Introduction

1.0 Petroleum Refining

1.1. What is refining?

A **refinery** is a production facility composed of a group of chemical engineering unit processes and unit operations refining certain materials or converting raw material into products of value.

1.2 Treatment in petroleum refining:

1.2.1 Acids, caustic treatment:

Sulfuric acid treatment results in partial or complete removal of unsaturated hydrocarbon sulfur, nitrogen and oxygen compounds, and resinous and asphaltic compounds. Caustic treatment with sodium (or potassium) hydroxide is used to improve odor and color by removing organic acid (naphthenic acids, phenols) and sulfur compounds (mercaptans, H_2S) by a caustic wash[26].

1.2.2 During and Sweetening:

Refinery units are sent to gas treatment plants where butane and butanes are removed for use as alkylation feed stock, heavier components are sent to gasoline blending propane recovered for LPG, and propylene is removed for use in petrochemicals[18].

1.3 Separation Processes:

1.3.1 Fractional distillation:

It is the separation of a mixture into its component parts, or fracti

separating chemical compounds by their boiling point by heating t temperature at which several fractions of the compound will evaporate. It is a special type of distillation.

Because crude oil is a mixture of hydrocarbons with different boiling temperatures, it can be separated by distillation into groups of hydrocarbons that boil between two specified boiling points[12].

1.4 How oil refining works?

The steps of fractional distillation are as follows:

1. You heat the mixture of two or more substances (liquids) is heated to different boiling points to a high temperature (600° C).

2. The mixture boils, forming vapor (gases) go into the vapor phase.

3. The vapor enters the bottom of a long column (Fractional Distillation Column) that is filled with trays or plates:

a. The trays have many holes or bubble caps to allow the vapor to pass through.

b. the trays increase the contact time between the vapor and liquid phases in the column.

c. The trays help to collect liquids.

d. There is a temperature difference a cross the column (hot at bottom, cool at top) and the vapor rises in the column and it cools. Where the substance in the vapor reaches a height where the temperature of the column is equal to that substances boiling point, it will condense to form liquid[33].

e. The trays collect the various liquid fractions and the collected liquid fractions may-

i. Pass to condenser, which cool them further and then go to storage tanks.

ii. Go to other area for further chemicals processing fractional distillation

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column[34].

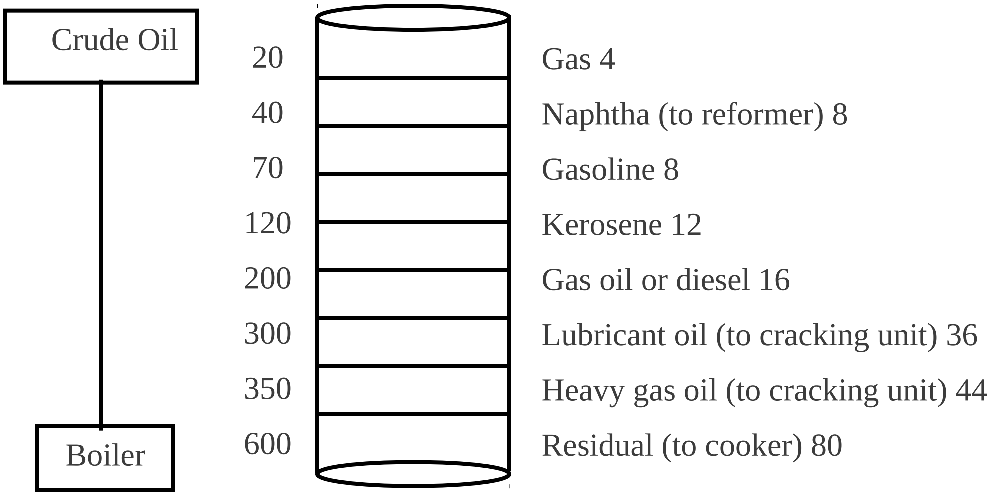

Fig (1.1): Crude oil refining[15]

1.5 Form crude oil:

Different hydrocarbon chain length have progressive higher boiling points, so they can all de separated by distillation. This happens in an oil refinery in one part of process. Crude oil is heated and different chains are separated by their vaporization temperatures[23]. Each different chain length has different property that makes it useful in a different way.

List of products that come from crude oil:

a. Petroleum gas:

b. Naphtha or Ligroin

c. Gasoline:

d.. kerosene:

e. Lubricating oil

1.6 Vacuum distillation:

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It is a method of distillation whereby the pressure above the liquid mixture to be distilled is reduced to less than its vapor pressure (usually less than atmospheric pressure) causing evaporation of the most volatile liquid(s) (those with the lowest boiling points).[1] This distillation method works on the principle that boiling occurs when the vapor pressure of a liquid exceeds the ambient pressure
The primary advantage of vacuum distillation is that is allows for distillation heavier materials at lower temperature than those that would required at atmospheric pressure, thus avoiding thermal cracking of the components[5].

1.7solvent extraction:

This process is to separate aromatic compounds in its simplest form, the process consist of mixing furfural with the feed stock and allowing the mixture to settle into two phases; the extract and the refinate. The two layers are separated, and the solvent is removed from each phase[11].

1.8 Chemical Processing

1.8.1. Thermal cracking (steam cracking):

In an effort to increase the yield from distillation, the thermal cracking process was developed. In this process, the heavier products of the crude oil were heated under pressure and at higher temperatures. This resulted in the large hydrocarbon molecules being split into smaller ones[17]. The reaction temperature is very high around 850° C. Steam is used to break ethane, butane and naphtha into ethylene, and benzene. Gas oil can be used as diesel fuel and heavy residue is converted into residual oil or coke.

1.8.2. Hydro cracking:

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[1]

Is a catalytic cracking in the presence of hydrogen similar to fluid catalytic cracking, but uses a different catalyst, lower temperatures, high pressure, and cracks it into gasoline and kerosene (jet fuel)[6].

1.8.3. Unification:

Sometimes we need to combine smaller hydrocarbons to make large ones. The major unification process is called catalytic reforming and uses a catalyst (platinum) to combine low weight naphtha into aromatics, which are used in making chemicals and in blending gasoline[34].

Objectives

The main objectives of the study are:

1. To assesse the chemical and physical properties of the lubricant oil in Sudanese market and compare it with global accepted oils standards

2 – To study the effects that occur in the oil of operation, oxidation and external influences.

3 – To check the validity and the lifeline of the oil.

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Chapter Two

Literature review

2.1 Basic Principles of Lubrication

2.1.1 Meaning of Lubrication:

Lubrication is simply the use of a material to improve the smoothness of movement of one surface over another, and the material that is used in this way is called a lubricant. Lubricants are usually liquids or semi-liquids, but may be solids, gases, or any combination of solids, liquids and gases. Lubricant oils can be defined as substance introduced between two surfaces in relative motion in order to reduce the frication between them. Lubricants are usually expected to reduce wear and often to prevent overheating and corrosion.

In most cases dry friction between two covered by two laws which are usually called **"Amonton's Laws**". **The first** of these laws that the friction between two solids is independent of the area of contact.

The second law is that the friction is proportional to the load exported by one surface on the another. In the 1850 s, small quantities of petroleum oil began to be produced in the U.S.A., Canada, Russia and Romania. The modern petroleum industry was born in 1880. Liquid petroleum has to be distilled and fractionated into a range of products in order to be fully exploited and the heavier of these confined to uses as lubricating oils. It was soon discovered that under reduced pressure, so called vacuum distillation, fractions could be separated with out the heavier product being oxidized and deteriorated, and the fractions are reduced as the pressure is lowered, and lower temperature is sufficient to separate the mixture[5].

2.1.2 Lubricants main functions:

The main functions of lubricating oils and lubricant are: Reducing the friction by putting lubricating oils between moving metal surfaces decrease friction. These results in energy conservation and significantly less wear.

2.1.2.1Reducing wear:

Lubricating oils reduce mechanical wear (caused by abrasion and erosion) and chemical wear (corrosion caused by combustion acids and water). Wear is influenced by various factors, which can be divided into the field of tool, rough part, forming machine and lubricant actual contact area. Possible ways to reduce wear lie in the increase of annealing durability as well as in the hardness of the surface, for example through retrying, and application of mostly wear resistant layers on the tool surface. Also massive wear reduction can't be achieved by lowering the tool temperature.

2.1.2.2 Cooling purposes:

Lubricating oil cools the mechanical components by remove heat and decreasing the amount of heat produced (by reduction of friction).

These also improve the engine performance and elongate the engine cycle life by keeping the engine operation conditions optimum ensuring leak tightness.

Lubricants ensure leak tightness between the mechanical component such as the cylinder and the piston, improving compression and producing better engine performance.

2.1.2.3 Removing impurities:

Lubricants keep engine components clean by preventing the formation of deposits and suspended impurities (dust, combustion residue and engine wear particles) that then build up on the oil filter.

2.2 Factors influencing lubricants functions:

a. Detergency – Dispersancy.
b. Corrosion prevention.
c. Rust protection.
d. Stability thermal and oxidative heat transfer.
e. Specific heat.
f. Thermal conductivity.
g. Stability – thermal and oxidative.

2.3 Reduction of frictional effects:

a. Coefficient of friction.
b. Oiliness or anti-wear.
c. Anti-weld, anti-seize.
d. Viscosity / temperature index. (Stability / thermal and oxidative)
e. Pressure / viscosity effect.

Common malfunction due to lubricant quality:

Most problems associated with engine lubricants are related to lubricant decomposition and the entry of combustion by products into the crank case. The major causes of engine malfunction due to lubricant quality are deposit formation, contamination, oil thickening, oil consumption, ring sticking, corrosion and wear.

Some of these causes are discussed below:

1. Deposit formation:

The two main sources of lubricant contamination are blow-by from the combustion chamber, gases and volatiles from the crank case that are vented into the intake manifold as an anti-pollution measure.

The various gases interact with one another and the lubricant to form soot, carbon lacquer, varnish and sludge.

2. Soot:

Particles are hydrocarbon fragments partially stripped of hydrogen atoms. They also contain an appreciable amount of oxygen and sulfur. Soot particles are strongly attracted to one another and to polar compounds in the oil. Soot tends to form aggregates, which have soft and flaky texture, and is commonly found in the combustion chamber.

3. Carbon deposits:

They are hard and result from the carbonized ion of liquid lubricating oil and on hot surfaces. These deposits have lower carbon content that soot and usually oily material and ash. They are commonly found on the piston top lands and crowns, in piston ring grooves, and on valve stems.

4. Lacquer and varnish:

Form when oxygenated products in the lubricant are exposed to high temperatures. Lacquer is often derived from lubricant and is generally water-soluble. It is commonly found on pistons and cylinder walls and in the combustion chamber. Varnish, on the other hand, is full related and is acetone soluble. It's commonly found on value lifters, piston rings and positive crank case ventilation valves.

5. Sludge:

It's caused by lubricant oxidation, oxidation and combustion products in the blow-by gas, and the accumulation of combustion water and dirt. It can vary in consistency from that of mayonnaise to a baked deposit. Low temperature sludge, most prevalent in gasoline engines, is watery in appearance and formed below 95° C. High temperature sludge is more common in diesel engines and forms above 120° C.

6. Oil thickening:

Oil thickening can result from lubricant oxidation, the accumulation of in soluble and soot. Viscosity increase due to:

- Polymerization of oxygenated products.
- Suspension of fuel derivatives insoluble in the bulk lubricant.

7. Oil consumption:

Oil consumption is related mainly to the lubricant that travels past piston rings and valves, and burns in the combustion chamber. The extent of lubricant consumption depends on a number of equipment and lubricant related factors, including viscosity, volatility and seal-swell characteristics. A certain minimum amount of oil is required to properly lubricate the cylinder walls and pistons. High oil consumption, however, indicates a problem such as cylinder wear, bore polishing, stuck piston rings out of square grooves.

These conditions increase the amount of blow-by gases entering the crank case. Lubricant volatility is another important factor responsible for oil consumption. Lighter base oils can leak past piston rings more readily and be burned.

8. Ring sticking:

The major cause of ring sticking is the formation of deposits in the piston grooves, resulting in the loss of an oil seal. This not only increases the potential for blow-by gases in the crank case but also leads to poor heat transfer from the pistons and can lead to loss of compression and engine seizure.

9. Corrosion and wear:

Diesel fuel with high sulfur content causes piston ring and cylinder wear. Corrosive wear is more commonly cased by combustion and oxidation products; it results from the attack of sulfur acids or organic acids on iron surfaces. This kind of wear is controlled by using lubricants with a base reserve.

2.5 Classification of lubricants:

Classification of Lubricants is usually divided into three basic classes, which are:

1. General classification of lubricants.
2. Classification of lubricants by application.
3. Classification of lubricants by additives.

2.5.1 General classification of lubricants:

Mineral lubricants:

These lubricants are used to a large extent in the lubrication of aircraft combustion engines. There are three classifications of mineral lubricants:

1. Liquid lubricants.
2. Semi solid lubricants.
3. Solid lubricants.

2.5.1.1 Liquid lubricants:

Liquid lubricants may be characterized in many different ways. One of the most common ways is by the type of base oil used. Following is the most common types:

a. Lanolin (wool grease, natural water repellant).
b. Water.
c. Mineral oils.
d. Vegetable (natural oils).
e. Synthetic oils.

Animal lubricants:

Lubricants with animal origin:

- Tallow. Tallow oil.

- Lard oil.
- Meat's foot oil.
- Sperm oil.
- Porpoise oil.

* These are highly stable at normal temperature.

Animal lubricants may not be used for internal combustion because they produce fatty acids. There are two animal fats; stern and soft fats (lard). Animal fats are mainly used for manufacturing greases.

Lanolin a natural water repellent, lanolin is derived from sheep wool grease, and is an alternative to the more common petro-chemical bases lubricants. These lubricants are also corrosion inhibitors, protecting against rust, salt and acids.

Water:

Water can be used on its own or as a major component in combination with one of the other base oils. Commonly used in engineering processes, such as milling and lathe turning.

Fluid lubricants (oils):

Mineral fluid lubricants are based on mineral (petroleum oils) are products of refining crude oil.

Types of lubricant base oil indentified as group:

1. Saturates < 90%.
2. Sulfur > 0.03%.
3. Society of Automotive Engineers (SAE).

Viscosity index (VI) = > 80 to < 120.

Manufactured by solvent extraction, solvent or catalytic de-waxing, and hydro finishing processes.

Common group "I" base oil are 150 SN (solvent neutral), 500 SN and 150 BS (bright stock).

Group "II":

Saturated > 90%.

Sulfur < 0.03%.

SAE viscosity index > 80 to > 120.

Manufactured by hydro cracking and solvent or catalytic de-waxing processes. Group "II" base oil has superior anti-oxidation properties since virtually all hydrocarbon molecules are saturated. It has water – white color.

Group "III":

Saturated > 90%.

Sulfur < 0.03%.

SAE viscosity index > 120.

Manufactured by special processes; such as iso-hydromerization. Can be manufactured from base oil or slax wax from de-waxing process.

Group "IV":

Poly alpha olefins (PAO).

Group "V":

All others not included above; such as naphthenic, PAG and esters. In North America group "III", "IV" and "V" are now described as synthetic lubricants, with group "III" frequently described as synthesized hydrocarbons. In Europe, only groups "IV" and "V" may be classified as synthetic. The lubricant industry commonly extends this[38] group terminology to include:

Group "I": with viscosity index of 103-108.

Group "III": with viscosity index of > 104.

Group "II": with viscosity index of 113-119.

Mineral fluids lubricants are based on mineral oils (petroleum oils) are products of refining crude oil.

Group (i) solvent freezing:

Group I base oils are the least refined of all the groups they are usually a mix of different hydrocarbon chains with little or no uniformity. While some automotive oils on the market use group/stocks, they are generally used in less demanding applications.

Group (ii) hydro processing and refining:

Group ii base oils are common in mineral-based motor oils currently available on the market. They have fair to good performance in lubricating properties such as volatility, oxidative, stability and flash / faire points. They have only fair performance in areas such as pour point, cold crank viscosity and extreme pressure wear.

Group (iii) hydro processing and refining:

Group (iii) base oils are subjected to the highest level of mineral oil refining of the base oil groups. Although they are not chemically engineered, they offer good molecular uniformity and stability. They are commonly mixed with additives and marketed as synthetic or semi synthetic products. Croup III base oils have become more common in American in the last decade.

Group (iv) chemical reactions:

Group iv base oils are chemically engineered synthetic base stocks poly alpha olefins (PAO's) are a common example of a synthetic base stock. Synthetics. When combined with additives, offer excellent performance over a wide range of lubricating properties. They have very stable chemical compositions and uniform molecular chains. Group iv base oils are becoming more common in synthetics and synthetic-blend products for automotive and industrial applications[36].

2.5.1.2 Semi Solid lubricant:

Semi-solid lubricants: By adding animal and vegetable fats to soap and water, it is possible to create grease lubricants. If you use large quantities of these greases as lubricants for surfaces such as railway wagon axles, you'll find them excellent. If the fats and greases you use have melting points that are close to the temperature of the objects around them, the lubricating films get so heated by the two surfaces rubbing against each other (or causing friction) that they melt and turn into oils or semi-solid lubricants. In this state, these semi-solid lubricants are put into bearings by a kind of industrial syringe with a spring piston[32].

2.5.1.3 Dry lubricant:

Solid lubricants are materials, which despite being in the solid phase, are able to reduce friction between two surfaces sliding against each other without the need for a liquid media. Such lubricants, including materials such as graphite, hexagonal boron nitride, molybdenum disulfide and tungsten disulfide are also able to offer lubrication at temperatures higher than liquid and oil-based lubricants are able to operate. Such materials can operate up to 350°C in oxidizing environments and even higher in reducing / non-oxidizing environments (molybdenum disulfide up to 1100°C). Their lubricating properties are attributed to a layered structure on the molecular level with weak bonding between layers. Such layers are able to slide relative to each other with minimal applied force, thus giving them their low friction properties. Limited interest has been shown in low friction properties of compacted oxide glaze layers formed at several hundred degrees Celsius in metallic sliding systems, however, practical use is still many years away due to their physically unstable nature.

The three most commonly used solid lubricants are:

- Graphite - Used in air compressors, foodstuff industry, railway track joints, open gear, ball bearings, machine shop works etc. It is also very common for lubricating locks, since a liquid lubricant allows particles to get stuck in the lock worsening the problem.
- Molybdenum disulfide - Used in space vehicles.
- Hexagonal boron nitride - Used in space vehicles. Also called "white graphite". [32.]

Poly tetra Fluor ethylene (PTFE)

Teflon or **Poly tetra Fluor ethylene** is typically used as coating layer on for example, cooking utensils to provide anon-stick surface.

Poly tetra Fluor ethylene (PTFE) and Boron nitride are other solid lubricants, which are used as additives to oils and greases.

Solid lubricants are also used in form of dry powder or as constituents of coatings.

Silicones:

Silicones are a group of inorganic polymers, molecules which represents a backbone structure built from repeated chemical units (monomers) containing Si=O moieties. Two organic groups are attached to each Si=O moiety = e.g. methyl + methyl L ($(CH_3)_2$), methyl + phenyl ($CH_3 + C_6H_5$), phenyl + phenyl($(C_6H_5)_2$).

The most popular silicon is poly diethylsiloxane (PDMS.). Its monomer is $(CH_3)_2SiO$. PDMS is produced from silicon and methyl L chloride; other examples of silicones are poly methyl phenyl siloxane and poly dipheny siloxane.

Viscosity of silicones depends on the length of the polymer molecules and on the degree of their cross-linking. Short non- cross-linked molecules make fluid silicone. Long cross-linked molecules result in elastomer silicone.

Silicone lubricants (oils and greases) are characterized by broad temperature range: -100°F to 400°F (73°C to 204°C)[3].

2.5.2 Classification of lubricants by application:

- Engine oils.
- Gear oils.
- Hydraulic oils.
- Cutting fluids (coolants).
- Compressor oils.
- Quenching and heat transfer oils.
- Rust protection oils.
- Transformer oils (insulating oils).
- Turbine oils.
- Chain lubricants.
- Wire rope lubricants.

2.5.3 Classification of lubricants by additives

- Extreme pressure (EP).
- Anti-wear (AW).
- Friction modifiers.
- Corrosion inhibitors.
- Anti-oxidants.
- Dispersants.
- Detergents.
- Anti-Foaming agents.

- Pour Point depressant.
- Metal deactivators.
- Viscosity index modifiers.
- Improvers.
- Demulsifying/ Emulsifying[32].

2.6 Types of oil:

Oils are generally classified as refined and synthetic. Paraffinic and naphthenic oils are manufactured.

2.6.1 Paraffinic oils:

Paraffinic oils are distinguished by a molecular structure composed of long chains of hydrocarbons. Paraffinic oils are produced by either hydrocraking or solvent extraction process. Most hydrocarbon molecules of paraffinic oils have non-ring long chained structure.

Paraffinic wax are the most widely used base stock for lubricating oils. Paraffinic oils are used for manufacturing engine oils industrial lubricants and processing oils in rubber, textile, and paper industries. In comparison with naphthenic oils, paraffinic oils have:

1. Excellent stability (higher resistance to oxidation).
2. Higher pour point.
3. Higher viscosity index.
4. Low volatility and, consequently, High Flash points.
5. Low specific gravities.

2.6.2 Naphthenic oils:

Naphthenic oils are produce from crude oil distillates. In contrast to paraffinic oils, naphthenic oils are distinguished by a molecular structure composed of (rings) of hydrocarbons.

Hydrogen and carbon atoms are linked in a circular pattern. These oils do not contain wax and behave differently than paraffinic oils.

Most hydrocarbon molecules of naphthenic oils process low viscosity, low Flash Points, low pour points and resistance to oxidation.

Naphthenic oils are used temperature in moderate applications, mainly for manufacturing transformer oils and metal working fluids.

Naphthenic oils have:

- Good stability.
- Lower pour point due to absence .of wax.
- Lower viscosity index.
- Higher volatility (lower Flash Point).
- Higher specific gravities.

2.6.3 Aromatic oils:

Aromatic oils are products of refining process in manufacture of paraffinic oils. Most hydrocarbon molecules of Aromatic oils have non- saturated ring structure. Aromatic oils are dark and have high Flash Point. Aromatic oils are used for manufacturing saturated compounds, adhesives and plasticizers in rubber and asphalt production.

