Influence of Polyisoprene as Additives on The Properties of Lubricating Oils

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of the Requirements for the Degree of
Master of Science
in
Chemical Engineering

by
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Certification

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Abstract

The object of this research is to study the influence of Polyisoprene as additive on the properties of base lubricating oils. Two types used of Polyisoprene which are (1502 &1320).

The reason of polyisoprene used as additive because polyisoprene is the one types of viscosity improvers, cheap cost and available in Iraq.

Measurements were made on three types of base lube oil stocks (40, 60&150) with a wide range of API gravities (34.97 for stock 40 , 29.29 for stock 60 and 20.65 for stock 150), first with (Polyisoprene 1502) and second with (Polyisoprene 1320) at different weight percent (concentration) of additives as follows: (0, 0.5 , 1 , 2 , 4 , 6 & 8 %).

The reason of used different weight percent of polyisoprene until 8% to showing the large influence of polyisoprene on base oil but in most industrial used additives from a few parts per million to 10 or 20 %.

The properties of binary mixtures such as (Flash Point, Rust Test, Pour Point, Viscosity, Viscosity Index & Foam Test) were measured. It was Found that the two types of Polyisoprene have succeeded to raise (Viscosity, Pour Point, Viscosity Index and Rust test), the percent of rust decreases when weight percent of Polyisoprene increase, (Flash Point) decrease when weight percent of Polyisoprene increase because of benzene used as solvent to Polyisoprene, and no effect occurred when Polyisoprene was added on the (Foam test) of base oil.

Comparison between the measured and calculated values of all the studied Iraqi-oil stock blends for different weight percent were found to be satisfactory, with an average absolute error of (3.9%) for (Flash Point), (8.4%) for (viscosity), (9.28%) for (Rust Test), (7.7%) for (Pour Point) and (6.56%) for (Viscosity Index) for the (498) data points used.

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Nomenclature

Variable Notations.

a , b , c , d = Constants in Eq. (4.1) to (4.24).

A,B,C,D,E = Constants in Eq. (4.28) to (4.30).

°API = American Petroleum Institute.

H = Viscosity of reference oil of 100 viscosity index at 37.8 °C.

L = Viscosity of reference oil of 0 viscosity index at 37.8 °C.

Mw = Molecular weight (g/g mole).

Sp.gr. = Specific gravity 15 °C/15 °C.

EP = Extreme Pressure.

T_f = Flash point of blending Polyisoprene with base oil, (°C).

$C_{on.}$ = Weight percent of polyisoprene, (%).

T_p = Pour point of blending Polyisoprene with base oil, (°C).

wt_{lost} = Weight lost of blending Polyisoprene with base oil, (g).

wt_a = weight fraction of additive.

μ_o = the dynamic viscosity of blends in cP at T_o= 303.15 k

Greek Letters

μ = Dynamic viscosity (cP).

υ,η = Kinematic viscosity (cSt).

Subscriptions

Exp. = Experimental value.
V.I. = Viscosity Index.
n.d. = not determined.

Abbreviation

ASTM = American Standard for Testing Materials.
ECN = Effective Carbon Number.
LOAs = Lubricating Oil Additives.
HDL = Hydrodynamic lubrication.
EHL = Elastohydrodynamic lubrication.
ISOVG = International Standard Organization viscosity.
OEM = Original Equipment Manufactures.
ppm = part per million.
PMMA = Poly methyl methacrylate.
PTFE = Poly tetra fluoro ethylene.
ALAN = Automatic laboratory analyzer network.

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CHAPTER ONE

INTRODUCTION

Lubricants include substances having a wide range of physical properties. They are usually in the liquid state (lubricating oils), although solid (graphite) and gases (air) may be used in certain applications **[1]**.

Lubricating oils can be produced by modern methods of refining from most crude oils. They may be distillates or residues derived from the vacuum distillation of a primary distillate with a boiling range above that of gas oil. They range from thin, easily flowing spindle oils to thick cylinder oils. The uses of lubricating oils are legion, and it would be impossible to make direct from the crude oil all the various grades required. A limited number of primary oils are therefore manufactured at the refinery and these are blended together in various properties with or without additives to produce oils with the required properties **[1]**.

