caps

RoHS

Type	Types	Material
PVCTC	TS Fittings	PVC
PVCHC	HI Fittings	Impact Resistance PVC

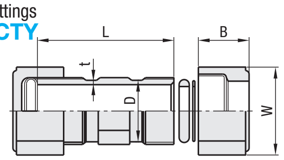


Part Number		L	Standards	Small Order Charge	Unit Price	
					PVCTC	PVCHC
Type	No.			1~19 pc(s).	20~49 pcs.	20~49 pcs.
PVCTC PVCHC	13	29	JIS K 6743			
	16	33.5				
	20	38.5				
	25	44				
	30	48				

Elastic Couplings

RoHS

TS Fittings
PVCTY



Material: PVC

Part Number		D	t	L	B	W	Standards	Unit Price
Type	No.							1~9 pc(s).
PVCTY	13	26	3	68	25	38	JIS K 6743	
	16	34	5.5	110	29	42	-	
	20	35	3.5	78	29	50	JIS K 6743	
	25	43	4	89	29	56		
	30	48	4	98	33.5	63		

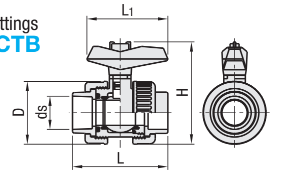
For PVCTY16, the nut is round-shaped.

Fittings for absorbing expasion / contraction of PVC Pipe due to heat

Valves

RoHS

TS Fittings
PVCTB



Material: PVC

Part Number		D	ds	H	L	L1	Standards	Unit Price	Volume Discount Rate
Type	No.							1~9 pc(s).	10~29 pcs.
PVCTB	16	50	22	78	109	77	JIS K 6743		
	20	59	26	89.5	125	97			
	25	68	32	101	142	97			
	30	80	38	119	158	129			

Adhesives

RoHS

PVCTBN
(For PVC)

PVCHBN
(For Impact Resistance PVC)

Part Number		Weight by Volume (g)	Unit Price
Type	No.		1~19 pc(s).
PVCTBN	100	100	
	500	500	

Part Number		Weight by Volume (g)	Unit Price
Type	No.		1~19 pc(s).
PVCHBN	100	100	
	500	500	

Ordering Example	Part Number
	PVCHSB20 PVCHBN100

Days to Ship Configure Online

Price Configure Online