2.7 Types of lubricant oil stocks:

Mineral base oils are of two types the conventional base oils which have viscosity indices of 95 or less and non-conventional base oil with viscosity indices above 100[30]. The conventional solvent refining processes and sever hydrogen nonconventional base oils are usually manufactured using refining process or from the isomerization of wax, high wax content feed stocks or from lubricant fractions

Table (2.1): The properties of selected crude oils:

Component	n paraffin	Iso paraffin	naphthinile	Aromatic
Viscosity index	**High**	**high**	**medium**	**Low**
Pour Point	**High**	**low**	**Low**	**Low**
Oxidative stability	**Good**	**good**	**fair**	**Poor**
Thermal stability	**Good**	**good**	**fair**	**Poor**

Table (2.2): Viscosity index of hydrocarbon:

Hydrocarbon type	Viscosity index
Normal paraffin	**175**
ISO-paraffin	**155**
Mono naphthenes	**142**
Dinaphthenes	**70**
Aromatics	**50**

2.7.1 Conventional base oils:

Conventional base oils consist of two types, those that are highly paraffinic and those that are highly naphthenic as defined by their naturally occurring viscosity index and pour point. Mineral base oils used in the manufacture of lubricant include:

Solvent natural oils (SNO), naphthene pale oils (NPO), bright stocks (BS), cylinder oils (CO) and specialty oils.

2.7.2 Neutral or solvent neutral oils (SNO):

Solvent neutral oils (SNOs) are vacuum distilled paraffinic base oils that are refined for VI, appreciation and aromatics removal, they are de-waxed for Pour Point reduction, and hydrogenated for stability. These base oils are characterized by high API gravity, Flash Point, aniline Point and VI[21].

2.7.3 Bright stocks and cylinder oils:

Bright stocks and cylinder oils are residual base oils manufactured from paraffinic and naphthenic vacuum residual. Bright stocks are made using propane deasphalting with solvent de-waxing .

2.7.4 Naphthene pale oils (NPOs):

Naphthene pale oils are vacuum distilled naphthenic base oils that are refined for aromatics removal, and dew axing is generally required.

2.8 Synthetic base stocks:

Synthetic lubricants have been used for many years in the early 1930, synthetic hydrocarbon and ester technologies were being simultaneously developed, the development of synthetic processes enable molecules to be built from simpler substance to give the precise properties required.

Another source of lubricant base fluids is the synthetic route,a suitable definition for such a material is "a product prepared by chemical reaction of lower molecular weight materials to produce a fluid of higher molecular weight, a designed to provide certain predictable properties". This is contrast to refined petroleum oils, which are composed, depending on the refining method and the crude stock source. Among the advantages claimed for synthetic lubricants over comparable petroleum-based fluids are improved thermal and oxidative stability, more desirable viscosity characteristics, improved low-temperature properties, superior volatility characteristics and preferred frictional properties. Commercial synthetic fluids are not confined to a single chemical type[2].

Table (2.3) The main classes of synthetic materials.

No.	Type	Principal application
1	**Olefin oligomers(PAOs)**	**Automotive and industrial**
2	**Dibasic acid esters**	**Air craft and automotive**
3	**Polyesters(neopentyl**	**Air craft and automotive**

	polyolestwers)	
4	**Alkylated aromatics**	**Automotive and industrial**
5	**Poly alkylene glycol**	**Automotive and industrial**
6	**Phosphate esters**	**Automotive and industrial**

Table 24 lists some inspection characteristics of synthetic fluids together with the applicable temperature range.

Table (2.4): Physical inspection characteristics of typical synthetic fluids:

Fluid	Dynamic viscosity(CD)@40F	Kinematic viscosity(CSt)40/100c		VI	PP	F.P	T.RANGE
Olefinoligomer	2371	18.12	3.96	12.6	-79	221	-65-232
Olefinoligomers	8176	34.07	6.00	1.34	-68	243	-65-232
Esterdibasicacid.dioctyl sebactote	3750	119.58	-	76	-51	232	-54-204
Ester of trimethyolo propane	2360	15.00	3.5	-	-51	232	-59-280
Alkylated aromatics	9047	29.37	5.1	119	-54	224	-40-177

Other fluids uses in very specialized applications. These include poly glycols, phosphate esters, silicones, silicones, silicate esters, and poly phenyl ethers. Synthetic materials in general, can be used over a wider temperature range than petroleum base fluids in the same viscosity range-certain synthetic lubricant base stocks can be blended with petroleum oils to obtain necessary high temperature volatility and low-temperature viscosity characteristics when the proper petroleum base oils are unavailable.

With the exception of poly glycol fluids, oil have viscosities in the range of the lighter HVI minerals. Their viscosity indexes and Flash Points are considerably Lowes. This makes them valuable blending component when compounding oils for extreme service at both high and low temperatures.

The main disadvantage of synthetics is that they are inherently more expensive than mineral oils and are in limited supply. This limits their use to specially oils and greases that command premium prices. Esters suffer the further disadvantages of greater seal-swelling tendencies than hydrocarbons; so caution must be exercised in using them in applications where they may contact ela stomers designed for use with mineral oils. Many components have been investigated as possible base stocks for synthetics lubricants.

Types of synthetic lubricants:

Polyalphaolefins.

- Polyol esters.
- Poly alkylene glycol.
- Poly butenes.
- Aliphatic diester.
- alkylated aromatics.
- Phosphate esters.

Other materials such as silicones, borate, esters, perfluoro ethers and Poly Phenylene ester are also of importance, but their applications are restricted due either to high cost or to performance limitations[3].

2.8.1. Polyalpholefins:-

The most widely used synthetic lubricants in the U.S and Europe. They are made by combining towor more pecene molecules into an oligomer, or short-chain-length-polymer Decene structure C_8H_2O.

The PAOs are All-hydrocarbon structure, and they contain no sulfur, phosphorus or metals.

Because they are wax-free they have low pour points usually below – 40 °C. viscosity grades range from 2 to 100 cst, and viscosity indexes for all but lowest grades exceed 140. They have good thermal stability, but they require suitable anti-oxidant additives to resist oxidation. The fluids have limited ability to dissolve some additives and tend to shrink seals. Both problems can be over comed by adding a small amount of ester.

Properties and applications:-

The complexity of the oligomerisation mechanism of dec-1-ene leads to one of important properties of PAOs as lubricant base fluids. The higher than expected degree of branching in the final product gives very good low-temperature properties, especially as the products are wax-free.

In addition, the molecular weights are therefore predictable. Thus, the volatilities of PAOs are lower than those of equiviscous mineral-derived products whether solvent refined, hydro cracked or hydro-isomerised. Overall, PAOs are able to operate effectively over a very wide temperature range[3].

Table (T-2.5): compares characteristics for -refined base fluids:

Characteristics	SN150	Hydro-isomerised	PAOs
Viscosity @100CSt	5043	5.64	5.98
Pour point c	-12	-15	-64
NOACK (loss %)	15	7.8	6.1

2.8.2. Dibasic acid ester:

They are synthesized by reacting an acid and an alcohol. Di-ester have more varied structures than PAOs, but like POAs; they contain no sulfur, phosphors metal or wax. Pour points range from -50 to -65 °C.

Advantages of di-esters include good thermal stability and excellent solvency. They are clean-running in that they tend to dissolve varnish and sludge rather than leave deposits. In fact, di-esters can remove deposits formed by other lubricants.

Proper additive selection is critical to prevent hydrolysis and provide oxidative stability. In addition, chemically resistant seals are recommended.

2.8.3. Polyol esters:

Like di-esters, they are formed by the reaction of an acid and alcohol (polyol) refers to a molecule with two alcohol functions in it is structure; some examples may include tri-methylol propane (TMP), neopententyl glycol (NPG) and pentaerythritol (PE).

Polyol esters contain no sulfur, phosphorus or wax. Pour points range from -30 to -70 °C, and viscosity indexes from 120 to 160. The fluids have excellent thermal stability and resist and hydrolysis some what better than di-esters. With the proper additives, polyesters are more oxdatively stable than di-esters and PAOs.

2.8.4- Ester types:

Manufacture of esters:

Organic acid + alcohol → ester + H_2O

Reaction conditions are 230 °C, 50-60 mm Hg pressure.

The direct effect of the ester group on the physical properties of a lubricant is to lower the volatility and raise the flash point.

The presence of the ester group also affects other properties such as:

- Thermal stability.
- Hydraulic stability.
- Solvency.
- Lubricity.
- Biodegradability..

Physico-chemical properties of ester lubricants:

Mineral oil base stocks are derived from crude oil and consist of complex mixture of naturally occurring hydrocarbons. Synthetic ester lubricants, on other hand, are prepared from man-made, base stocks having uniform properties that can be tailored to specific applications.

Properties of ester lubricants:

1. Viscosity:

The viscosity of an ester lubricant can be altered by:

I. Increasing the molecular weight of the molecule by:

a) Increasing the carbon chain length of the acid.
b) Increasing the number of ester groups.
c) Increasing the carbon chain length of alcohol.

II. Including cyclic groups in the molecular backbone.

III. Maximizing dipolar interactions.

2. Viscosity index:

The VI of an ester lubricant can be increased by:

a) Increasing the acid chain length.

b) Increasing the alcohol chain length.

c) Increasing the linearity of the molecule.

3-The pour point of the lubricant can be increased by:

a) Increasing the amount of branching.

b) The positioning of the branch-branching in the center of the molecule gives better pour points than branches near the end[3].

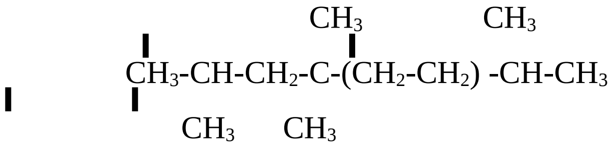
2.8.5- Alkylated aromatics:

Three types of alkyl benzenes are available for use as or in lubricants:-

(1) Di alkyl benzenes produced as by, product in the manufacture of linear dodecyl or tridecyl benzene, a sulphonation feedstock for anionic detergent manufacture.

(2) Di alkyl benzenes produced from this detergent alkylates by reacting further with Alfa-olefins.

(3) Synthesized alkyl aromatics purpose built from benzene and short chain olefins such as propylene[2].



$$CH_3\text{-}\underset{CH_3}{CH}\text{-}CH_2\text{-}\overset{CH_3}{\underset{CH_3}{C}}\text{-}(CH_2\text{-}CH_2)\text{-}\overset{CH_3}{CH}\text{-}CH_3$$

SYNTHETIC ALKYL BENZENE

They are formed by the reaction of olefins or alkyl halides with an aromatic material such as benzene. The fluids have good low temperature properties and good additive solubility. Viscosity index is about 50 for fluids with liner molecules and zero or lower for fluids with branched side chains. Thermal stability is similar to that of PAOs, and additives are required to provide oxidative stability.

The polyalkyleneglycols are polymers of alkylene oxides lubricant .Performance and properties of particular PGA depend on the monomers used to manufacture it, molecular weight and the nature of the terminal groups. Thus, a wide range of properties is possible[3].

2.8.6 Phosphate esters:

They are synthesized from phosphorus oxy-chloride and alcohol or phenols. They are used both as base oil and as anti-wear additives in mineral and synthetic lubricants. Thermal stability is good, and pour points ranges from -25 to -5 °C. However, viscosity index is extremely low, ranging from 0 to -30, which limits their high temperature capabilities.

2.8.7 Poly butanes:

Poly butanes used in lubricants are composed mainly of isobutene and are often referred to as poly isobutene or PIBs. Poly- butenes show different properties compared with PAOs, which are generally made from higher molecular weight straight-chain alpha-olefins. Poly- butenes are produced by the polymerization of hydrocarbon stream containing isobutene. Polybutenes are non-polar and (poly butene structure) and aromatic hydrocarbons, chlorinated hydrocarbons soluble in aliphatic and certain oxygenated solvent, such as tetrahydrofuran and diethyl ether. They are soluble in simple alcohols, ketons and esters[2].

2.8.8 Poly-alkylene glycols

The term polyalkylene glycol covers an extensive range of polymeric molecules, which depending on chemical structure, can exhibit quite different physical properties.

For example, poly alkylene glycol can be solid or liquid, water-soluble or water in soluble, and can be produced to give almost any viscosity-required Polyalkylene glycols have the following properties:

- Wide viscosity range

- Good thermal stability
- High flash point.
- Good lubricity.
- Low toxicity .-
- Non-corrosive to common metals practically non-flammable in aqueous solution.
- Low pour point.
- Excellent viscosity/temperature characteristic [3] .

Application:

Poly alkylene glycol (PAGs) was first developed in the mid 19th century. but weren’t used commercially until 1930s when an applications are replacement for castor oil in automotive brake fluids was found .

2.8.9 Semi-synthetic oil:

Semi synthetic oils (also called synthetic blend) are blends of mineral oil with no more than 30% synthetic oil designed to have many of the benefits of synthetic oil without-matching the cost of pure synthetic oil[19] .

Table (2.6): Application of synthetic lubricant:

Synthetic lubricants	Application
Synthesized hydrocarbons (OAOs & DABs)	Engine and turbine oils, compressor oils,hydroaulic fluids gear and bearing oils
Organic esters Dibasic acid and ployol esters	Crankcase oils compressor lubricants
Phosphate esters	These oils are suited for fire-resistance
Polyglycols	Applications include gears, bearing, and compressor for hydrocarbon gas
Silicones	Fire-resistant and water repellant.

2.9 Quality assessment:

New use and formulation technology for lubricating oils necessitate a constant review of the methods for assessing the quality of both new and used lubricating oils. The traditional physical and chemical tests are still applied, but these are being supplemented and in some cases replaced by instrumental techniques based on physicochemical method which include infrared absorption, ultraviolet, emission spectroscopy, x-ray absorption and fluorescence method. It is convenient to consider these tests in five categories. The first three determine the characteristics and compositions of lubricants, and the last two are laboratory tests that simulate service conditions[4].

2.9.1 Physical tests:

Physical tests are comparatively simple laboratory procedures, which define the nature of the product by measuring physical properties. Examples are viscosity, flash point, specific gravity, color, and appearance.

2.9.2 Chemical tests:

Chemical tests define the composition of the lubricant oil by determining the presence of such elements as sulfur, chlorine, phosphorus and metal which often are related significantly to the additive content of the lubricant.

2.9.3 Physic-chemical tests:

Tests in this classification are either:

Those, which determine the presence of elements using instrumental physical procedures.

Those, which give information on the molecular structure of component of lubricant, or those, which give pH, acidity and alkalinity values.

Laboratory bench tests:

Laboratory bench tests subject the lubricating oil to individual environment conditions which are designed normally to exceed the appreciate service requirements. These include tests such as thermal stability, oxidation stability and corrosion resistance which are used frequently for screening formulations during the development of a new product. Also in this category are test machine for measuring wear and load-carrying properties[4].

2.9.4 Engine and digests:

Mechanical tests are used to assess the perfects on various properties of lubricating oils that will be produced by the environment in which the lubricant will function. The equipment is set up in a prescribed manner on laboratory stands, and tests are carried out under carefully controlled conditions. Such tests generally are designed to correlate as far as possible with actual service, but for new products, laboratory mechanical testing usually is flowed by field evaluation.

2.9.5 Filed testing:

It might be expected that field testing would be the most meaning full performance evaluation to which a lubricant could be subjected, but the truth is that it is surprisingly difficult to obtain worthwhile results from field tests.

A great deal of time and effort has to be expended and a good field test is not cheap to run.

With care, however, valuable result is can be obtained, and some filed testing is always desirable when new technology has been developed in order to be sure that the standard laboratory tests have adequately screened the new approach. Field tests generally fall into three distinct types, uncontrolled tests, controlled tests and caravan testing. Physical tests, chemical tests, laboratory bench tests an engine tests are extremely valuable as tools for attempting to predict low a specific lubricant formula will perform in full size machinery under many different operating condition. They always be used and interpreted, however, with the full realization that they are not fallible or fool proof. The ultimate decision as to the success or failure of lubricating fluid can be made only on the basis of its behavior in the end. Use item such as production engines, pumps gear drives, hydraulic system, etc. it is usually on the basis this ultimate performance that many equipment manufacturers will recommend a brand name product for use in their equipment

2.10 Lube oil-refining process

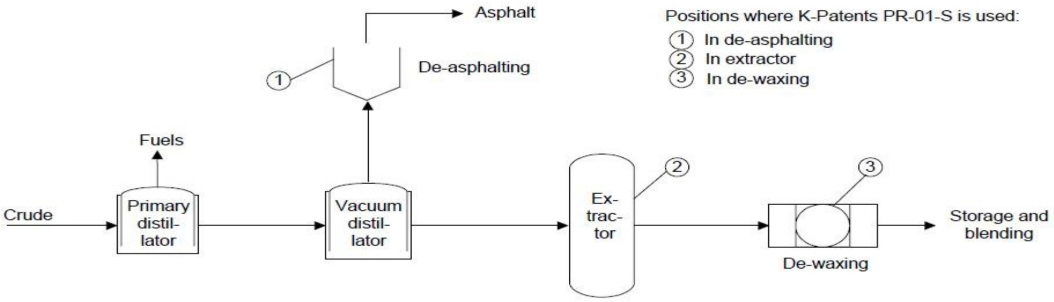


Figure 2.1[37]

2.10.1 Vacuum distillation unit:

The first step in the processing of lubricating oils is separation in the distillation units of the individual fractions according to viscosity and boiling range specifications. The heavier lube oil raw stocks are included in the vacuum fractionating tower bottoms with asphaltenes, resins and other undesirable materials. The raw lube oil fractions from most crude oils contain components which have undesirable characteristics for finished lubricating oils. These must be removed or reconstituted by processes such as extraction, crystallization, hydro cracking and hydrogenation.

Vacuum distillation separates raw lube oil into two or three streams with increasing viscosity. The heavier stream is derived by removing asphalt from the residue in a de-asphalting unit. The lighter feedstocks are sent directly to a solvent extraction. This first stage determines the final base oil viscosity grades.

The further process sequence is usually in the order of de-asphalting, solvent extraction, de-waxing and finishing.

2.10.2 De-asphalting:

Propane is usually used as the solvent in de-asphalting but it may also be used with ethane or butane in order to obtain the desired solvent properties. Propane has unusual solvent properties in temperatures from 40°C .to 60°C. Paraffin’s are very soluble in propane but the solubility decreases with an increase in temperature until at the critical temperature of propane (96,8°C/206,2°F) all hydrocarbons become insoluble. In the range of 40°C (104°F) to 96,8°C (206°F) the higher molecular weight asphaltanes and resins are largely insoluble in propane. Separation by distillation is generally by molecular weight of the components and solvent extraction by type of molecule structure[1].

2.10.3 Solvent extraction

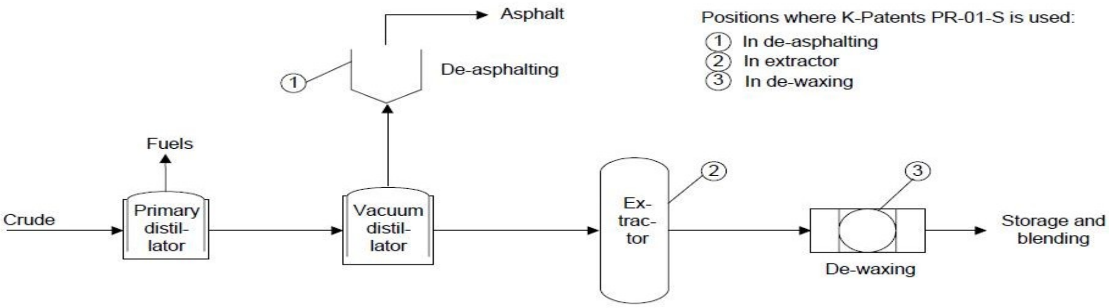


Figure 2.2[37]

There are three solvents used for the extraction of aromatics from lube oil feedstocks and the solvent recovery portions of the systems are different for each. The solvents are furfural, phenol and N-methyl-2- pyrrolidione (NMP). The purpose of solvent extraction is to improve the viscosity index (VI), oxidation resistance, and color of the lube oil base stock and to reduce the carbon- and sludge-forming tendencies of the lubricants by separating the aromatic portion from the naphthenic and paraffinic portion of the feedstock.

2.10.4.1 Furfural extraction:

The process flow through the furfural extraction unit is similar to that of the propane de-asphalting unit except for the solvent recovery section, which is more complex. The oil feedstock is introduced into a continuous countercurrent extractor at a temperature, which is a function of the viscosity of the feed; the greater the viscosity the higher temperature is used.

2.10.4.2 Phenol extraction:

The process flow for the phenol extraction unit is somewhat similar to that of the furfural extraction unit but differs markedly in the solvent recovery section because phenol is easier to recover than furfural.

2.10.4.3 N-methyl-2- pyrrolidone (NMP) extraction:

NMP extraction uses N-methyl-2- pyrrolidone as the solvent to remove the condensed ring aromatics and polar components from the lubricating oil distillate bright stocks. This process was developed as a replacement for phenol extraction because of the safety, health, and environmental problems associated with the use of phenol.

2.10.4.4 De-waxing:

All lube oil stocks, except those from a relatively few highly naphthenic crude oils, must be dew-axed or they will not flow properly at ambient temperatures. Dew axing is one of the most important and most difficult processes in lubricating oil manufacture.

2.10.4.5 Hydro finishing:

Hydro treatment of de-waxed lube oil stocks is needed to remove chemically active compounds that affect the color and color stability of lube oils[1].

Table (2.7): Propane De-asphalting Conditions:

Solvent dosage, vol. %	**500 – 1500**
Temperature F°	**100 – 190**
Pressure Psig	**-3500 – 550**
De-asphalted oil yield, vol. %	**30 – 90**

2.10.4.6 Effects of De-asphalting Solvent to Feed and Temperature:

At constant temperature, increasing solvent-to-feed ratio:

- Increases DA oil yield, viscosity and carbon residue.
- Increases DA oil metals, sulfur and nitrogen content.
- Decreases DA oil API gravity and viscosity index [1].

2.11 Viscosity classifications:

Industrial Lubricant Classifications:

ISO (International Standard Organization) viscosity classification

The ISO viscosity classification uses mm^2/s (cst) units and relates to viscosity at 40C°. it consists of a series of viscosity brackets between 1.98 mm^2/s and 1650 mm^2/s, each of which defined by a number.

This system is now used to classify all industrial lubricating oils where viscosity is an important criterion in the selection of the oil. Cutting oil and same other specialized products are more important in relation to grade selection of the oil.

2.11.1. Engine oil lubricant classifications

SAE J300 September 1980 (Engine oils).

The most widely used system for engine oil viscosity classification is that established by the Society of Automotive Engineers (SAE) in the USA. In this system two series of viscosity grades are defined – those containing the letter W and those without the letter W.

Grades with the letter were intended for use at lower temperatures and are based on a maximum low temperature viscosity and a maximum borderline pumping temperature, as well as a minimum viscosity at 100C°.