Mineral oils, ranging from extremely fluid liquid to highly viscous products, are commonly used. They may serve many purposes such as conducting the heat of friction away from the bearings, serving as a seal to exclude undesirable substances from the area being lubricated, and acting as a carrier for rust preventives, anti-friction agents, extreme-pressure additives, and other properties. However, their primary purpose is in general to lubricate, i.e., to reduce friction **[2]**. The internal flow resistance or viscosity is the most important property of lubricating oil, which is a measure of its internal friction or ability to flow, and largely determines its stability for any particular application **[1]**.

Mineral oils don't have good antirust properties, although they do offer some protection, and they must be fortified with appropriate additives if any marked degree of rust prevention is to be achieved. Lubricating oil additives are normally used in low concentration from a fraction of a percent to five percent **[2]**. Their purpose may be one or more of the following **[2]**:

1. Improve lubricity under "boundary" condition.
2. Impart extreme pressure characteristics.
3. Reduce pour point.
4. Improve viscosity-temperature relationship (raise viscosity index).
5. Inhibit oxidation.
6. Combat catalytic effect of metals and contaminants.
7. Reduce bearing corrosion.
8. Disperse sludge particles, thus helping to maintain.
9. Cause emulsification (e.g. soluble cutting oils).
10. Reduce or eliminate rusting.
11. Reduce or eliminate foaming.
12. Reduce ring and cylinder wear.

Auxiliary materials, added to their liquids to enhance their properties in one direction or another to meet the requirements of special applications, are commonly employed. Known, as ***additives*** are the more important of the numerous materials that have been proposed for this purpose.

Lubricating oils additives (LOAs) are used to enhance the performance of the lubricants and functional fluids. Each additive is selected for its ability to perform one or more specific functions in combination with other additives. Selected additives are formulated into package for use with a specific lubricant base stock and for a specified end-use application. The largest end use is in automotive engine crankcase lubricants. Other automotive applications include hydraulic fluids and gear oils. In addition, many industrial lubricants and metalworking oils also contain (LOAs). The major functional additives types are dispersant, detergents, oxidation inhibitors, antiwear agents, extreme pressure (EP) additives, and viscosity index (VI) improvers. Most oil additives are complex organic chemicals or mixtures evaluated by their performance rather than their composition or purity **[1]**.

The selection of the right additive or of the most suitable combination of additives depends very much on the specific use of the oil **[1]**.

1.1 Aim Of The Work.

The aim of the present work is to study the influence of additives (Polyisoprene) on the properties of lubricating oils especially Flash Point, Pour Point, Foaming, Rust, Viscosity and Viscosity Index **.**

The reasons of polyisoprene used as additives because polyisoprene is the one types of viscosity improvers, cheap cost and available in Iraq.

The reason of used different weight percent of polyisoprene until 8% to showing the large influence of polyisoprene on base oil but in most industrial used additives from a few parts per million to 10 or 20 %.

CHAPTER TWO
LITERATURE SURVEY

2.1 Lubricating Oil Properties.

2.1.1 General Properties.

The large numbers of natural lubricating and specially oils sold today are produced by blending a small number of lubricating oil base stocks and additives. The lube oil base stocks are prepared from crude oils by distillation and special processing to meet the desired qualifications. The additives are chemicals used to give the base stocks desirable characteristics, which they lack, or to enhance and improve existing properties. The properties considered important are **[2]: -**

1. Viscosity.
2. Viscosity change with temperature (VI).
3. Pour point.
4. Oxidation resistance.
5. Flash point.
6. Boiling point.
7. Acidity (neutralization number).

2.1.1.1 Viscosity.

Viscosity is the property of a fluid that causes it to resist flow, which mechanically is the ratio of shear stress to shear rate. Viscosity may be visualized as a result of physical interaction of molecules when subjected to flow. Lubricating oils have long chain hydrocarbon structures, and viscosity increases with chain length. Viscosity of an oil film, or a flowing column of oil, is dependent upon the strong absorption of the first layer adjacent to the solid surfaces, and the shear of adjacent layers **[1]**.