The low temperature viscosity is measured by means of a multi-temperature version of ASTM D602 'Method of test for apparent viscosity of motor oils at low temperature using the cold cranking simulator'. Viscosities measured by this method have been found to correlate with engine speeds developed during low temperature cranking. Borderline pumping temperature is measured according to ASTM D3829' standard method for predicting the borderline pumping temperature of engine oil[40].

Oil without the letter W, intended for use at higher temperatures, are based on the viscosity at 100C° only. These are measured by ASTM D445. Method of test for kinematic viscosity of temperature on Opaque liquids.

Amuti-grade oil is one whose low temperature viscosity and borderline temperature satisfy the requirements of one of the W grades and whose viscosity at 100C° is within the stipulated range of one -W- grades [40].

Table(2.8)ISOviscosityccation

ISO. V.Grade	MidKinematic viscosity40C^0	Kinematic viscosity limits40C^0	
		Min	Max
ISO-VG2	2.2	1.9	2.4
ISOVG3	3.2	2.88	3.52
ISOVG5	4.6	4.41	5.06

ISOVG10	**10**	**9**	**11**
ISOVG15	**15**	**13.5**	**16.5**
ISOVG1500		**1350**	**1650**

Table (2.9): Automotive lubricant viscosity grades Engine oils-SAE J300, June 2001 (Dec 1999)[3]:

SAE V.G	Viscosity (CP) at temp (C°) Max		Viscosity (CST) at 100 C°		High-shear viscosity (CP) at 150 C° and 10 sec-(Min)
	Cranking	Pumping	Min	Max	
0 W	6200 at-35	60.000 at-40	3.8		
5 W	6200 at-30	60.000 at-35	3.8		
10 W	7000 at-25	60.000 at-30	4.1		
15 W	7000 at-20	60.000 at-25	5.6		
20 W	9500 at-15	60.000 at-20	5.6		
25 W	135000 at-10	60.000 at-15	9.3		
20			5.6	< 9.3	2.6
30			9.3	< 12.3	2.9
40			12.5	<16.3	2.9[6] low-40-5w40/ low 40 grades
40			12.5	<16.3	3.7[7] 15w40 low 40 25 w 40 and 40 grade
50			16.3	< 12.9	3.7
			21.9	< 26.1	3.7

Table (2.11): API diesel oil[29]

Diesel Engines

Category	Status	Service
CI-4	**Current**	Introduced September 5, 2002. For high-speed, four-stroke engines designed to meet 2004 exhaust emission standards implemented in 2002. CI-4 oils are formulated to sustain engine durability where exhaust gas recirculation (EGR) is used and are intended for use with diesel fuels ranging in sulfur content up to 0.5% weight. Can be used in place of CD, CE, CF-4, CG-4, and CH-4 oils.
CH-4	**Current**	Introduced in 1998. For high-speed, four-stroke engines designed to meet 1998 exhaust emission standards. CH-4 oils are specifically compounded for use with diesel fuels ranging in sulfur content up to 0.5% weight. Can be used in place of CD, CE, CF-4, and CG-4 oils.
CG-4	**Current**	Introduced in 1995. For severe duty, high speed, four-stroke engines using fuel with less than 0.5% weight sulfur. CG-4 oils are required for engines meeting 1994 emission standards. Can be used in place of CD, CE, and CF-4 oils.
CF-4	**Current**	Introduced in 1990. For high-speed, four-stroke, naturally aspirated and turbocharged engines. Can be used in place of CD and CE oils.
CF-2	**Current**	Introduced in 1994. For severe duty, two-stroke cycle engines. Can be used in place of CD-II oils.
CF	**Current**	Introduced in 1994. For off-road, indirect injected and other diesel engines including those using fuel with over 0.5% weight sulfur. Can be used in place of CD oils.
CE	**Obsolete**	Introduced in 1987. For high-speed, four-stroke, naturally aspirated and turbocharged engines. Can be used in place of CC and CD oils.
CD-II	**Obsolete**	Introduced in 1987. For two-stroke-cycle engines.
CD	**Obsolete**	Introduced in 1955. For certain naturally aspirated and turbocharged engines.
CC	**Obsolete**	For engines introduced in 1961.

Table (2.10): API motor oil[29]

Gasoline Engines

Category	Status	Service
SM	Current	For all automotive engines presently in use. Introduced November 30, 2004. SM oils are designed to provide improved oxidation resistence, improved deposit protection, better wear protection, and better low-temperature performance over the life of the oil. Some SM oils may also meet the latest ILSAC specification and/or qualify as Energy Conserving.
SL	Current	For 2004 and older automotive engines.
SJ	Current	For 2001 and older automotive engines.
SH	Obsolete	For 1996 and older engines. Valid when preceded by current C categories.
SG	Obsolete	For 1993 and older engines.
SF	Obsolete	For 1988 and older engines.
SE	Obsolete	CAUTION - Not suitable for use in gasoline-powered automobile engines build after 1979.
SD	Obsolete	CAUTION - Not suitable for use in gasoline-powered automobile engines build after 1971. Use in more modern engines may cause unsatisfactory performance or equipment harm.
SC	Obsolete	CAUTION - Not suitable for use in gasoline-powered automobile engines build after 1967. Use in more modern engines may cause unsatisfactory performance or equipment harm.
SB	Obsolete	CAUTION - Not suitable for use in gasoline-powered automobile engines build after 1963. Use in more modern engines may cause unsatisfactory performance or equipment harm.
SA	Obsolete	CAUTION - Not suitable for use in gasoline-powered automobile engines build after 1930. Use in more modern engines may cause unsatisfact

2.11.2 Automotive Engine Oils [29]:

Motor oil is a lubricant used in internal combustion engines. These include motor or road vehicles such as cars and motorcycles, heavier vehicles such as buses and commercial vehicles, non-road vehicles such as go-karts, trains and air craft, and static engines such as electrical generators. In engines there are parts which move very closely against each other causing friction which wastes otherwise useful power by converting the energy to heat.

Contact between moving surfaces also wears away those parts, which could lead to lower deficiency and degradation of the motor. This increases fuel consumption and decreases power output and can in extreme cases lead to total engine failure.

Lubricant oil creates a separating film between surfaces of adjacent moving parts to minimize direct contact between them, decreasing friction, wear and production of excessive heat, thus protecting the engine. Motor oil also carries away heat from moving parts, which is important because materials tend to become softer and less abrasion-resistant at high temperatures. Some engines have an additional oil cooler for this purpose.

Coating metal parts with oil also keeps them from being exposed to oxygen, inhibiting oxidation at elevated operating temperatures preventing rust or corrosion. Corrosion inhibitors may also be added to such motor oil. Many motor oils also have detergent and dispersant additives to help the engine clean of oil sludge build up[3].

2.11.3 Properties of Motor Oil:

Most motor oils are made from a heavier, thicker petroleum hydrocarbon base stock derived from crude oil with additives to improve certain properties. One of the most important properties of motor oil in maintaining a lubricating film between moving parts is its viscosity.

The viscosity of a liquid can be thought of as its "thickness" or a quantity of resistance to flow.

The viscosity must be high enough to maintain a satisfactory lubricating film, but low enough that the oil can flow around the engine parts satisfactorily to keep them well coated under all conditions. The viscosity index is a measure of how much the oil's viscosity changes as temperature changes. A higher viscosity index indicates the viscosity changes less with temperature that a lower viscosity index.

Motor oil must be able to flow at cold winter temperatures to lubricate internal moving parts upon starting up the engine. Another important property of motor oils its pour point, which is indicative of the lowest temperature at which the oil could still be poured satisfactorily. The lower pour-point temperature of the oil, the more desirable the oil is when starting up at cold temperature.

Oil is largely composed of hydrocarbons which can burn if ignited. Still another important property of motor oil is its flash point, the lowest temperature at which the oil gives off vapors which can ignite. Its dangerous for the oil in motor to ignite and burn, so a high flash point is desirable at a petroleum refinery, fractional distillation separates a motor oil fraction from other crude oil fractions, removing the volatile components which ignite more easily, and therefore increasing the oil's flash point.

Another test is to determine the Total Base Number (TBN), which is a measurement of the reserve alkalinity of an oil to neutralize acids. The resulting quantity is determined as mg KOH (gram of lubricant).

Analogously, total acid number (TAN) is the measure of lubricants acidity.

2.11.4 Grades:

The Society of Automotive Engineers, usually abbreviated as SAE, has established a numerical code system for grading motor oils according to their kinematics viscosity. SAE viscosity grading include the following: 0,5, 10, 20, 25, 30, 40, 50 and 60. Some of the numbers can be suffixed with letter "W", designating their "winter" or cold-start, viscosity at lower temperature.

Viscosity is graded by measuring the time it takes for standard orifice, at standard temperatures. The longer it takes, the higher the viscosity, and thus higher SAE code.

Note that the SAE operate a separate viscosity rating system for transmissions oil which should not be confused with engine oil viscosity.

The higher number of a transmission oil (e.g. 75w-140) do not mean that it is necessary higher viscosity than an engine oil.

2.11.5 Single Grades:

For single grades oils, the kinematics viscosity is measured at a reference temperature of 100 °C in units of mm^2/s or the equivalent older non SI units, centistokes (abbreviated cst).

Based on the range of viscosity the oil falls in at that temperature the oil is graded as an SAE number 0, 5, 10, 20, 30, 40, 50, or 60. The higher the viscosity, the higher SAE grade number is.

These numbers are often referred to as the weight of motor oil.

The reference temperature is meant to approximate the operating temperature to which motor oil is exposed in an engine.

The viscosity of the single grade oil derived from petroleum unimproved with additives changes considerably with temperature. As the temperature increases, the viscosity of the oil decreases logarithmically in a relatively predictable manner. On single grade oils, viscosity testing can be done at cold winter (W) temperature (as well as checking minimum viscosity at 100 °C) to grade an oil as SAE number 0w, 5w, 10w, 15w, 20w or 25w. A single grade oil graded at the hot temperature is expected to test into the corresponding grade at the winter temperature; ie a 10 grade oil should correspond a low oil for some applications, such as when the temperature ranges in use are not very wide.

2.11.6. Multi-grade:

The temperature range the oil is exposed to in most vehicles can be wide, ranging from cold ambient temperatures in winter before the vehicle is started up to hot operating temperatures when the vehicle is fully warmed up into summer weather.

A specific oil will have viscosity when cold and allow viscosity at the engines operating temperature. The difference in viscosities for any single-grade oil is too large between the extremes of temperature to being difference in viscosities closer together, special polymer additives called viscosity index improvers, or VIIS are added to the oil. These additives make the oil multi-grade motor oil. The idea is to cause the multi-grade oil to have the viscosity of the base number when cold, and the viscosity of second number when hot.

This enables on type of oil to be generally used all the year and when multi-grades were initially developed, they were frequently describe as all-season oil. The viscosity of multi-grade oil still varies logarithmically with temperature, but the shape representing the change is lessened. This shape representing the change with temperature depends on the nature and amount of the additives to the base oil. The SAE designation for multi-grade oils includes two grade numbers, for example; 10w – 30 designates common multi-grade oil, been replaced with a more technical test where a" cold crank in the cold is diminished soon after being put into service.

2.12. Lubrication Theory and Practice

2.12.1. Lubricant Properties and the Role of Additives

Some of the most important properties necessary for satisfactory lubricant performance are:

1. Low volatility under operating conditions. Volatility characteristics are essentially inherent in the choice of base oil for a particular type of service and cannot be improved by the use of additive materials.

2. Satisfactory flow characteristics in the temperature range of use. Flow characteristics largely depend on the choice of base oil; however, they can be improved through the use of pour point depressants and viscosity modifiers. The former improve low-temperature flow properties, while the latter enhance high-temperature viscosity characteristics.

3. Superior stability or ability to maintain desirable characteristics for a reasonable period of use. While these characteristics depend to some extent on the base oil, they are, primarily associated with additive materials, which enhance base fluid properties in this area. Lubricant stability is affected by the environment in which it operates. Such factors as temperature, oxidation potential and contamination with water, unburned fuel fragments, and corrosive acids limit the useful life of a lubricant. This is the area where additives have made a major contribution in improving the performance characteristics and extending the useful life of lubricants.

4. Compatibility with other materials in the system. Compatibility of lubricants with seals, bearings, clutch plates, etc., may also be partially associated with the base oil. However, additive chemistry can have a major influence on such characteristics.

Additives can be classified as materials that impart new properties to or enhance existing properties of the lubricant or fuel into which they are incorporated. It is not an objective of this study to give a complete bibliography of the literature pertaining to these materials. An attempt will be made to present an overview of the field both as to chemistry and function.

The principal types of engine lubricant additives have been described in the literature by various authors. Materials of current interest in this area include[2]:

Table (2.12)Lubricant Additive Types

Detergents (Metallic Dispersants)	Salicylates Sulfonates Phenates Sulfophenates
Ashless Dispersants	N-substituted long-chain alkenyl succinimides High-molecular-weight esters and polyesters Amine salts of high-molecular-weight organic acids Mannich base derived from high-molecular-weight alkylated phenols *Copolymers of methacrylic or acrylic acid derivatives containing polar groups such as amines, amides, imines, imides, hydroxyl, ether, etc. *Ethylene-propylene copolymers containing polar groups as above
Oxidation and Bearing	Organic phosphites

Corrosion Inhibitors	Metal dithiocarbamates Sulfurized olefins Zinc dithiophosphates
Antioxidants	Phenolic compounds Aromatic nitrogen compounds Phosphosulfurized terpenes
Viscosity Modifiers	Polymethacrylates Ethylene-propylene copolymers (OCP) Styrene-diene copolymers Styrene-ester copolymers
Antiwear Additives	Organic phosphites Sulfurized olefins Zinc dithiophosphates Alkaline compounds as acid neutralizers
Pour Point Depressants	Wax alkylated naphthalene Polymethacrylates Crosslinked wax alkylated phenols Vinyl acetate/fumaric-acid-ester copolymers Vinyl acetate/vinyl-ether copolymers Styrene-ester copolymers

2.12.2-Detergents:

Materials of this type are generally molecules having a large hydrocarbon "tail" and a polar head group. The tail section, an oleophilic group, serves as a solubilizer in the base fluid, while the polar group is attracted to contaminants in the lubricant.

Although these compounds are commonly called detergents, their function appears to be the dispersing of particulate matter rather than cleaning up existing dirt and debris. Therefore, it is more appropriate to categorize them as dispersants. The molecular structure and a brief outline of the preparation methods for some representative types of metallic dispersants are discussed below[37].

2.12.3. Sulfonates

Sulfonates are the products of the neutralization of a sulfonic acid with a metallic base. The reaction can be illustrated as[25] :

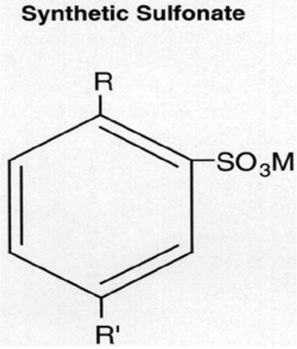
$$R\text{-}SO_3H + MO \text{ or } MOH \longrightarrow R\text{-}SO_3M + H_2O$$

Where MO = divalent metal oxide and MOH = divalent metal hydroxide. R represents the organic radical that acts as an oil-solubilizing group.

The molecular weight of the hydrocarbon must be about 350 or more, and the presence of the organic radical in the molecule is considered necessary for the oil solubility of the sulfonate. Commercially available sulfonates are of two types: petroleum sulfonates and synthetic sulfonates.

Petroleum (or natural) sulfonates are metal salts of sulfonic acids that were formerly byproducts of sulfuric acid treatment of oil fractions in the manufacture of white oils. Currently, with the high demand for detergent oils, sulfonates rather than white oils have become the principal product. The structure of the organic portion of petroleum sulfonates is not completely known. Depending on the crude oil source, the structure can have varying proportions of aliphatic, naphthenic, and aromatic hydrocarbon groups.

2.12.4. Synthetic sulfonates are metal salts of acids produced from the sulfonation of alkylated aromatics by reaction with sulfur trioxide. In many cases, synthetic sulfonates were derivatives of benzene with long alkyl substituents, whose structure is illustrated at left, where R and R' are aliphatic radicals with a combined carbon number over C_{20}.

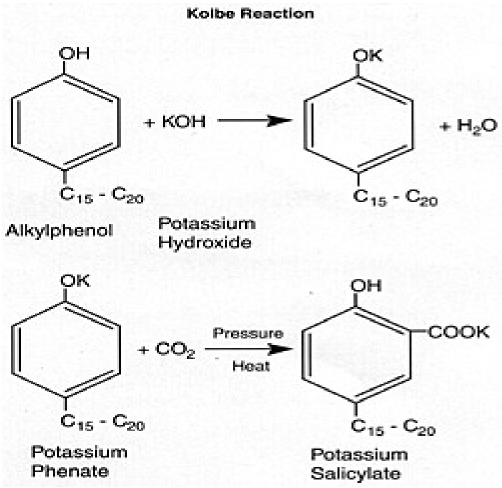


Most metallic cations of sulfonate detergents are calcium, magnesium, and sodium. Alkaline-earth sulfonates can be prepared by direct reaction of sulfonic acid with the metal oxide or hydroxide, or by reacting the sodium sulfonate with the metal chloride.

Oil-soluble sulfonates containing metal in excess of the stoichiometric amount are called basic sulfonates. Among the advantages of basic sulfonates is a greater ability to neutralize acidic bodies in addition to serving as a dispersant for contaminants[5].

2.12.5. Salicylates:

Salicylates are generally prepared from alkyl phenols by a chemical scheme known as the Kolbe reaction [1].

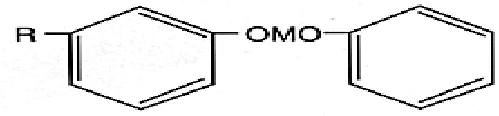


The potassium salicylate may be metathesized with calcium chloride or magnesium chloride. The resulting salts are then overbased to form highly basic detergents that have proven effective in diesel engine oil formulations.

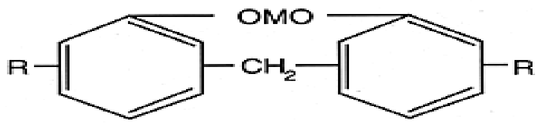
2.12.6. Phenates and Phenol Sulfide Salts

The broad class of metal phenates includes the salts of alkylphenols, alkylphenol sulfides, and alkylphenol aldehyde products. Oil solubility is provided by alkylating the phenol with olefins that generally contain seven or more carbon atoms.

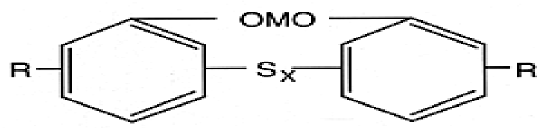
Normal Phenate



Methylene Coupled Phenate



Sulfur Coupled Phenate

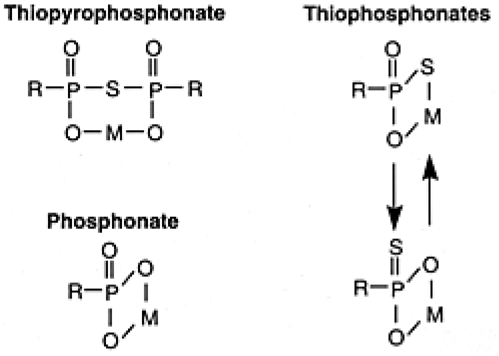


[25]

Sulfur is incorporated into the phenates by reacting the alkylphenol with sulfur chloride or elemental sulfur. The introduction of sulfur and the presence of a methylene bridge lower the corrosivity of the products toward bearing materials and improve their antioxidant characteristics.

Calcium phenates are currently the most widely used types. They are manufactured by reacting the substituted phenols with the oxides or hydroxides of the metals. Basic phenates can be produced by using an excess of the metal base over the theoretical amounts required to form neutral phenates. Basic phenates have greater acid neutralization potential per unit of weight. Such products have two to three times the amount of metal required for neutral phenates.

In the structures for the various phenates shown, M = divalent metal and R = alkyl group [25].



2.12.7. Thiophosphonates

Commercial products of this type are generally derived from acidic components produced by the reaction between polybutene (500 to 1000 molecular weight ranges) and phosphorus pentasulfide. A study of the structure of these compounds indicated that the organic salts present are principally thiopyrophosphonates, accompanied in some cases by 10 to 25 mole percent of thiophosphonates and phosphonates. Oil-soluble phosphonates and thiophosphonates that contain metal in excess of the stoichiometric amount can also be prepared. However, these materials have almost vanished from use[5].

2.12.8 Dispersants

A major development in the additive field was the discovery and use of ash less dispersants. These materials may be categorized into two broad types: high-molecular weight polymeric dispersants used to formulate multigrade oils and lower molecular weight additives for use where viscosity modification is not necessary. These additives are much more effective than the metallic types in controlling sludge and varnish deposits that result from intermittent and low-temperature gasoline engine operation[37].

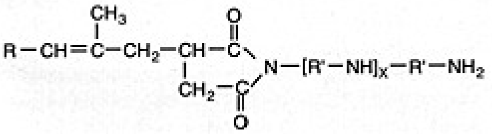
Compounds useful for this purpose are again characterized by a polar group attached to a relatively high molecular weight hydrocarbon chain. The polar group generally contains one or more of the elements nitrogen, oxygen and phosphorus. The solubilizing chains are generally higher in molecular weight than those in detergents; however, they may be quite similar in some instances.

No attempt will be made to describe all the materials that fit into this category. The discussion will be limited to some of the more widely used commercial products.

2.12.9.1 N-Substituted Long-Chain Alkenyl Succinimides [25].

The majority of products currently in use are of this type or related materials that correspond to the following general formula:

Succinimide Type

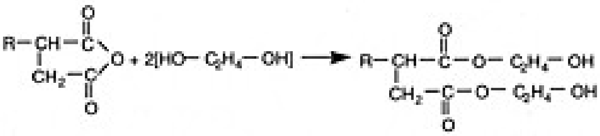


The alkenylsuccinic acid intermediate is obtained by condensing an olefin polymer, generally a polyisobutylene with a molecular weight in the range of 800 to 1200, with maleic anhydride. The basic part of the additive usually results from N-amino alkylpolyamines, especially the polyalkylene amines such as triethylenetetramine, tetraethylene pentamine, etc.