Viscosity is by far the most significant property for establishing the thickness, pressure, and temperature of an oil film in hydrodynamic lubrication (HDL) and in elastohydrodynamic lubrication (EHL). Viscosity is also a significant factor in predicting the performance and fatigue life of rolling element bearings and gears. Plastohydrodynamic lubrication accounts for the existence of hydrodynamic effects in metalworking.

Calculations for oil film thickness require knowledge of the viscosity of the oil film at the temperature, pressure, and shear rate in the component. Viscosity is in the numerator of all equations predicting oil film thickness, fluid friction or hydraulic pressure. Oil film thickness increases with viscosity. Viscosity is also in equations for calculating the Summerfield Number, velocity in an oil film, shear stress, fluid friction force, and power loss for hydrodynamic bearings **[4]**.

Viscosity of industrial lubricants is commonly classified using the International Standard Organization Viscosity Grade (ISOVG) system, which is the average viscosity in centistokes (cSt) at 40°C. For example, ISOVG 32 is assigned to oils with viscosity between 28.8 and 35.2 cSt at 40° C.

The viscosity of oils is dependent upon temperature, pressure, and shear rate. Viscosity decreases as temperature increases because the molecules vibrate more and interact less. Conversely, the viscosity of oil increases as temperature decreases.

2.1.1.2 Viscosity Index (VI).

VI is a commonly used expression of an oil's change of viscosity with temperature. VI is based on two hypothetical oils with arbitrarily assigned VI's of 0 and 100. The higher the viscosity index the smaller the relative change in viscosity with temperature. Most industrial mineral lubricating oils have a VI between 55 and 100, but VI varies from 0 to "high VI" oils with VI up to 175. Viscosity-Temperature-VI relationship is shown in the following table (2.1):

Table (2.1) Viscosity-Temperature-VI relationships [2].

Industrial Oil ISOVG32	**Viscosity, cSt 40°C**	**Viscosity, cSt 100°C**	**Viscosity Index**	**Visc-Temp Coefficient**
Machine Oil	30.4	4.8	58	0.842
Turbine Oil	32	5.4	102	0.831
Hydraulic Oil	30.4	5.4	154	0.799

A less arbitrary indication of the change in viscosity with temperature is the viscosity temperature coefficient **[2]**.

For 40 to 100°C it is: Viscosity (cSt) at 40°C minus Viscosity (cSt) at 100°C = C^{-1}, divided by the Viscosity (cSt) at 40°C. Calculated values of the viscosity-temperature coefficient are also shown in the table (2.1). The lower the value of the coefficient, the higher the VI. The coefficient for mineral oils can vary by a factor of 10 depending on the temperatures.

The most commonly used method for expressing the relationship between viscosity and temperature is the viscosity index of Dean and Davis, which is based on an empirical scale. The standards are two series of lubricating oil fractions; the one obtained from Pennsylvania crude which was arbitrarily assigned a viscosity index of 100 and the other from gulf coast crude, which was assigned a viscosity index of zero.

The viscosity index is an arbitrary scale for comparing the rates of viscosity changes of lubricating oil with temperature. A high number (100 or more) indicates the oil is still fluid at low temperature and retains its viscosity at high temperature, an obviously desirable characteristic **[4]**.

2.1.1.3 Viscosity Pressure Coefficient.

Viscosity increases with pressure because the molecules are squeezed together forcing greater interaction. In an EHL contact where the pressure can be 2.1 GPa (300,000 psi) the viscosity is so high that the oil is considered a plastic-like solid. Viscosity at high pressures is measured by flow through pressurized capillary tubes, or a ball falling down a pressurized tube. The higher the temperature the lower the viscosity increase due to pressure.

Viscosity pressure coefficient is the slope of lines on graphs of the log of viscosity vs. pressure. The unit for pressure viscosity coefficient is the reciprocal of pressure. The SI units are 1/Pa or ($m^2.N^{-1}$). The pressure viscosity coefficients of several mineral oil showing a variation from 1.6 to $2.68 * 10^{-8}$ Pa^{-1}. The coefficient increases with viscosity, and can vary by a factor of (3). Pressure viscosity coefficient can also be measured from oil film thickness and other parameters from a transparent disk-on-ball apparatus **[5]**.

Pressure viscosity coefficient is used in the calculation of oil film thickness in tribological contacts. For example, in EHL contacts, oil film thickness is directly proportional to the 0.74 power of the pressure viscosity coefficient.

2.1.1.4 Viscosity Shear Rates.

Mineral oil viscosity does not change with shear rate, that is, they are Newtonian fluids. However, the viscosity of multi-grade, non-Newtonian oils usually change with shear rate because of the temporary alignment or breaking down of long chain hydrocarbon molecules to form shorter molecules. Shear rate is speed divided by oil film thickness: Shear rate $=m.s^{-1}/m = s^{-1}$, or reciprocal seconds. For example, with a speed of 1 $m.s^{-1}$ and an oil film 1 micrometer thick, the shear rate is 10^6 s^{-1} **[36]**.

Shear stability is defined as the ability of a lubricant to withstand shearing without breaking of the long chain hydrocarbon molecules. In lubrication, the viscosity of an oil at high shear rates is important to understanding performance in high speed, thin oil film equipment. An example is a large tilting pad thrust bearing in a hydroelectric generator.

Viscosity, as a function of shear rate, is measured by various rotating instruments. The instruments measure the force resisting the flow of oil films of known thickness and speeds. (ASTM method D 4683-90) prescribes a tapered roller rotating in a matched tapered stator with a known oil film thickness between them. Results are reported as: viscosity in cP (at 150°C and a shear rate of 10^6 s^{-1}) **[5]**.

Another rotating apparatus is the Couette Rheometer, where a precision cylinder rotates at high speed in a larger cylinder with an oil film of known thickness between them. Viscosity at high shear rates is also measured with an ultrasonic shear tester, and a high shear rate capillary at specified frequency, temperature and time **[5]**.

Many original equipment manufacturers (OEM) now require minimum shear stability. Some original equipment manufacturers (OEM) now require a viscosity of 2.9 cP (at 150°C and 10^6 s^{-1}) **[5]**.

2.1.1.5 Pour Point.

Pour point is a viscosity temperature phenomenon. It is defined as the lowest temperature at which a lubricant will flow under specified conditions. Most lubricant suppliers give the pour point of their oils so that the user can determine if it can be pumped and would be fluid in low temperature applications **[2]**.

The pour point increases with viscosity. For example, an ISOVG 46 mineral oil might have a pour point of -39°C, whereas an ISOVG 460 would have a pour point of -15°C. For mineral oils, the increase in viscosity as temperature is reduced, is due to gelling of the oil by the precipitation of crystalline wax **[5]**.

Although this paper is a review of mineral oil properties, it should be noted that one advantage of many synthetic oils is their very low pour points because of the absence of wax. Pour point depressants for mineral oils are additives which lower the pour point by interfering with wax crystallization.

Pour point is measured by (ASTM D97), which describes the procedure for cooling an oil until it will not pour out of a vessel.

2.1.1.6 Density.

Density is the mass of a unit volume of a substance. Oil density is used to determine the mass of a given volume, or the volume of a given mass **[5]**.

Density is used in lubrication to identify an oil, or oil fractions, and in the measurement of kinematic viscosity (absolute viscosity divided by density). Also, density is in the equations for the calculation of temperature rise in an oil film, and the equation for Reynolds Number (which determines if flow of an oil film is laminar (smooth layers) or turbulent (tumbling)).

2.1.1.7 Specific Gravity.

For many liquids, specific gravity is used which is ratio of the mass of a given volume to the mass of an equal volume of water. Therefore, specific gravity is dimensionless. The specific gravity of mineral oils also varies from 0.86 to 0.98 since the specific gravity of water is 1 at 15.6°C. Specific gravity decreases with increased temperature and decreases slightly as viscosity decreases for similar compositions **[5]**.