2.12.9.2 High Molecular Weight Esters [25].

Materials of commercial interest in this area include products formed by the esterification of olefin-substituted succinic acids with mono or polyhydric aliphatic alcohols. The olefin substituent in the acids has at least 50 aliphatic carbon atoms and a molecular weight of about 700 to 5000. An example of such a material is the reaction product of ethylene glycol with a substituted succinic anhydride:

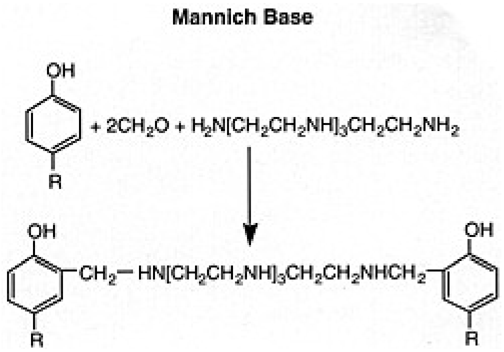
Succinate Type



Polyhydric alcohols such as glycerol, pentaerythritol and sorbitol may be employed in such a reaction.

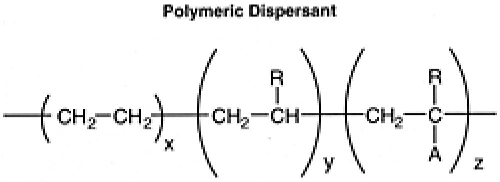
Mannich Bases from High Molecular Weight Alkylated Phenols:

Such products are formed by the condensation of a high molecular weight alkyl-substituted phenol, an alkylenepolyamine, and an aldehyde such as formaldehyde. A description of the reaction product from polypropylenephenol, tetraethylenepentamine, and formaldehyde is:

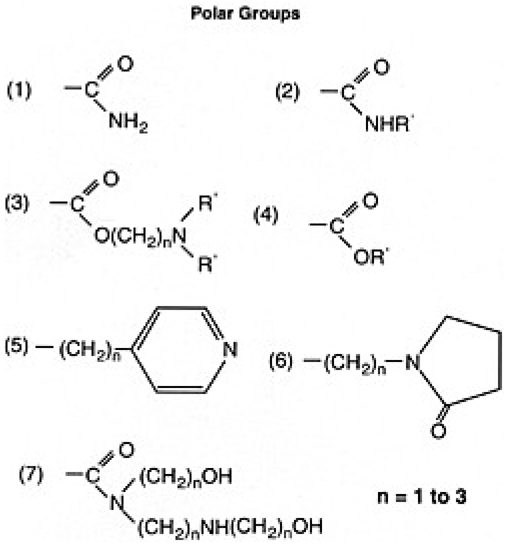


2.12.9.3 Polymeric Dispersants [25]:

These ashless dispersants may serve the dual function of dispersant and viscosity modifier. They have two different structural features: those that are similar to materials employed as viscosity modifiers and those of polar compounds (which impart dispersancy). The viscosity modifiers will be discussed in a separate section. The general formula for dispersant polymers might be:



where the hydrocarbon portion is the oleophilic group, A = polar group, and R = hydrogen $C_{1\text{-}6}$ alkyl, $C_{4\text{-}6}$ alkenyl, or alkyl. Some of the many possibilities for the polar groups are:



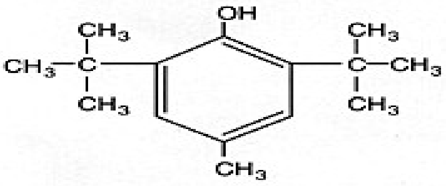
2.13. Oxidation and Bearing Corrosion Inhibitors

The function of an oxidation inhibitor is to prevent deterioration of the lubricant associated with oxygen attack. These inhibitors either destroy free radicals (chain breaking) or interact with peroxides involved in the oxidation mechanism. Among the widely used antioxidants are phenolic types and zinc dithiophosphates. The former are considered to be of the chain-breaking variety, whereas the latter are believed to be peroxide destroyers.

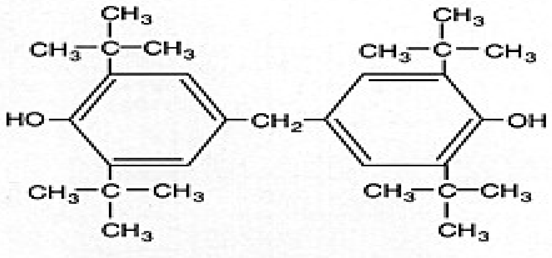
The corrosion of bearing metal is generally considered due largely to reaction of the acid with the oxides of the bearing metal. In engine operation, these acids either originate from products of incomplete fuel combustion that find their way into the lubricant as blowby gases or are produced from lubricant oxidation. Oxidation inhibitors can significantly reduce this tendency[5].

Detergents can reduce bearing corrosion by neutralizing the corrosive acids. Other inhibitors such as zinc dithiophosphates and phosphosulfurized olefins not only inhibit oxidation but also form a protective film on the bearing surface, making it impervious to acid attack. 3.1:-

Phenolic Inhibitors



2,6 -di-tert-butyl para cresol



4-4' Methylenebis [2,6-di-tert-butylphenol]

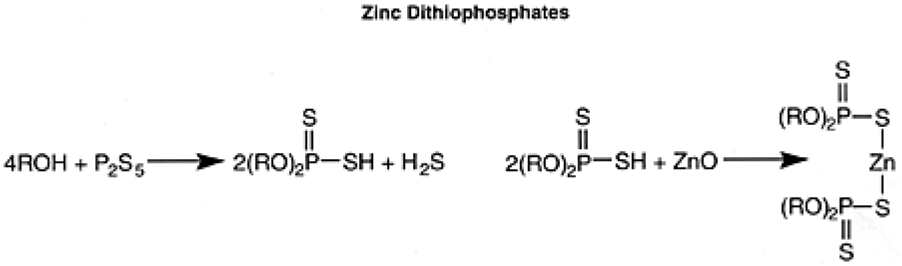
2.13.1. Phenolic Inhibitors (Chain-Breaking) [25] :

The inhibitor efficiency of phenol is markedly increased by substituting alkyl groups in the two ortho and para positions. It is particularly enhanced when the ortho substituents are bulky groups such as tert-butyl and the para substituent is a primarily alkyl group. A variety of hindered phenols are produced commercially and employed as inhibitors in transformer, turbine, and engine oils.

The methylenebis structure is more effective in high-temperature applications due to its lower volatility characteristics compared to the other molecule.

2.13.2. Zinc Dithiophosphates (Peroxide Destroying):

Of greatest commercial importance in engine, lubricants are the zinc di thiophosphates, which not only serve as antioxidants but also provide both antiwar and bearing corrosion protection. The zinc dithiophosphates are made as follows:



Where: R = alkyl or aryl. Both alkyl and aryl derivatives are employed commercially. Alkyl derivatives are generally more effective as antiwear additives. Aryl derivatives have a higher degree of thermal stability.

Both the antiwar and thermal stability characteristics of the alkyl compounds can be varied by using different alcohols; i.e. primary vs. secondary and high vs. low molecular weight. The principal alkyls are propylbutylhexyloctyl, and mixtures of these. The effect of the alkyl radical on the thermal decomposition temperature of zinc dialkyldithiophosphates (ZDP) is shown below:

(T-13): Effect of Alkyl Radical on Thermal Decomposition of ZDP

Alkyl Radical	Decomposition Temperature (°C)
Isopropyl	196
4-Methyl 2-pentyl	197
N-Amyl	212
N-Octyl	>251

Stability increases with the length of the alkyl chain and is lower for secondary alkyl groups with the same number of carbon atoms. It should be noted, however, that the overall performance characteristics of ZDPs are not related to the decomposition temperature.

2.13.3 Antiwar Additives:

Wear is the loss of metal with subsequent change in clearance between surfaces moving relative to each other. If continued, it will result in equipment malfunction. Among the principal factors causing wear are metal-to-metal contact, presence of abrasive particulate matter, and attack of corrosive acids.

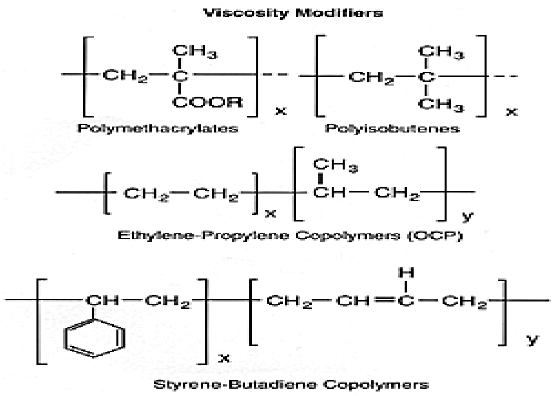
Metal-to-metal contact can be prevented by adding film-forming compounds that protect the surface either by physical absorption or chemical reaction. The zinc dithiophosphates are widely used for this purpose and are particularly effective in reducing wear in valve train mechanisms. These compounds are described under oxidation and bearing corrosion inhibitors. Other effective additives contain phosphorus, sulfur, or combinations of these elements[25.]

Abrasive wear can be prevented by effective removal of particulate matter by filtration of both the air entering the engine and the lubricant during engine operation.

Corrosive wear is largely the result of acidic blowy products formed during fuel combustion. This type of wear can be controlled by using alkaline additives such as basic phonates and sulfonates.

2.13.4 Viscosity Modifiers [25] :

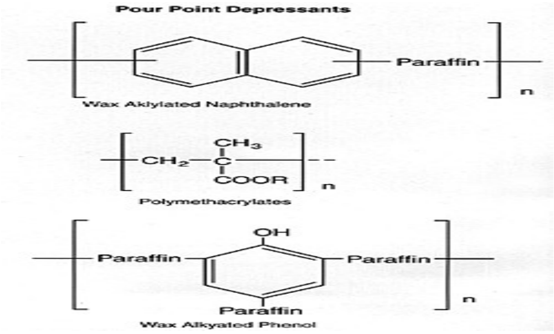
Viscosity modifiers, or viscosity index improvers as they were formerly known, comprise a class of materials that improves the viscosity/temperature characteristics of the lubricant. This modification of rheological properties results in increased viscosity at all temperatures. The viscosity increase is more pronounced at high temperatures, which significantly improves the viscosity index of the lubricant. This is manifested by a decrease in the slope of the viscosity/temperature line plotted on ASTM log paper[5].



Viscosity modifiers are generally oil-soluble organic polymers with molecular weights ranging from about 10,000 to 1 million. The polymer, molecule in solution is swollen by the lubricant, and the volume of the swollen entity determines the degree to which the polymer increases viscosity. The higher the temperature, the larger the volume and the greater the "thickening" effect of the polymer. Hence, the oil tends to "thin" less due to increased temperature. In addition to viscosity improvement, the performance of these polymers also depends on shear stability or resistance to mechanical shear and on their chemical and thermal stability. With a given polymer system, shear stability decreases with an increase in molecular weight. The loss due to shear is reflected in a loss in lubricant viscosity. On the other hand, the "thickening power" of the viscosity modifier increases with an increase in molecular weight for a given polymer type. A performance balance must then be established which takes into consideration shear stability and viscosity needs as well as thermal and oxidative stability in actual engine operation.

2.13.5 Pour Point Depressants:

Pour point depressants prevent the gelation of oil at low temperature. This phenomenon is associated with crystallization of the paraffin wax that is present in mineral oil fractions. To provide low pour points, the refiner removes wax constituents, which solidify at relatively high temperatures, in a process known as dewaxing. Complete dewaxing would reduce the yield of lube oil to an uneconomical level. Therefore, the dewaxing process is supplemented by using additives that lower the pour point of the oil [25] .



Pour point depressants do not prevent wax from crystallizing in the oil. Rather, they are absorbed on the wax crystals and, thus, reduce the amount of oil occluded on the crystal. Reducing the crystal volume permits lubricant flow.

Chapter Three

Materials & Methods

3.0 THESE ARE ACCORDING TO (ASTM) AMERICAN STANDARD FOR TESTING MATERIAL.

1- Flash point D 93 :

Apparatus:

Flash point instrument normal lab analis (**model (NCL 440).**

Procedure:-

The specimen was placed in the cup of the tester and closed with the lid. It was heated at slow constant rate. An ignition source was directed into the cup at regular intervals, the flash point was then taken.

2-Kinematic viscosity D 445:

Apparatus:

Viscometer instrument **(Model luada E200).**

Procedure:

A specific weight of the oil was placed in the viscometer, in a $40C^0$-oil bath and allowed to stand for 15 min; the flow time between the two lines was then recorded.

3-Total Base Number D4739.

Apparatus

Potentiometric instrument, metrohm model (**702smtitrino).**

Procedure:

10 g of the oil sample was dissolved in a 125 ml of the solvent (chloroform-isopropan-toluene). The mixture was then titrated against o.1M alcoholic hydrochloric acid.

4-Density D 1298:

Apparatus:

Manual Hydrometer –thermometer beakers- measuring cylinder.

Procedure

A specific weight of the oil was placed in the in measuring cylinder 500 ml was then calculated temperature of the sample and entered hydrometer inside the sample and the reading was taken at the last line above the sample.

5- Color D1500:

Apparatus:

Comparative box, Lavibond petroleum oil ,model **(pocAF650).**

Procedure:

The degree of the color was recorded using the comparative box.

6- Elements D5863:

Apparatus

Atomic absorption spectrophotometer. Model (800 shimadzu).

Producer:

10 g of the oil sample was heated on flame and then ignited at 775 C^{0} in furnace for 30 min .the crucible was cooled and the ash dissolved in 1:1 diluted hydrochloric acid .the volume was completed to 50 ml .the elements concentration was determined using atomic absorption spectrophotometer.

7- Ash D482

Apparatus:

Crucible- flame- electric muffle furnace **(model s336rb).**

Procedure:

10g of the sample was burnt on the flame in crucible and then ignited in 775 C^0 in furnace for 30 min .the crucible was allowed to cool to room temperature and then weighed.

8- Sulphated ashD874:

Apparatus:

Crucible- flame- electric muffle furnace **(model s336rb).**

Procedure:

10g of the sample was burnt on the flame in crucible and then treated with sulfuric acid and ignited in 775 C^0 in furnace for 30 min, the crucible was allowed to cool to room temperature and then weighed.

9- Carbon residue:

Apparatus

Apparatus:

Crucible- flame- electric muffle furnace **(model s336rb).**

Procedure:

10g of the sample was burnt on the flame in crucible and then ignited in 550 C^0 in furnace for an hour, the crucible was allowed to cool to room temperature and then weighed.

10- X-ray fluorescenceD6481:

Apparatus:

X-ray florescent analyzer. Norma lab analysis **(model(23210N).**

Procedure:

Plastic container was filled with sample and inserted into the device then the reading was then taken.

Chapter four

4.0Result & Discussion

The results and discussions of physical & chemical properties of lubricating oil in Sudanese market as follow:

4.1-viscosity of lube oil:-

Table (4.1) viscosity at40 C ^{0} for gasoline engine oils:

NO	SAMPLES	unused V.40C^0 0 Km	used V.40C^0 3000km	API&SAE
1	VALVOLIN	157	128.77	SL/CF-20W50
2	FUCHS	159.2	162.26	SL/CF-20W50
3	PETRONAS	158	154.1	SM/CF20W50
4	LAMA	161.2	149	SL/CD-20W50
5	TOYOTA	155.46	128.7	SL/CF-20W50
6	TAPPCO	241	173.47	S –SAE 50
7	MASTER	114.1	114	SL/CF-20W50
8	MITISUBISHI	109.86	101.65	SL/CF-20W50

(1)-Viscosities at40 C ^{0} for gasoline oils produced by different companies. Comparing the viscosities of unused with used oils, it is clear that the viscosity of used oils is reduced for all total samples except for Fuchs oil.

(2)- Mechanical or thermal degradation, which reduces the thickening power of the viscosity index improver.

The viscosity is usually reduces due to the following reasons:

1- Dilution by fuel (gasoline or diesel fuel) in engines.

2- Mechanical or thermal degradation, which reduces the thickening power of the viscosity index improver.

The viscosity is usually rises for these reasons;

1- Volatile component evaporation, formed during oxidation.

2- Formation of heavy products formed during oxidation.

3- Oxidation products are polar, and can lead to in-soluble products in suspension on the oil, or deposits.

4- Contamination from outside, such as dust and sand, which are then returned to the oil.

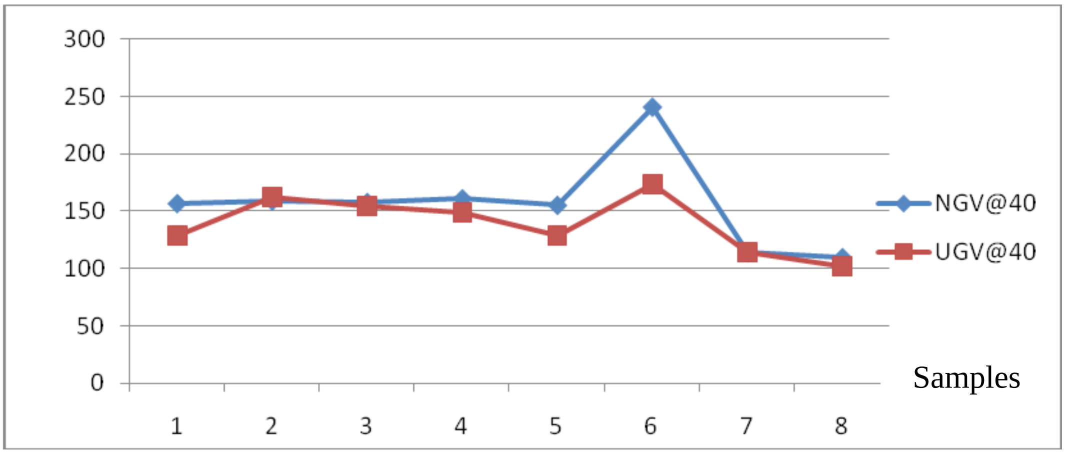


FIG (4.1).VISCOSITY AT 40C^{O} UNUSED&USED GASOLINE OIL

4.2-Viscosity index of lube oils.

:Table (4.2) Viscosity index for gasoline engine oils

NO	SAMPLES	UNUSED V.I 0Km	Used V.I 3000km	API&SAE
1	VALVOLIN	117.2	118.92	SL/CF-20W50
2	FUC	131	116.5	SL/CF-20W50
3	PETRO	113.7	116.9	SM/CF20W50
4	LAMA	136	115.15	SL/CD-20W50
5	TOYOTA	116.2	113	SL/CF-20W50
6	TAPPCO	98.4	114.3	S50
7	MASTER	121.4	116.36	SL/CF-20W50
8	MIS	125.1	138.9	SL/CF-20W50

VI remained steady for all samples except samples for the fresh oil there is a drop in sample (6) Tappco oil.

Whenever the difference in viscosity @40 and 100 C^0 was large, this lead to large viscosity index, but the opposite lead to small viscosity index.

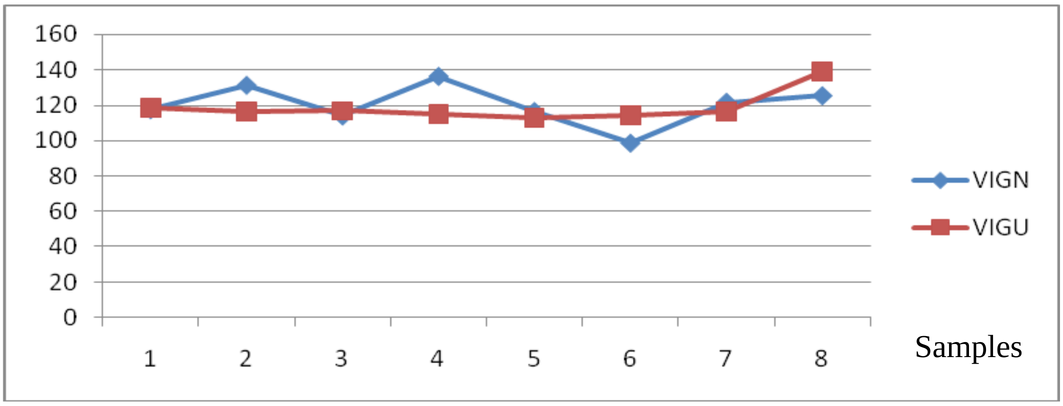


FIG (4.2). VISCOSITY INDEXES UNUSED &USED GASOLINE OIL.

4.3Flash point of lube oils .

Table (4.3) F.P for gasoline engine oils.

NO	SAMPLES	UNUSED F.P.C⁰ O Km	Used F.P C⁰ 3000km	API&SAE
1	VALVOLIN	218	226	SL/CF-20W50
2	FUCHS	228	240	SL/CF-20W50
3	PETRONAS	204	216	SM/CF20W50
4	LAMA	228	218	SL/CD-20W50
5	TOYOTA	238	210	SL/CF-20W50
6	TAPPCO	240	220	S50
7	MASTER	220	210	SL/CF-20W50
8	MITISUBISHI	220	202	SL/CF-20W50

Flash point give less value in used oil than fresh oil except used Fucks oil.

A change in F.p could be due to the possible following reasons:

1. Decreasing in the flash point may be due to solvent (cleaner for engine) or fuel dilution (Gasoline or Diesel fuel).

2-Contamination by solid increasing the F.P.

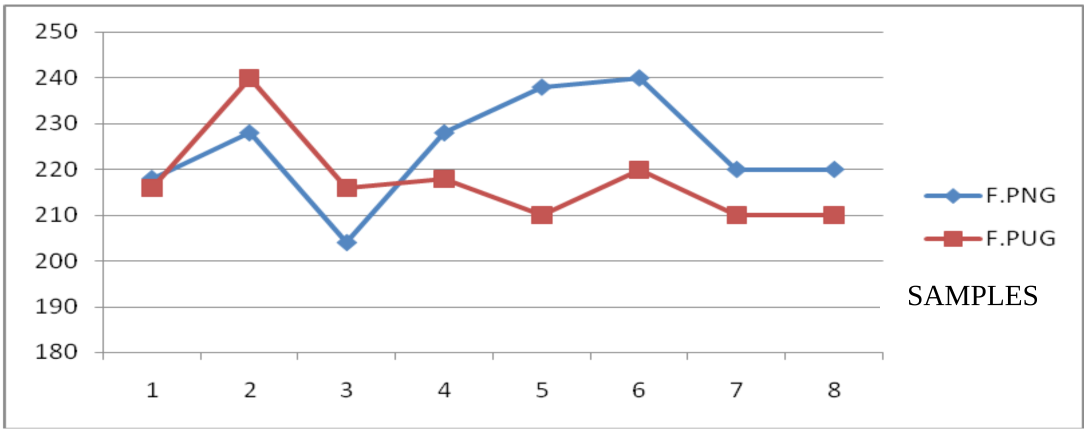


FIG (4.3).FLASH POINT UNUSED&USED GASOLINE OIL.

4.4-Ash content and sulphated ash of lube oil.