Most lubricant supplier's typical data bulletins give A.P.I. (American Petroleum Institute) Gravity in degrees for lubricating oils instead of specific gravity. A.P.I. gravity is an expression of density measured with a hydrometer. A.P.I. gravity has an inverse relationship with specific gravity, as shown in the following table (2.2).

Table (2.2) A.P.I gravity vs. specific gravity [5].

A. P. I. Gravity	Specific Gravity
15	0.97
34.9	0.85

$$A.P.I._{gravity} = \frac{141.5}{sp.gr_{(60^\circ F/60^\circ F)}} - 131.5 \qquad \text{… (2.1)}$$

Density, specific gravity, and A.P.I. gravity are measured by (ASTM D1298), using a calibrated, glass hydrometer and a glass cylinder. The cylinder is partially filled with the sample oil and the hydrometer is set into the oil and allowed to stabilize. A reading of the gravity is taken from the markings on the stem of the hydrometer at the surface of the oil. The temperature of the oil is measured and the final result is converted to 15.6°C (60 ^{o}F) and reported as A. P. I. gravity at 60 ^{o}F.

Two other oil properties related to density are thermal expansion and bulk modulus or compressibility.

2.1.1.8 Thermal Expansion.

The volume of a given oil mass increases with temperature, therefore, its density decreases. The degree of expansion is expressed as the coefficient of thermal expansion. Thermal expansion is useful to determine the size of a container needed when the oil will be heated. Inexperienced people often have an oil overflow because of a surprising amount of thermal expansion **[1]**.

In HDL, the thermal expansion of the oil in the clearance of a bearing increases the hydraulic pressure. Some researchers discuss the "thermal wedge" mechanism of film formation and apply it to parallel sliding surfaces, especially flat, non tilting, thrust bearings.

The coefficient of thermal expansion is the ratio of the relative change of volume to a change in temperature. Thermal expansion is expressed as the ratio of volume change to the initial volume after heating 1°C. Therefore, the unit is reciprocal °C, or degree C^{-1}. The values of the coefficient of thermal expansion for mineral oil are near $6.4 * 10^{-4}$ degree C^{-1}.

Thermal expansion (or contraction) determinations require the measurement of the volume of a given mass of oil at various temperatures. The sample is placed in a graduated cylinder and the volume is observed as the temperature is either increased or decreased. A simplified method of calculating the thermal expansion of petroleum products can be found in (ASTM D1250) **[5]**.

2.1.1.9 Bulk Modulus Or Compressibility.

Bulk modulus expresses the resistance of a fluid to a decrease in volume due to compression. A decrease in volume would increase density **[13]**.

Compressibility is the reciprocal of bulk modulus or the tendency to be compressed. Bulk modulus varies with pressure, temperature, molecular structure and gas content. Generally, mineral oils are thought to be incompressible. In high pressure hydraulic systems a high bulk modulus or low compressibility is required to transmit power efficiently and dynamically.

In EHL, bulk modulus is a factor used in some film thickness calculations. Bulk modulus is a consideration in some viscosity-pressure relationships. (Low viscosity polysiloxane fluids have a low bulk modulus or high compressibility compared to mineral oils). Dissolved gases decrease bulk modulus of mineral oils.

The unit for bulk modulus is pressure and the unit for compressibility is the reciprocal of pressure. The SI units are $N.m^{-2}$, and $m^2 N^{-1}$ respectively.

Bulk modulus is determined by measuring the volume of an oil at various pressures or derived from density measurements at various pressures. Bulk modulus can also be measured by the speed of sound in oils under various pressures. Since a graph of pressure versus volume gives a curve, the secant to the curve is used and is called Isothermal Secant Bulk Modulus.