Table (4.4) ash and sulphatedd ash for gasoline engine oil

NO	SAMPLES	WHIGH g	unused .ASH % 0 km	Used ASH % 3000 km	New SULFATED ASH%	Used .SULFATED ASH%3000km
1	VALVOLIN	10.0330	1.5%	1.6%	1.11%	10.9%
2	FUCHS	10.1870	1.06%	1.038%	0.82%	0.8%
3	PETRONAS	10.0988	1.8%	1.73%	1.6%	1.5%
4	LAMA	9.9931	1.22%	2.109%	1.12%	1.1%
5	TOYOTA	10.0156	0.727%	1.0%	0.77%	0.78%
6	TAPPCO	10.0082	1.0941	2.0%	0.9352%	0.84%
7	MASTER	10.0005	1.3%	1.4%	0.9785%	0.835%
8	MITISUBSHI	9.9991	0.825%	1.02%	0.76528%	0.90%

Increasing the ash in all total samples used oil.

Increasing the ash & sulphated ash due to oxidation of used oil produces some materials that formed with dust and minerals in oil more ash when burned for testing.

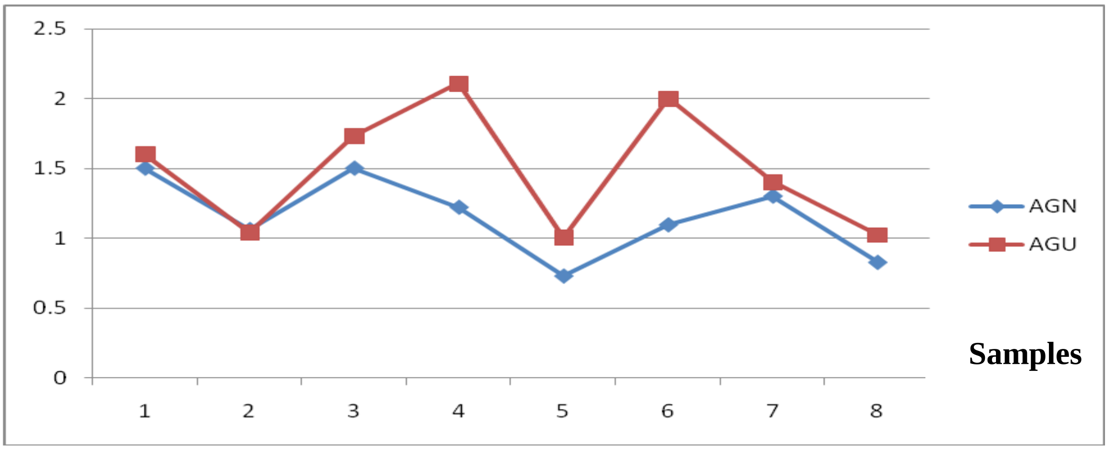
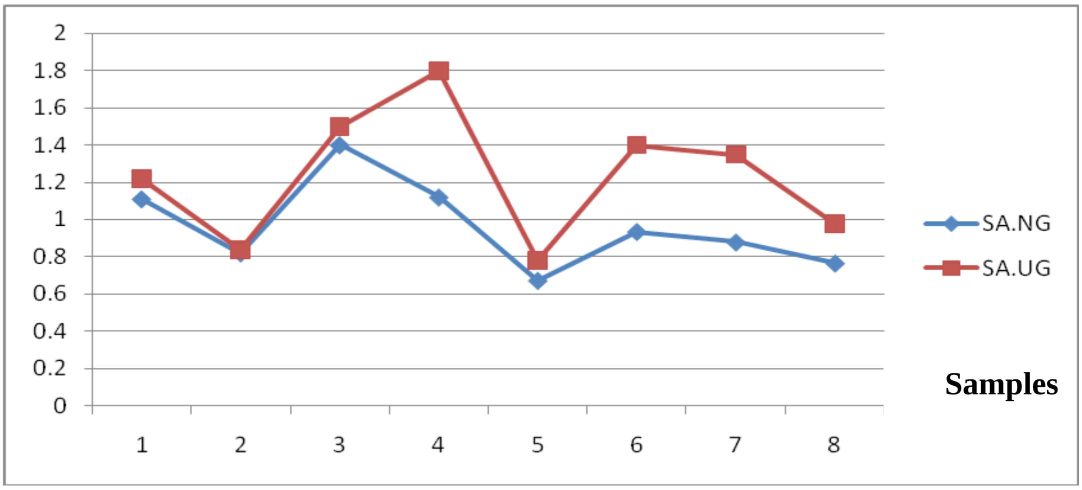


FIG (4.4).ASH UNUSED&USED GASOLINE OIL



.FIG (4.5).SULPHATED ASH UNUSED&USED GASOLINE OIL

4.5-Element additives of lube oils.

Table (4.5) Element additives of gasoline engine oils

NO	SAMPLES	Ca(unused)0Km	Ca(used) 3000Km	Mg(unused) 0Km	Mg(used) 3000Km	Zn(unused) OKm	Zn (used) 3000 Km
1	VALVOLIN	2781	2640	73	28	1669	1548
2	FUC	284.8	254.9	1686	1227	108.7	147
3	PETRO	1994	1875	49	<19	1804	1416
4	LAMA	1753	1673	1694	154	1101	612.9
5	TOYOTA	2849	1688	9.12	20.8	117.8	91.3
6	TAPPCO	3980	3262	204	240	1320	1285
7	MASTER	3964	3005	1761	1018	1026	865
8	MIS	413.7	394.9	1075	1018	1821	1710

Ca, Mg, Zn and P elements were decreased in all used oils. This due to the consumption. **(CONC pp.m).**

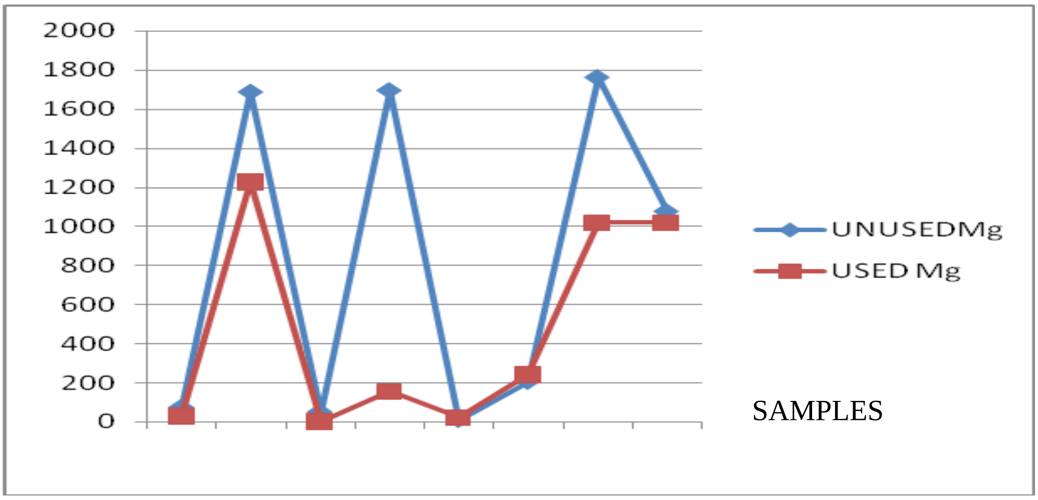


FIG (4.6).Mg- ADDITIVE FOR (UNUSED &USED-OIL(GASOLINE).

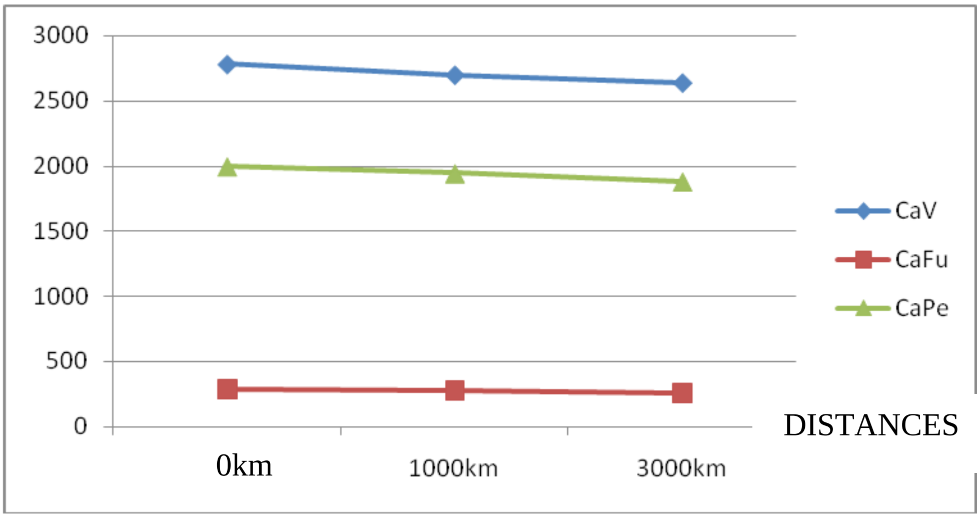
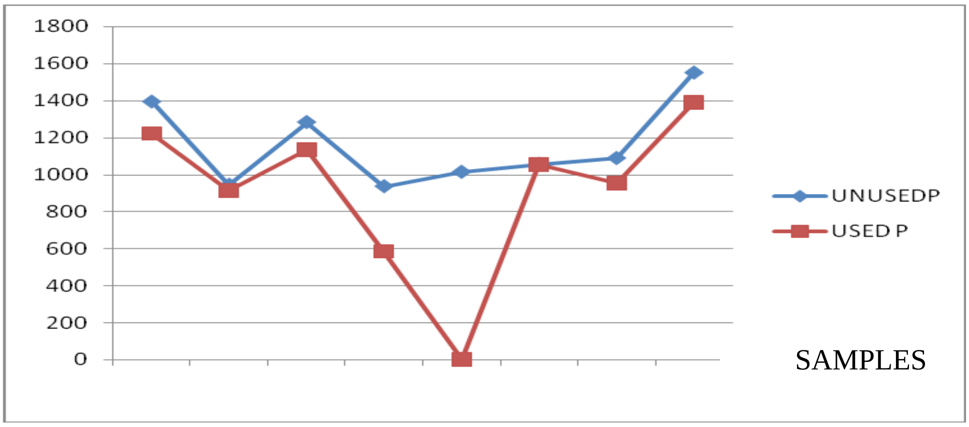


FIG (4.7).ELEMENT ADDITIVE (Ca) FOR UNUSED&USED-OILS (GASOLINE).

Table (4.6) Element additives for gasoline engine oils

NO	SAMPLES	(UNUSED) P 0Km	(used) P 3000km	(UNUSED) S 0Km	(used) S 3000km	(UNUSED) Cl OKm	(used) Cl 3000km
1	VALVOLIN	1395	1222	9240	8226	83.3	142.1

2	**FUC**	**944.1**	**913.4**	**13600**	**7462**	**66.2**	**111.4**
3	**PETRO**	**1284**	**1134**	**3945**	**3982**	**160.3**	**125**
4	**LAMA**	**936.1**	**584.6**	**13560**	**11970**	**143**	**827**
5	**TOYOTA**	**1014**	**163.6s**	**13650**	**4729**	**150**	**86.8**
6	**TAPPCO**	**1058**	**1054**	**7990**	**7929**	**63**	**67.8**
7	**MASTER**	**1089**	**954**	**7809**	**2354**	**99.3**	**54**
8	**MIS**	**1552**	**1391**	**10740**	**9833**	**64.6**	**1224**



.(FIG (4.8). ELEMENT ADDITIVE (P) FOR GASOLINE OIL (UNUSED&USED-OIL

4.6-Total Base Number of lube oils.

Table (4.7) TBN gasoline engine oils.

SAMPLES	TBN UNUSED	TBN

	0Km	USED3000Km
VALVOLIN	**10**	**8**
FUCHS	**6.8**	**6**
PETRONAS	**8**	**6**
LAMA	**9**	**6.3**
TOYOTA	**6**	**3.6**
TAPPCO	**9**	**7.5**
MASTER	**7**	**3.8**
MITISUBISHI	**9**	**8**

It is measured in milligrams of potassium hydroxide per gram (mg KOH/g).

We found that all samples of used oils less base number than the unused oils. Alkaline is lower in the oil used, depending on using and formation of acids (oxidation products).

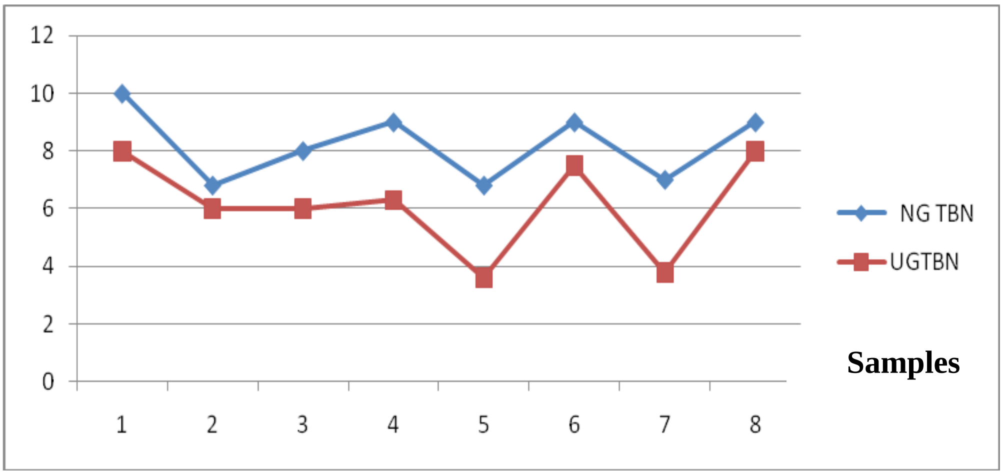


FIG (4.9).TBN. UNUSED&USED GASOLINE OIL.

4.7- Density lube oils.

Table (4.8) Density for gasoline engine oils:

SAMPLES	UNUSEDDENSITY 0Km at52C^0	USEDDENSITY 3000 Km at52C^0
VALVOLIN	**0.8683**	**0.8698**

FUCHS	**0.8671**	**0.8686**
PETRONAS	**.8655**	**0.8745**
LAMA	**0.8655**	**0.8774**
TOYOTA	**0.8620**	**0.8690**
TAPPCO	**0.8690**	**0.8695**
MASTER	**0.8653**	**0.8680**
MITISUBSHI	**0.8675**	**0.8696**

De g/cm ^{3}

All oils used gave the highest density than the new one

Increase in density could be due to the possible following reasons.

1- Oxidation products (water and acids).
2- Combustion products (sludge, varnish and carbon deposits).
3- Heavy metals (Fe, Cu, Pb and Ni).

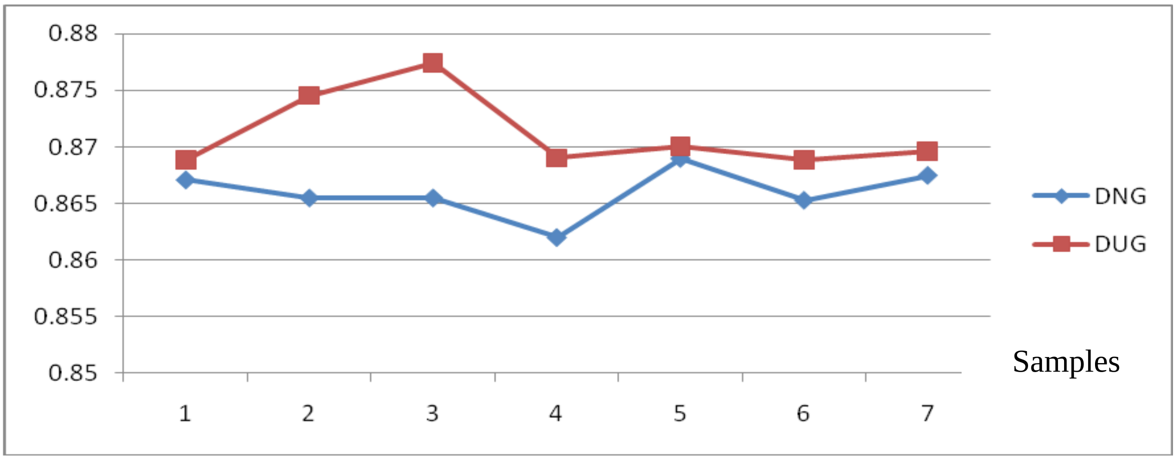


FIG (4.10).DENSITY NEW&USED GASOLINE OIL.

4.8- Elements corrosion(gasoiline).

Table (4.9) Iron in unused &used gasoline engine oils:

SAMPLE	(UNUSED) Fe0Km	(Used)Fe3000Km
FUCKS	NIL	1.678
PETRONAS	NIL	0.98
LAMA	NIL	1.3

MASTER	**NIL**	**1.51**
MISTUBSHI	**NIL**	**1.09**
TAPPCO	**NIL**	**1.75**

Solid particles contaminating oil usually come from many sources:-

1. External contamination, due to the environment around the machine e.g. dust and sand.
2. Particles or corrosion of the lubricated machine.
3. Decomposition products form coking or oxidizing of the lubricant e.g. sludge and deposits.
4. Products from the fuel e.g. lead salts from the gasoline, product of the incomplete combustion of diesel fuel or heavy fuel in diesel engines (soot, carbon).

Metals in the oils:

1. Iron increase indicates either wear or corrosion of steel and cast iron (piston ring, cylinder walls, cams, follower’s gears etc).
2. Proportion of iron, nickel, copper and lead increased in the used oils some oils increase the proportion of lead.

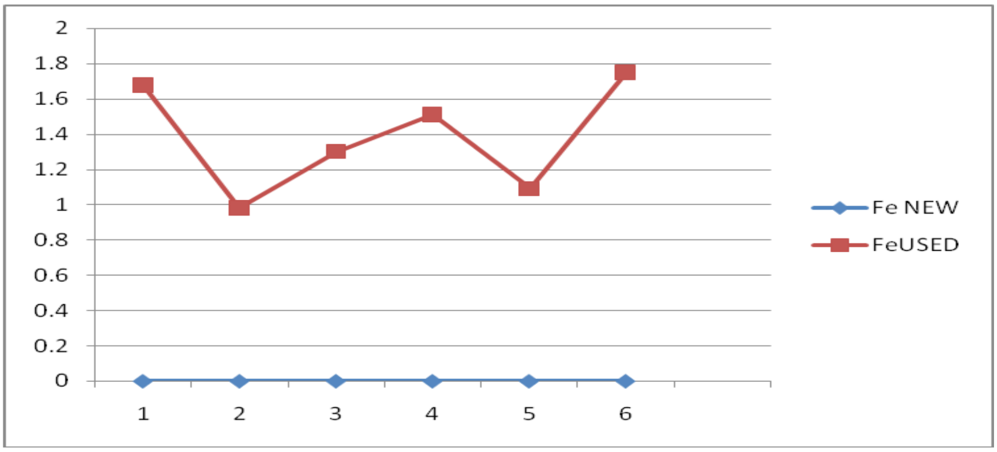


FIG (4.11) Fe-UNUSED & USED GASOLIN OIL

:Table (4.10) Nickel unused & used gasoline engine oils

SAMPLES	(unused) Ni	(Used) Ni	(unused) Cu	(Used) Cu
FUCKS	NIL	NIL	0.021	0.1
PETRONAS	NIL	NIL	0.01	0.05
LAMA	NIL	NIL	0.031	0.095
MASTER	NIL	NIL	0.008	0.067
MISTUBSHI	NIL	NIL	0.05	0.1
TAPPCO	NIL	NIL	0.007	0.13

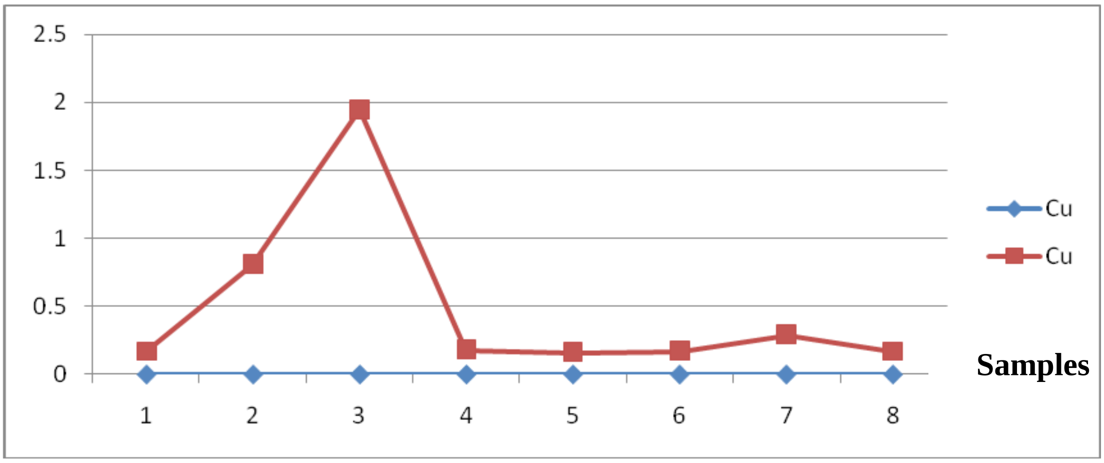


FIG (4.12) CU- UNUSED & USED GASOLIN OIL.

Table (4.11) Pb unused & used gasoline engine oils:

SAMPLES	(unused)Pb	(Used)Pb
FUCKS	NIL	1.08
PETRONAS	NIL	1.25
LAMA	NIL	2.3
MASTER	NIL	0.85
MISTUBSHI	NIL	0.778
TAPPCO	NIL	0.96

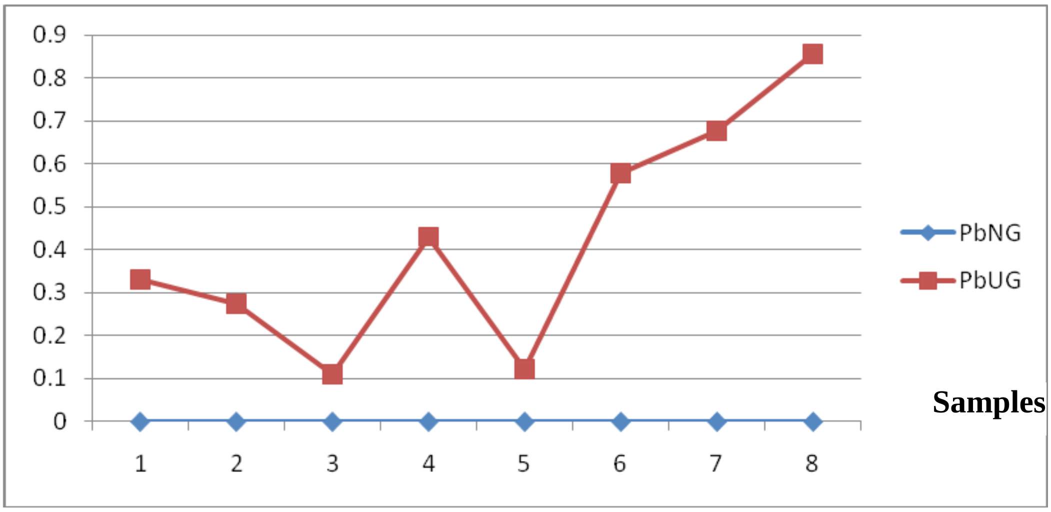


FIG (4.13) Pb- UNUSED & USED GASOLIN OIL

4.9-viscosity at 40 C^0 of lube oils .

.**Table (4.12) Viscosity at 40 C^0 for diesel engine oils**

NO	SAMPLES	V̊.40C- Sct	V̊.40CSct	API&SAE

		Km zero	3000km	
1	FUC	109.2	116	CL/SF-20W50
2	PETRO	110	136.5	Cf-4/SF
3	LAMA	227.6	112.2	CF/SF 50
4	MASTER	109.2	115.2	CL/SF-20W50
5	MIS	107.63	109.5	CF/SF
6	TABCO	240.2	203.2	CH4 -50

The viscosity of used oils is increased for all total samples except for sample (3) lama and sample (6) Tappco .

The viscosity usually rises for these reasons:

1-Volatile component evaporation, formed during oxidation.

2-Formation of heavy products formed during oxidation.

3 -Oxidation products are polar, and can lead to in-soluble products in suspension on the oil, or deposits.

4-Contamination from outside, such as dust and sand, which are then returned to the oil.

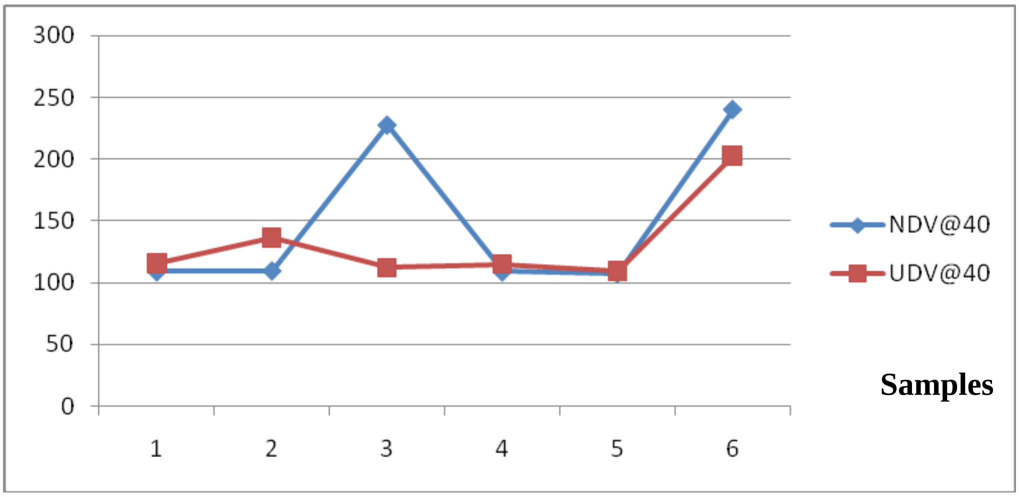


FIG (4.14) VISCOSITY@40C^{O} UN USED&USED DIESEL OIL.

4.10- VI, of lube oils.

:Table (4.13) VI, for diesel engine oils

NO	SAMPLES	Unused V.I	Used V.I
1	FUC	147	137.25
2	PETRO	137	125.2
3	LAMA	103	118.3
4	MASTER	147	132.2
5	MIS	126.67	127.38
6	TABCO	106	113.18

VI remained steady for all samples except samples for the fresh oil there is a drop in sample (6) Tappco oil. (3) Lama oil.

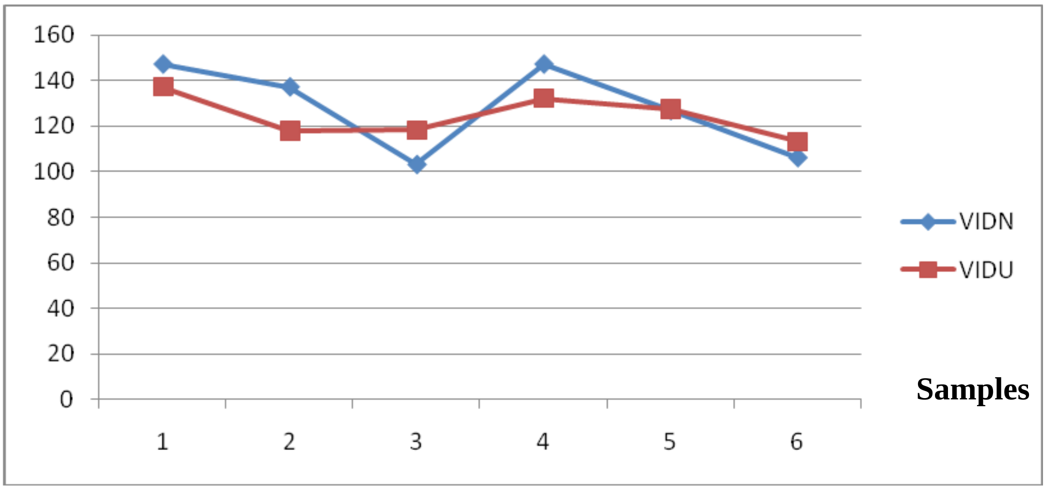


FIG (4.15) VI NEW&USED DIESEL OIL

4.11-Flash point for diesel engine oils.

.Table |(4.14) Flash point for diesel engine oils

NO	SAMPLES	F. P.C^0	F.P. C^0	API&SAE

		0Km	3000Km	
1	**FUC**	**230**	**218**	**CF/SF-20W50**
2	**PETRO**	**216**	**210**	**MOTCCH4**
3	**LAMA**	**240**	**226**	**CF/SF 50**
4	**MASTER**	**228**	**230**	**CF/SF-20W50**
5	**MIS**	**220**	**225**	**CF/SF**
6	**TABCO**	**250**	**204**	**CH4 -50**

F.P of used oils are reduced except sample (5) Mitsubishi.

A change in FP could be due to the possible following reasons:

1 Decreasing in the flash point may be due to solvent (cleaner for engine) or fuel dilution (Gasoline or Diesel fuel).

2-Contamination by solid increasing F.P.

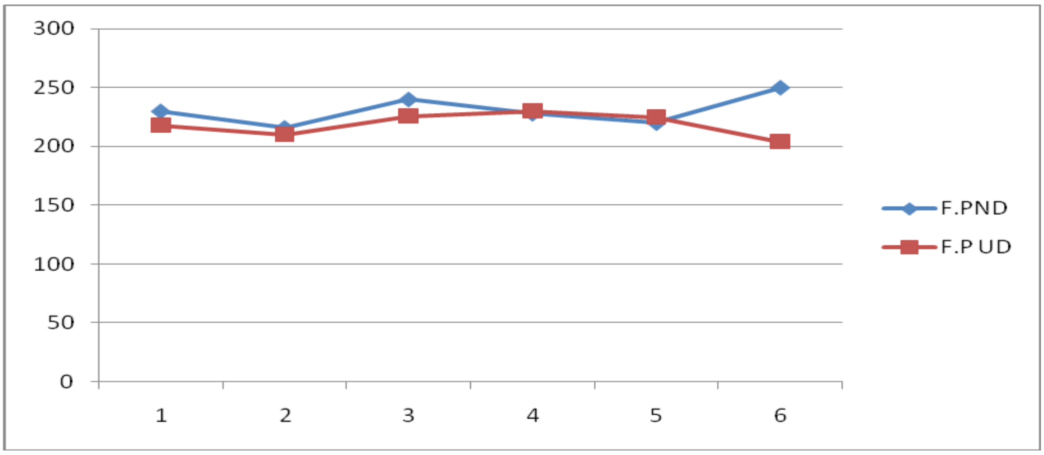


FIG (4.16) FLASH POINT UNUSED&USED DIESEL OIL.

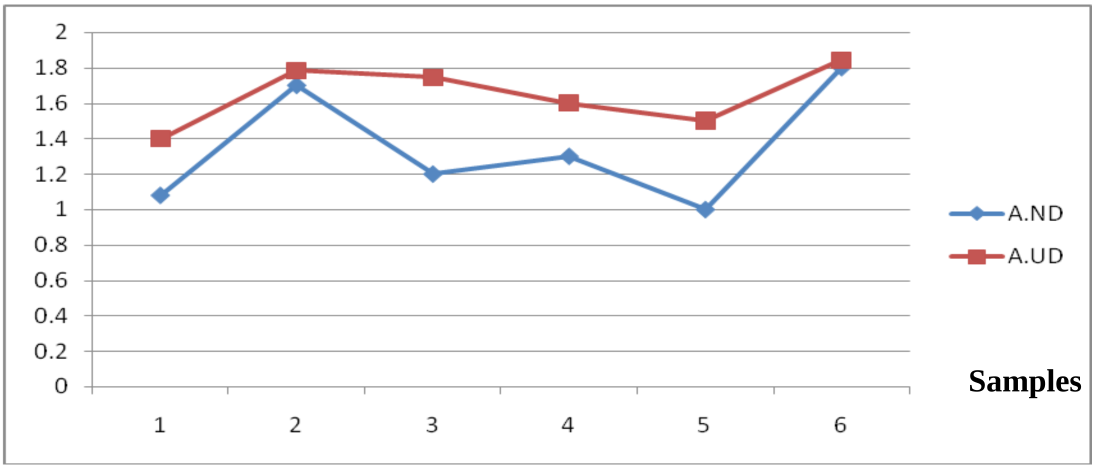
4.12-Ash content, sulphated ash of lube oils.

.Table (4.15) Ash content&sulphated ash for diesel engine oils

NO	SAMPLES	WHIGH g	UNUSED .ASH %	Used ASH % 3000 km	UNUSED SULFATED ASH %	Used .SULFATED ASH%3000km
1	FUC	10.0784	1.99%	2.4	1.865%	1.996
2	PETRO	7.04	1.08	1..685	1.03	1.0227
3	LAMA	9.005	1.2	1.746	1.16	1.6603
4	MASTER	10.0008	1.3	1.6	1	1.95
5	MIS	10.0210	1.00	1.5	0.970	1.15
6	TABCO	10.0007	1.8	1.8421	1.16	1.4871

Increasing the ash in all samples used oil.

Increasing the ash & sulphated ash due to Oxidation of used oil produces some materials that formed with dust and minerals in oil more ash when burned for testing.



% ASH

FIG(4.17)ASH CONTENT NEW&USED DIESEL OIL.

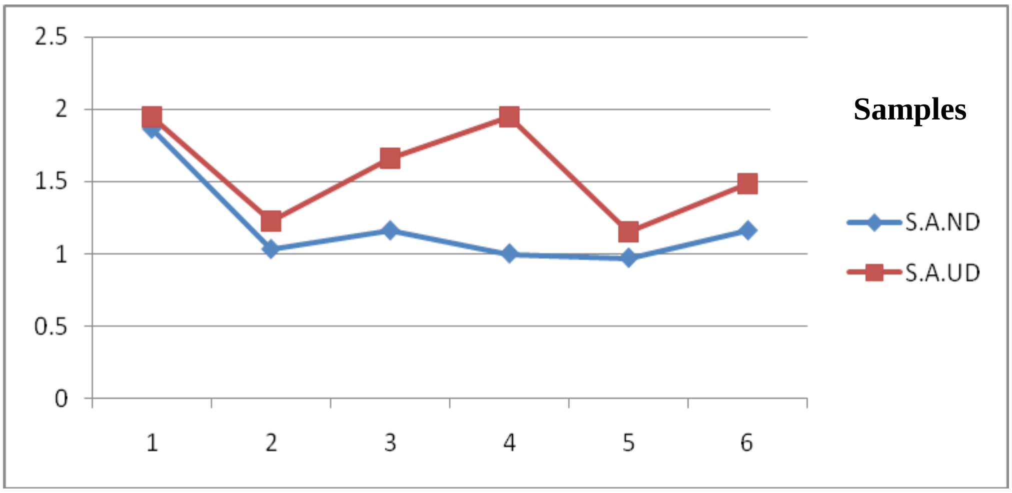


FIG (4.18) SULPHATED ASH unused USED DIESEL

4.13-Element additives for diesel engine oils.

.Table (4.16) Element additive for diesel engine oils

NO	SAMPLES	Ca(UNUSED)	Ca(used)	Mg(UNUSED)	Mg(used)	(UNUSED)Zn	(used)Zn
1	FUCHS	3393	2534	163	160	1626	1315
2	PETRONAS	2375	1599	226	149	1434	609.1
3	LAMA	2691	2205	1958	149	742.6	1888
4	MASTER	2996	3741	137	125	1306	1281
5	MISTUBISHI	2307	3048	218	206	1162	1423
6	TAPPCO	3765	3741	189	125	1335	1281

Ca, Mg, Zn and P are reduced in all used oils samples due to the consumption

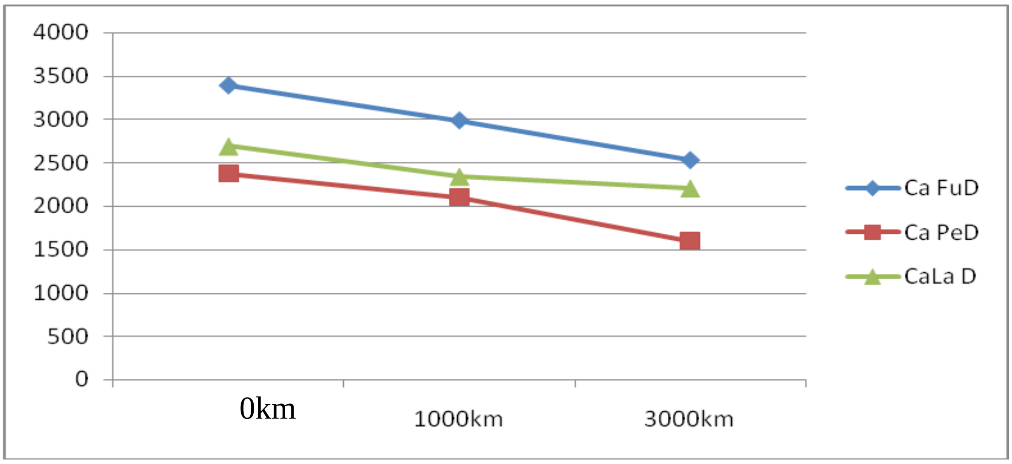


FIG (4.19) Ca UNUSED &USED DIESEL OIL

.Table (4.17) Element additive for diesel engine oils

NO	SAMPLES	(UNUSED) P	(used) P 3000km	(UNUSED) S	(used) S 3000km	(UNUSED) Cl	(used) Cl 3000km
1	FUCHS	1340	1076	8256	5337	44	149.8
2	PETRONAS	1225	1129	4138	11960	112.7	136.3
3	LAMA	566.8	490	15040	10620	5.1	119.5
4	MASTER	1359	565	842.3	6255	133.8	85
5	MITISUBISHI	978.9	113.6	9889	10440	25.2	144.7
6	TAPPCO	1456	565	113	6255	56.6	85

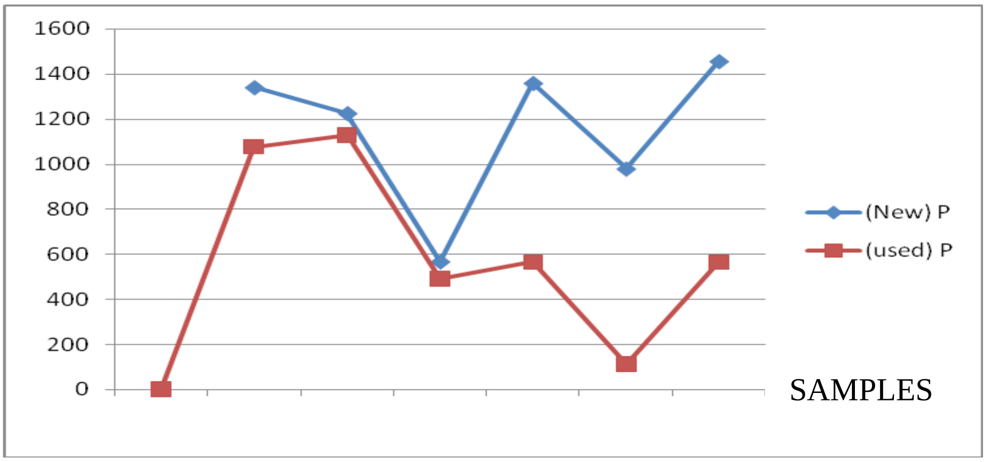


FIG (4.20) P UNUSED &USED DIESEL OIL

4.14-Total Base Number for diesel engine oils.

Table (4.18) TBN diesel engine oils.

SAMPLES	TBN UNUSED 0Km	TBN USED3000Km
FUCHS	10	6.5
PETRONAS	11.5	5.9
LAMA	10	4.5
MASTER	10	5.5
MITISUBISHI	11	7
TAPPCO	12	8.53

We found that all samples of used oils less base number than the new oils, due to, consumption of the base materials (Ca & Mg) and the acids resulting from oxidative stress.

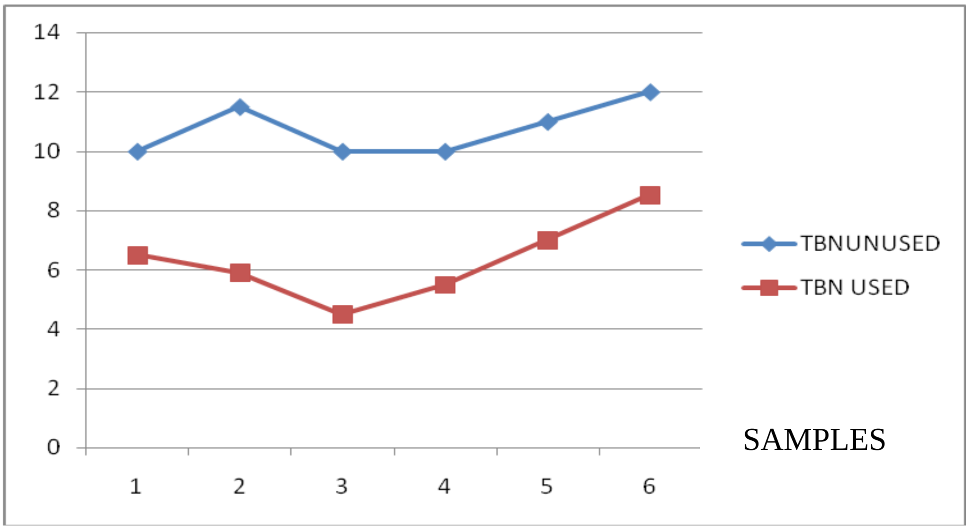


FIG (4.21) TBN FOR UNUSED &USED DIESEL OILS

4.15-Density lube oils.

Table (4.19) Density for diesel engine oils:

SAMPLE	DE-NEWat 52c0Km	DE-USED OIL 3000Km
FUCHS	0.8651	0.87645
PETRONAS	0.8665	0.8684
LAMA	0.8700	0.8890
TAPPCO	0.8860	0.8970
MASTER	0.8652	0.8765
MITISUBSHI	0.8880	0.8980

All oils used gave the highest density than the new one.

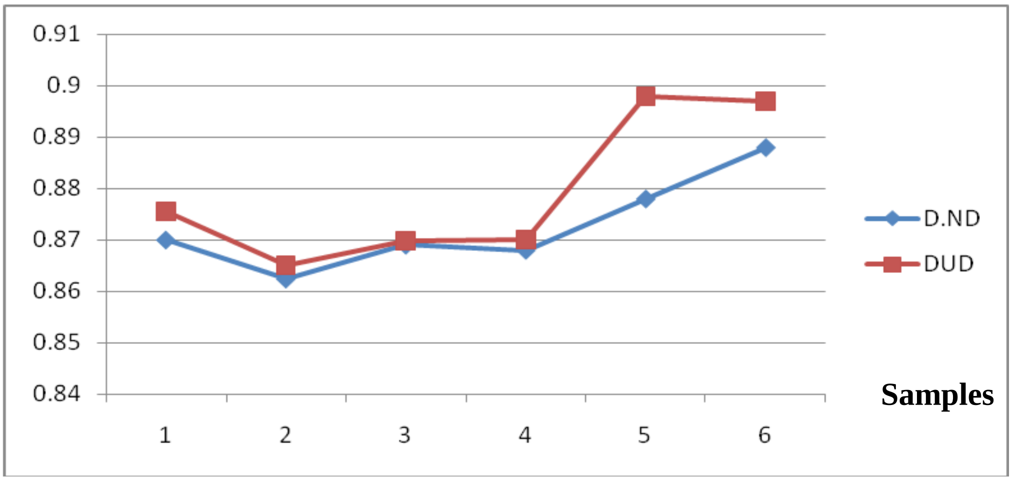


FIG (4.22) DENSITY UNUSED&USED DIESEL OIL

4.16-Elements corrosion for diesel engine oils (Fe, Cu and Pb).

Table (4.20) Elements Fe, Cu and Pb.

SAMPLE	Fe-UNUSED0Km	FeUSED3000Km
FUCHS	NIL	1.678
PETRONAS	NIL	0.98
LAMA	NIL	1.3
MASTER	NIL	1.51
MITISUBISHI	NIL	1.09
TAPPCO	NIL	1.75

Iron increase indicates either wear or corrosion of steel and cast iron (piston ring, cylinder walls, cams, follower's gears etc).

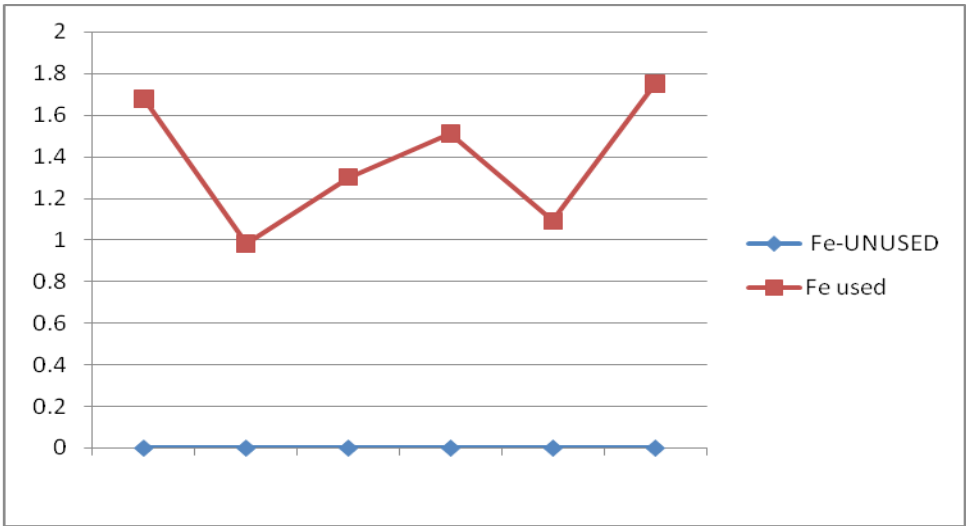


FIG (4.23) Fe CORROSION

Table (4.21) elements corrosion :

SAMPLE	Ni –UNUSED 0Km	Ni-USED 3000Km	Cu-UNUSED 0Km	Cu-USED 3000Km	Pb-UNUSED 0Km	Pb-USED 3000Km
FUCHS	**NIL**	**NIL**	**0.021**	**0.1**	**NIL**	**1.08**
PETRONAS	**NIL**	**NIL**	**0.01**	**0.05**	**NIL**	**1.25**
LAMA	**NIL**	**NIL**	**0.031**	**0.095**	**NIL**	**2.3**
MASTER	**NIL**	**NIL**	**0.008**	**0.067**	**NIL**	**0.85**
MITISUBSHI	**NIL**	**NIL**	**0.05**	**0.1**	**NIL**	**0.778**
TAPPCO	**NIL**	**NIL**	**0.007**	**0.13**	**NIL**	**0.96**

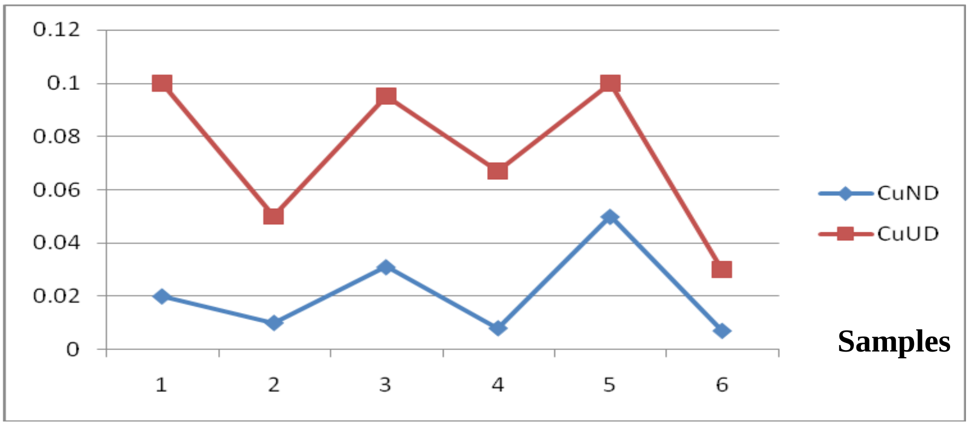


FIG (4.24) Cu IN DIESEL OIL.

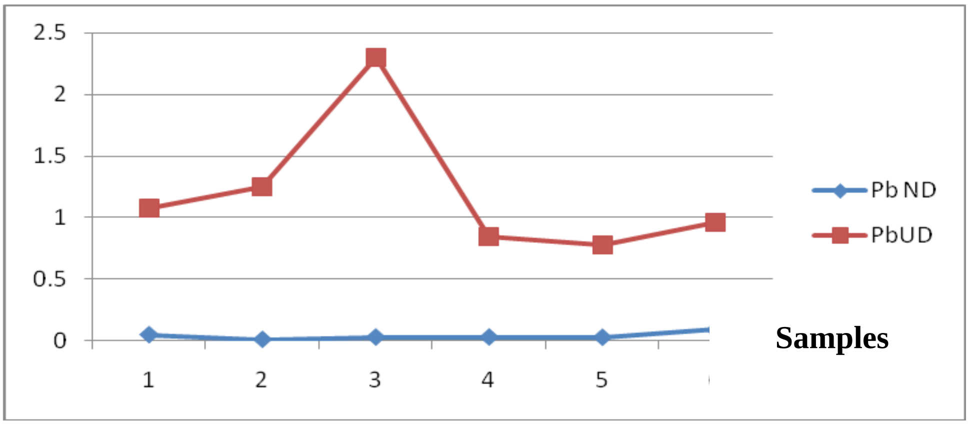


FIG (4.25) Pb IN DIESEL OIL

4.17-Extent of usage and propereties of Total rubiaS50 mono grade.

Table (4.22) propereties of Total rubiaS50 mono grade:

1-Viscosity at $40C^0$andTBN for TOTAL RUBIA BS50 (monograde) diesel engine oils.

Properties/distance	O Km	1000 Km	3000 Km
VISCOSITY100C^O	20	22	69.4
TBN	12	11.8	11.11
Ca (pp.m)	4800	4759	4477
Zn (ppm)	1260	1220	1199
P (ppm)	889	881	838
Fe (ppm)	0	310	662
Pb (ppm)	0	36	97
Si (ppm)	1.3	98	153
Cu (ppm)	0	21	57
Mg (ppm)	59	52	43

The viscosity is increased ,due to distances traveled where the result of combustion products, oxidative stress and other external pollutants e.g. silica, were the main reasons to that viscosity increase.

We found that all samples of used oils less base number than the unused oils. Alkaline is lower in the oil used, depending on using and formation of acids (oxidation products).

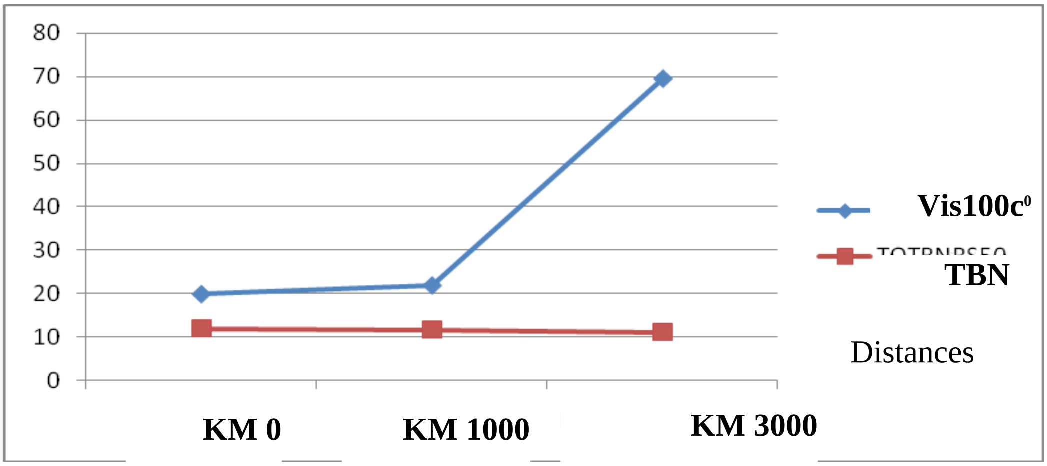


FIG (4.26)-TOTAL OIL R S50 VISCO. & TBN

2-Element additives for TOTAL RUBIA S50 (monograde) diesel engine oils.

All element additives are decreased with distances increasing, due to the consumption and the formation of acids.

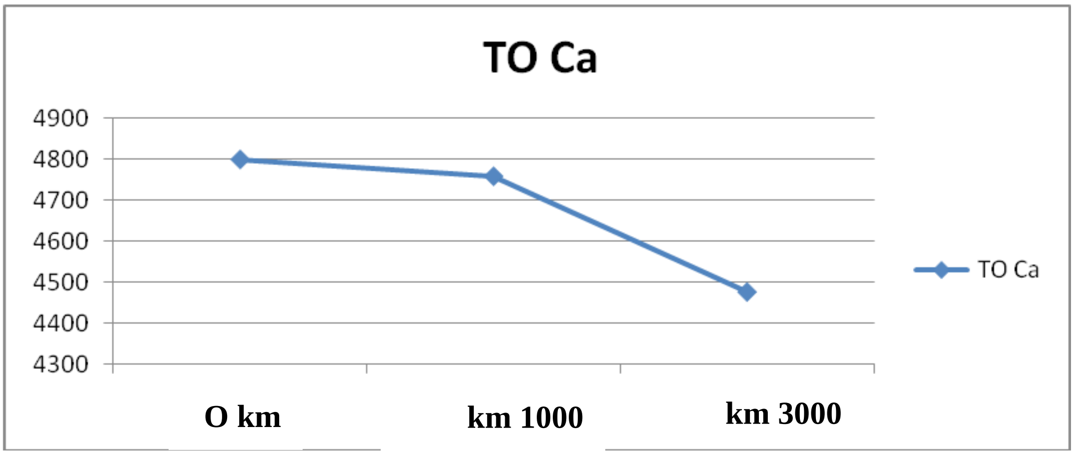


FIG (4.27) **Element additive (Ca)**

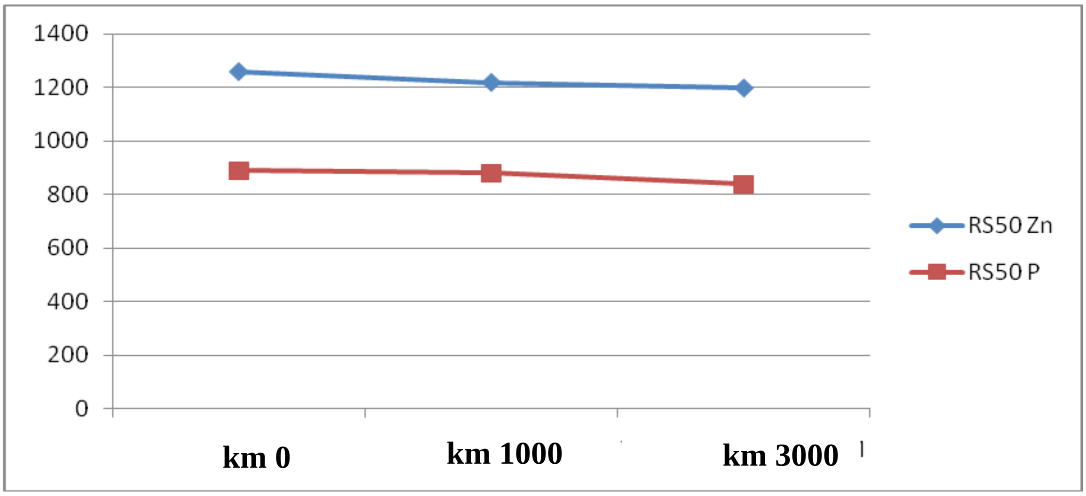


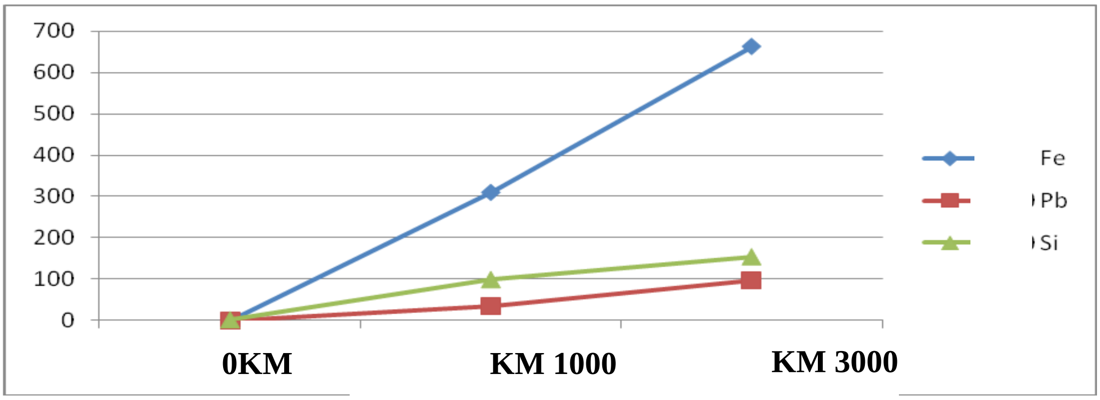
FIG (4.28) TOTAL RS50 (Zn & P) ELEMENT ADDITIVES (unused& used OILS).

3- Elements contaminants for RS50.

All metals contaminant are increased on used oils ,due to solid particles contaminating oil usually come from many sources:-

1. External contamination, due to the environment around the machine e.g. dust and sand.
2. Particles or corrosion of the lubricated machine.
3. Decomposition products form coking or oxidizing of the lubricant e.g. sludge and deposits.

4. Products from the fuel e.g. lead salts from the gasoline, product of the incomplete combustion of diesel fuel or heavy fuel in diesel engines (soot, carbon).



FIG(4.29)TOTAL RS50 Fe, Si & Pb ELEMENTS CONTAMINATES (unused& used OILS)

4.18- Extent of usage and properties of Total diesel engine oil (multi-grade)

Table(4.23) properties of Total Total 15w40 diesel oil

Properties/distance	O KM	1000 KM	4000 KM	5000 KM
VISCOSITY100C^{O}	14.5	13.8	13.37	13.29
TBN mg/KOH	13	12.16	12.16	12
Ca (ppm)	4812	4352	4032	3814
Zn(ppm)	1450	1378	1258	1227
P(ppm)	1510	1021	992	975
Fe(ppm)	0	25	17	17
Pb(ppm)	0	3.6	12	22
Si(ppm)	.39	1.5	5	5
Mg(ppm)	37	25	17	17
Cu(ppm)	0	1.2	5	7

1- Viscosity at 100 C^{0} andT BN for total diesel engine oil.

The Viscosity at 100C^{0} and TBNare decreased , due to the reasons as following:-

1- Dilution by fuel (gasoline or diesel fuel) in engines (Viscosity decreased).

2- Mechanical or thermal degradation, which reduces the thickening power of the viscosity index improver (Viscosity decreased).

3- Alkaline is lower in the oil used, depending on using and formation of acids -oxidation products-(TBN decreased).

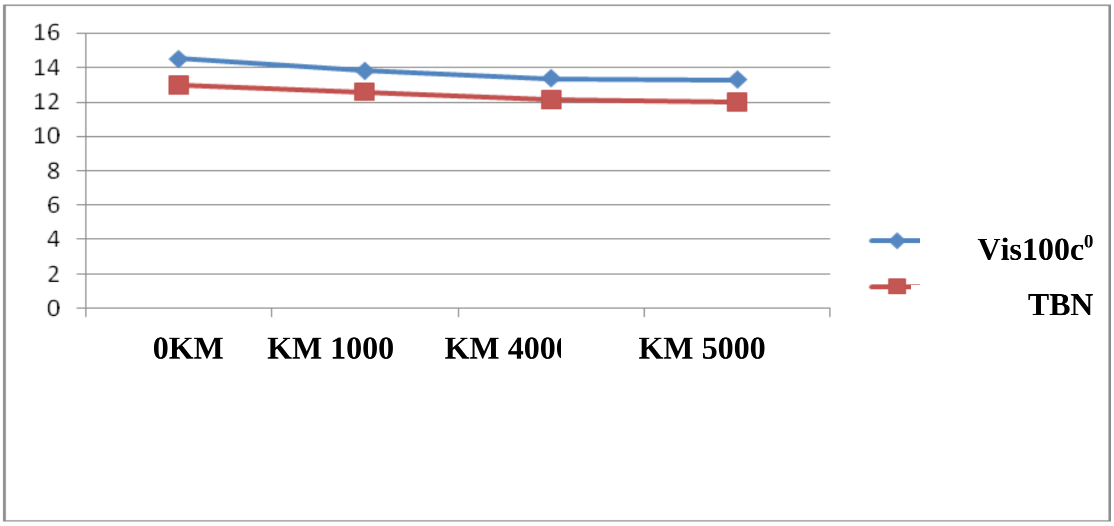
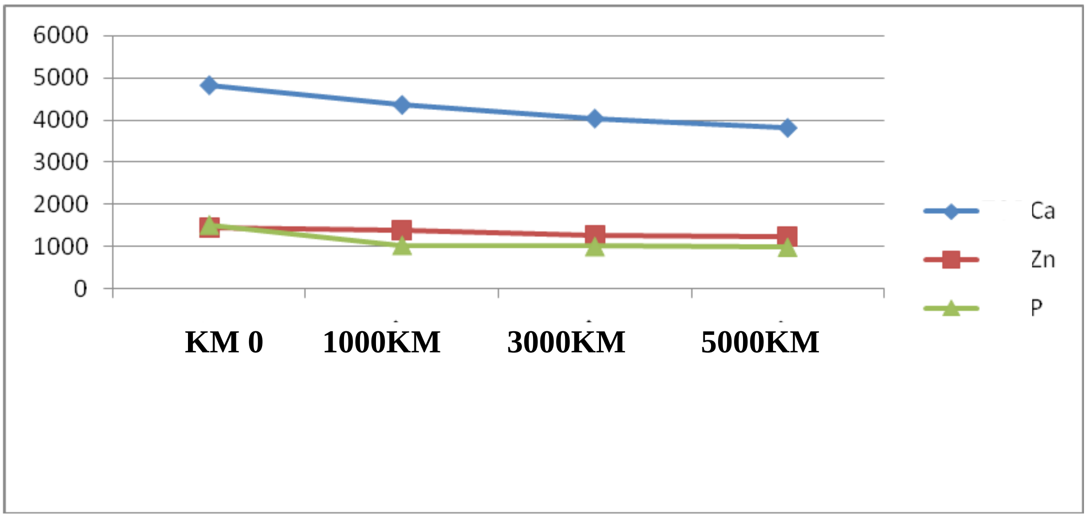


FIG (4.30) TOTAL DIESEL 15W40 VISCOSITY& TBN (UNUSED&USEDOILS).

2- Element additives total diesel oil .

All element additives are decreased in used oils , due to the consumption and the formation of acids.



FIG(4.31)TOTAL DIESEL 15W40 Ca, Zn & P ELEMENT ADDITIVE.S (N& U OILS).

All metals contaminant are increased on used oils ,due to solid particles contaminating oil usually come from many sources:-

1. External contamination, due to the environment around the machine e.g. dust and sand.
2. Particles or corrosion of the lubricated machine.
3. Decomposition products form coking or oxidizing of the lubricant e.g. sludge and deposits.
4. Products from the fuel e.g. lead salts from the gasoline, product of the incomplete combustion of diesel fuel or heavy fuel in diesel engines (soot, carbon).

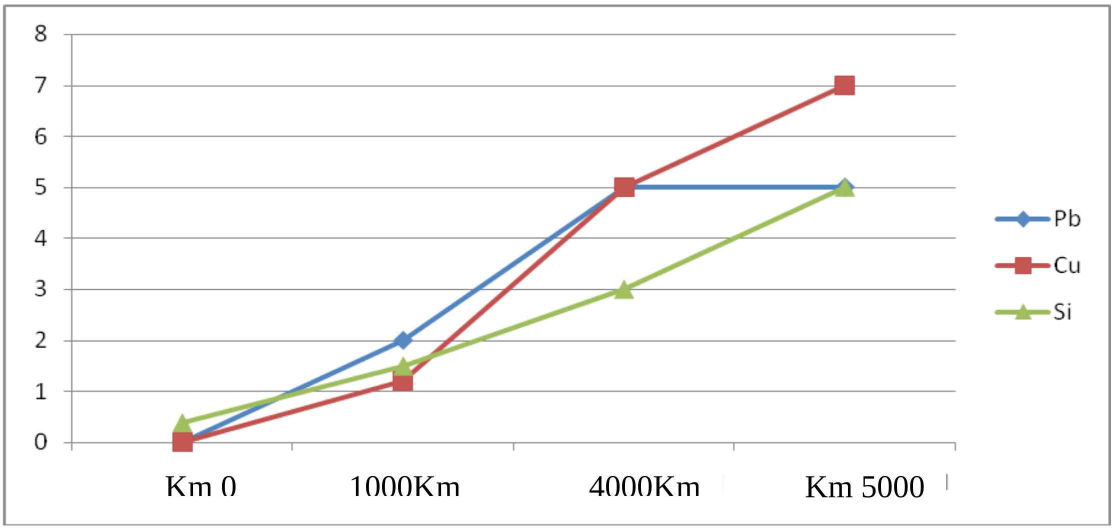


FIG (4.32)-TOTAL D15W40 (Pb, Cu &Si) ELEMENTS CONTAMINATES

4.19- Properties of Mitsubishi diesel engine oil.

Table (4.24) Properties of Mitsubishi diesel engine oil:

Properties/distance	O KM	KM 1000	KM 3000	km 5000
VISCOSITY100C^{O}	14.69	14.8	15	12.37
TBN mg/KOH	11	9.5	9	8.5
Ca (ppm)	3307	3300	3048	1761
Zn(ppm)	162	1142	1123	1120
P(ppm)	1178.9	1151	1136	666.7
Fe(ppm)	0	1.2	1.9	2.7
Pb(ppm)	0	0.48	0.95	2.07
Si(ppm)	0.85	1.1	1.3	1.6
Mg(ppm)	218	211	206	190
Cu(ppm)	0	0.1	0.8	1.99

1-viscosity and TBN:

The viscosity is increased from 0km to 4000km for these reasons;

1-Volatile component evaporation, formed during oxidation.

2 -Formation of heavy products formed during oxidation.

3- Oxidation products are polar, and can lead to in-soluble products in suspension on the oil, or deposits.

4-Contamination from outside, such as dust and sand, which are then retended to the oil .

The viscosity is decreased from 4000km to 5000 km, due to the following reasons:

1- Dilution by fuel (gasoline or diesel fuel) in engines.

Mechanical or thermal degradation, which reduces the thickening power of the viscosity index improver.

2-TBN is decreased, due to the using and formation of acids (oxidation products).

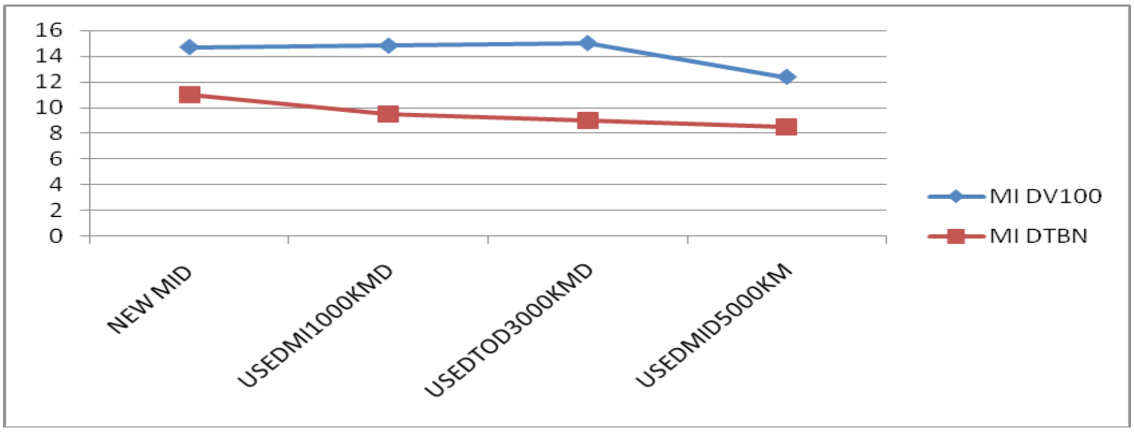


Figure (4.33) viscosity at 100 C^0 and TBN for MiTSIBSHI diesel engine oil

2- Element additives for Mits diesel oil.

All element additivesare decreased in all used oils samples due to the consumption .

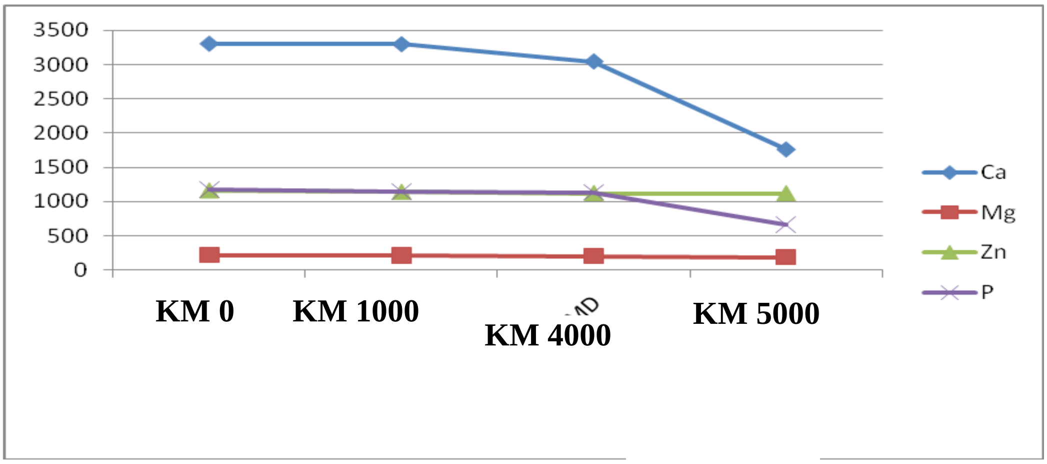


FIG (4.34) - MI DIESEL 15W40 (Ca, Mg, Zn & P) ADDITIVES (UNUSED& USED OILS).

4.20-Element contaminants for Mitsubishi diesel oil.

All elements contaminats are increased on used oils ,due to the solid particles contaminating oil usually come from many sources:-

1. External contamination, due to the environment around the machine e.g. dust and sand.
2. Particles or corrosion of the lubricated machine.
3. Decomposition products form coking or oxidizing of the lubricant e.g. sludge and deposits.
4. Products from the fuel e.g. lead salts from the gasoline, product of the incomplete combustion of diesel fuel or heavy fuel in diesel engines (soot, carbon).

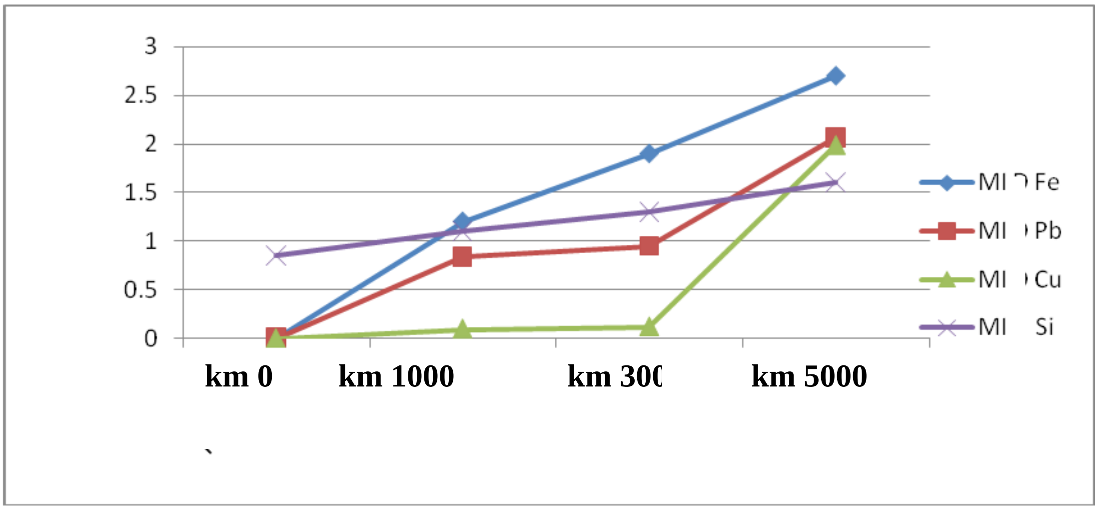


FIG (4.35) MI DIESEL (Fe, Cu, Pb & Si) ELEMENTS CONTAMINATES (N& U OILS).

4.21- INFRARED SPECTRA (UNUSED &USED OIL).

:Table (4.25) IR .ABSORBTION

UNUSED F.UCHSGASOLINPEACKS	USED FUCHS GASOLIN PEACKS	UNUSEDTOTAL PEACKS	USED TOTAL PEACKS
3583.49	3583.49	3622.07	3612.42
3170.76	3172.53	3159.18	ABSENT
2921.96	2921.96	2921.96	2921.96
…………..	2852.52	2725.23	2725.23
2727.76	2725.23	2304.78	2300.92
…………	2341	1703.03	1703.03
1706.88	1706.88	1595.02	1598.86
1600.61	1602.74	1458.06	1458.06
1456.16	1460.01	1367.44	1373.22
1377.08	1377.08	………….	1307.65
1305.72	1303.79	1161.07	1161.07
1157.21	1155.28	968.2	ABSENT
975.91	ABSENT	871.76	ABSENT
813.9	813.90	817.76	813.90
721.33	721.33	730.97	729.04
439.74	468.67	551.6	ABSENT
		424.31	435.88

However, caution is needed in interpreting the band 1700-1800 cm. Many additives in the oil have functional oxygen groups, it is essential to compare the spectrum of the used oil with that of the new oil, on order to assess oxidation, which also absorb in these bands.

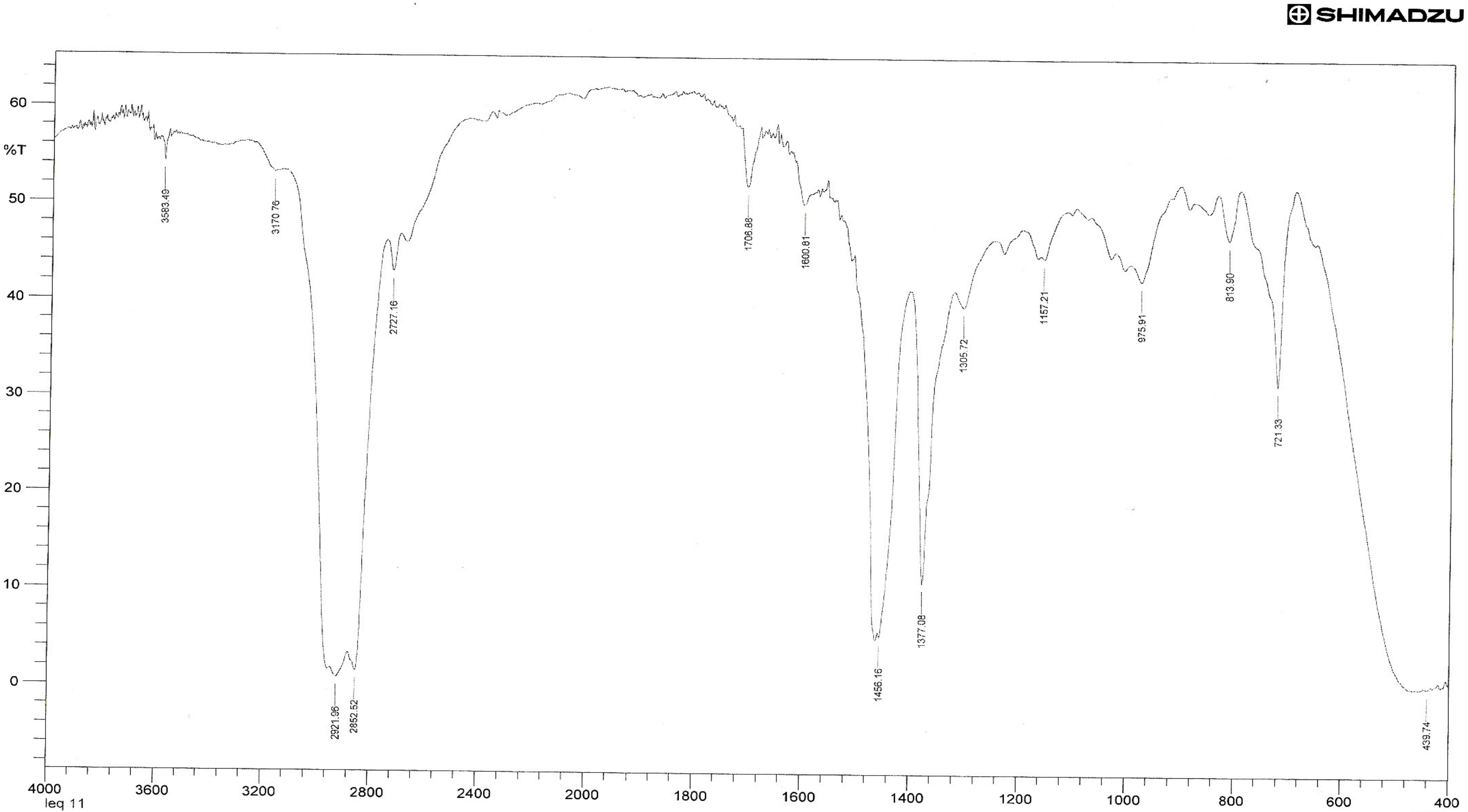
1- Infrared spectra of unused& used Fuchs gasoline engine oil.

A peak 2852.52 and 2341(wave number) are appeared in the used oils (Fuchs), due to oxidation or chemical reaction and peak 975.91 is absent, due to consumption.

2- Infrared spectra of diesel unused & used total.

Peak 1307.07 is appeared on the used oil due to oxidation or chemical reaction.

In addition, 968.2, 8177.6 and 551.6 are absent, due to consumption.



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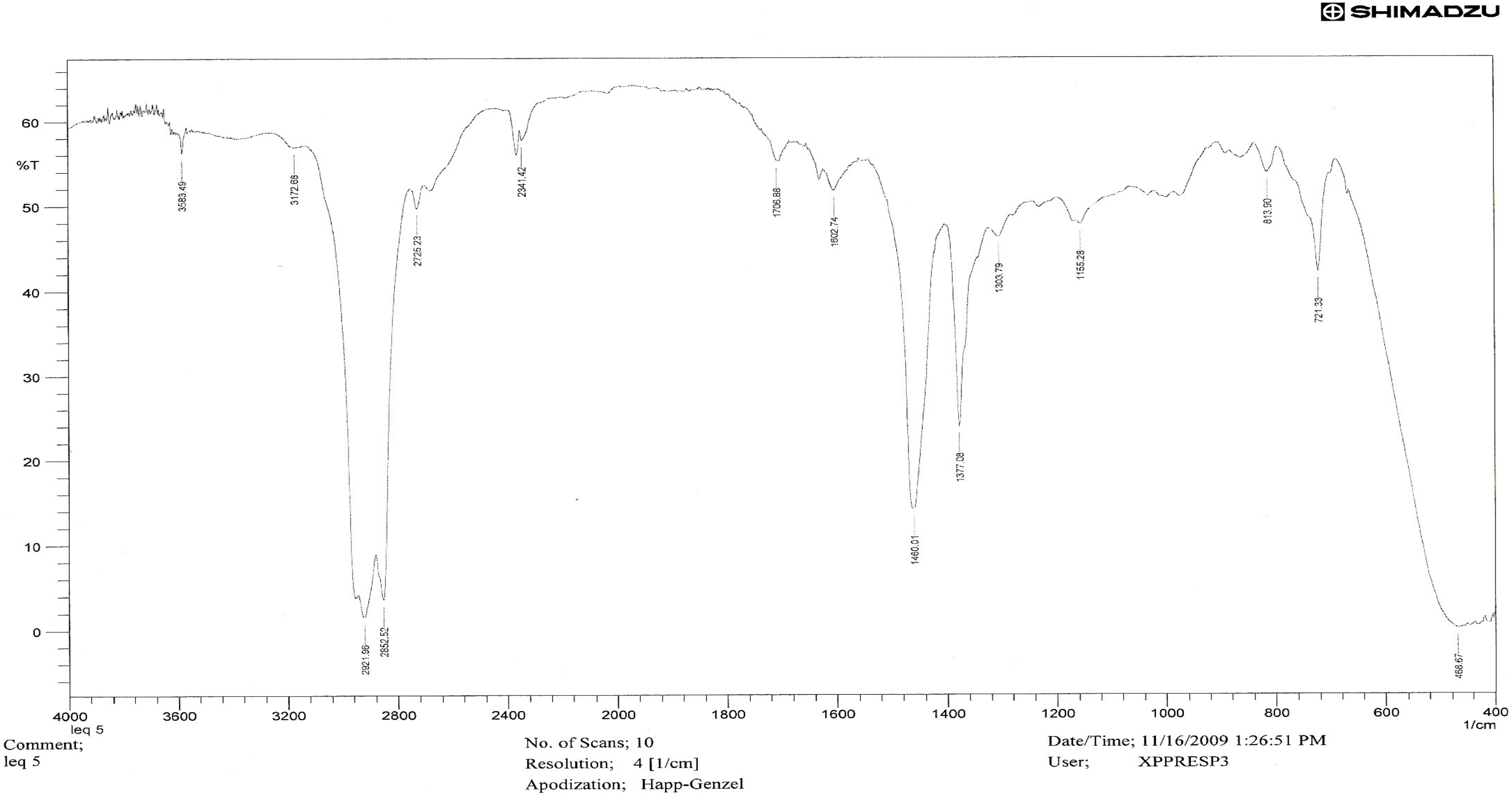
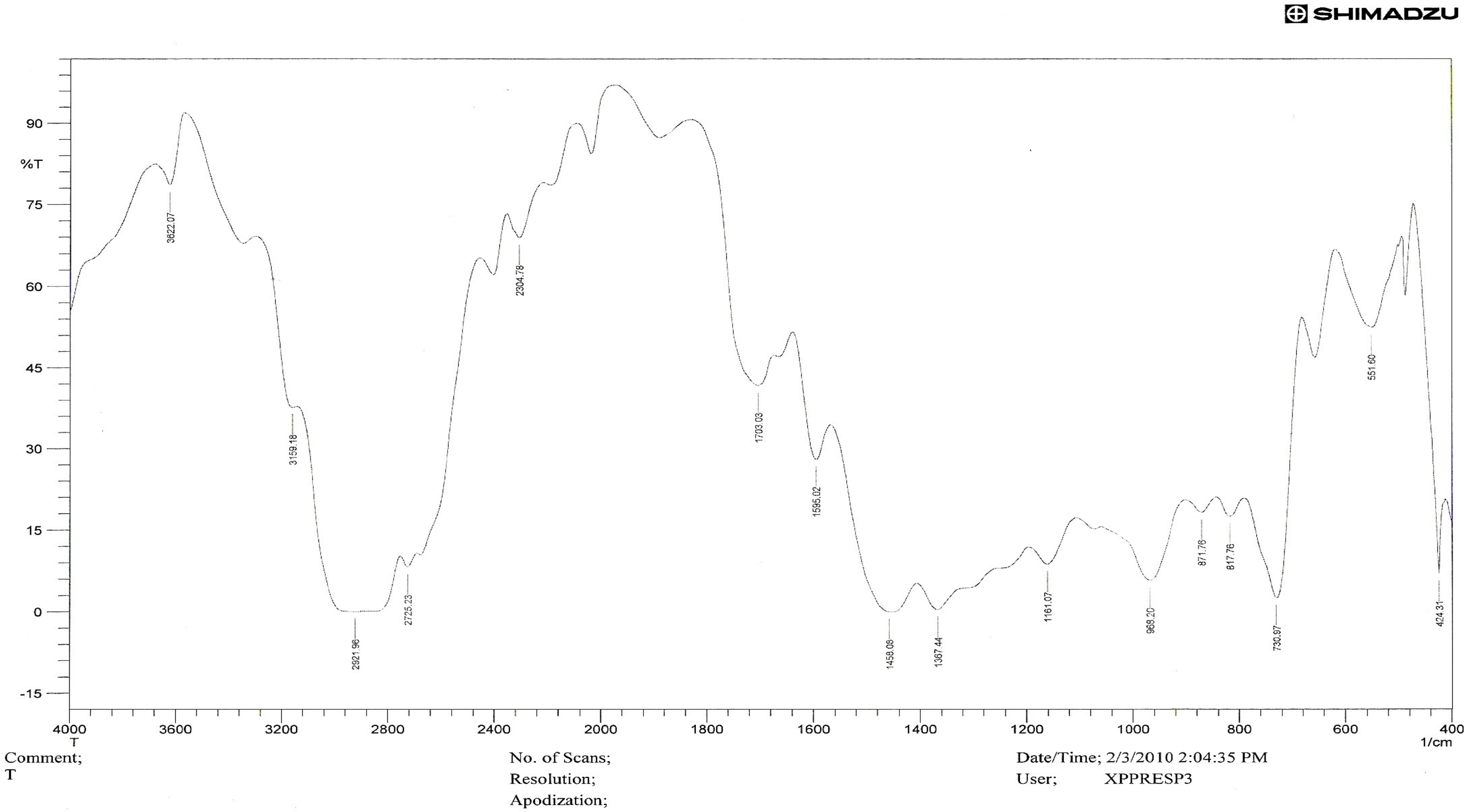
.Figure (4.36) infrared spectra of new gasoline fu



.Figure (4.37) infrared spectra of used fu



.Figure (4.38) infrared spectra of new Tot

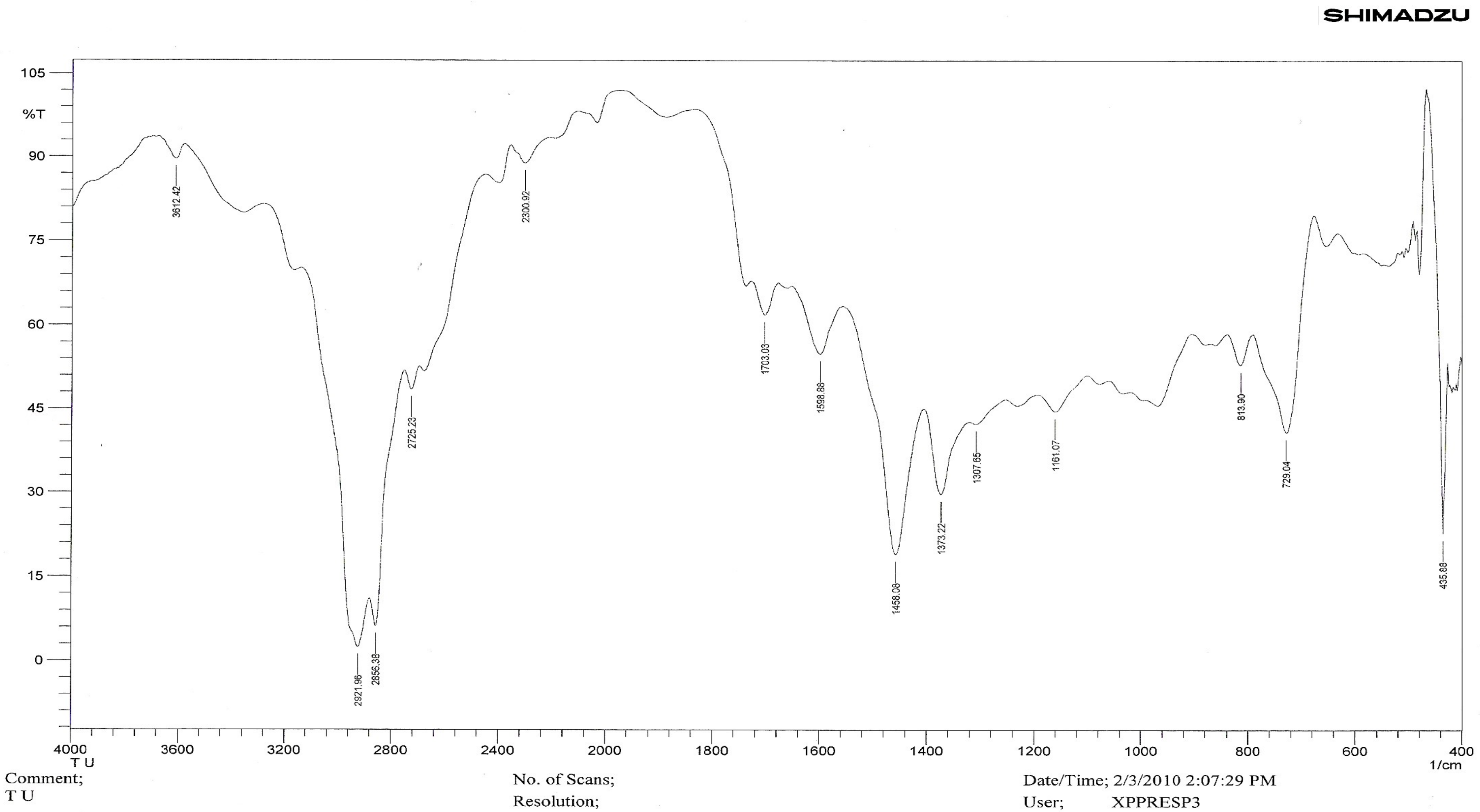


FIG (4.39 INFRARED SPECTRA OF USED TOTA

Recommendations

1-To use the Sudan crude oil for producing oils to manufacture lube oils, especially that there are studies conducted on the Fula crude oil and proved that it is possible to produce with high quality.

2- Prefer change mono grade engine oil every 2500 to 3000 km.

3-Prefer change multi grade engine oil every 3500 to 4500 km,aloso find some oil that have special additives change oil after 6000 km to 7000 km

4- To use multi grade oil in new models because is suitable for cold or hot weather (for all seasons) and for long distance and high speeds.

5- To treat used oil to introduce base oil, which has high quality, so as to reduce environmental pollution.

6- Due to the natural conditions in Sudan as so as rains and dust that usually lead to decrease the age of oil, must be change the oils before the main distance complete.

7- we hope in the future , in the presence of services dedicated to exposing the oil to determine its validity .

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