2.1.1.10 Foam.

Foaming is defined as the production and coalescence of gas bubbles on a lubricant surface. Foam may be a result of a variety of problems including air leaks, contamination, and over filling of sumps. Foaming can cause loss of oil out of a vent and serious operational problems in most lubricated systems. Excessive foam can starve bearings and pumps of liquid lubricant (pump cavitation) causing failure, and cause poor performance in hydraulic systems. The foaming characteristics of an oil are measured by (ASTM D892). Using a calibrated porous stone, air is blown into the bottom of a graduated cylinder for a specified time. Immediately upon completion of the blowing period, the foam that has formed on the top of the oil is measured. Ten minutes after the completion of the blowing period, an additional measurement is made of the remaining foam as the foam retention characteristics of the oil. The results are reported in milliliters **[5].**

Most commercial lubricants contain foam inhibitors, as these inhibitors reduce foaming. A few ppm of silicone is commonly used **[4].**

2.1.1.11Flash Point.

Flash point is an indication of the combustibility of the vapors of a mineral oil, and is defined as the lowest temperature at which the vapor of an oil can be ignited under specified conditions. Flash point is clearly related to safety. Flash point of lubricating oils is measured using (ASTM D 92). An open cup of oil is heated at a specific rate while periodically passing a small flame over its surface. The flash point is considered to be the lowest temperature at which the oil vapors will ignite, but not sustain a flame **[3]**.

For example, the flash point of an ISOVG 32 turbine oil might be 222 °C. If one continues to heat the oil and continues to pass the small flame across the surface, the vapors will eventually sustain a flame and this is the fire point. The fire point of the same turbine oil would approach 252° C. **[5]**.

2.1.1.12 Thermal Conductivity.

Thermal conductivity is the rate of transfer of heat for a given temperature gradient through a material. The rate of transfer of heat from a hot spot to a cooler area in a bearing is a factor in controlling overheating. Therefore, an oil with a high thermal conductivity would be expected to lower the temperature of a bearing. Thermal conductivity of lubricating oil is used in equations to calculate heat transfer in bearings. The unit of thermal conductivity is heat over a distance per degree of temperature. Most mineral oils have approximately the same thermal conductivity of near 0.1 $W.m^{-1}.°C^{-1}$.

Thermal conductivity is measured using (ASTM D 2717). This method consists of test vessel containing oil and a platinum resistance thermocouple. Thermal conductivity is determined by measuring the temperature gradient produced across the liquid sample by a known amount of heat introduced into the cell by an electrically heated platinum element. Thermal conductivity increases slightly with higher temperatures **[5]**.

2.1.1.13 Surface Tension.

Surface tension is the surface energy between a liquid and its own vapor, or air, or a metal surface. The word tension comes from the force that resists any attempt to increase the surface area. Surface tension is thought to be a factor in the ability of an oil to "wet" a surface, in emulsion stability, and in the stability of dispersed solids. However, "wetting" has been found to be a complex phenomenon involving oleophobic and oleophilic films on the metal surface. Some additives markedly change surface tension. An example is water containing soap for the formation of bubbles. Silicone is added to mineral oils to reduce surface tension and as result, foaming characteristics may change. The SI unit of surface tension is $N.m^{-1}$, but dynes/cm is commonly used **[5]**.

Surface tension of oils on metals can be compared by placing a small drop on a clean metal surface and observing if the drop has a high contact angle (high surface tension) or very low contact angle (spreads out, low surface tension). Surface tension between an oil and a metal surface is measured by using the Nouy ring method. The method involves placing a clean, platinum wire ring on the surface of the oil, where the force required to pull the ring away from the surface is measured.

Interfacial tension exists between two liquid layers and is measured by (ASTM D 971). The method uses a tensiometer and a platinum ring. The ring is lowered into a beaker of water and oil. It is then brought up to the water-oil interface where the actual measurement takes place. The force required to pull the ring through the interface is measured by the tensiometer and considered to be the interfacial tension of the oil. The value for mineral oil varies from 30 to 35 dynes cm^{-1} **[8]**.

2.1.1.14 Thermal Capacity/Heat Capacity AND Specific Heat.

Thermal capacity is the heat required to raise a body one unit or degree of temperature. Thermal capacity and heat capacity are synonymous. The SI unit is ($J.kg^{-1}.°C^{-1}$) **[5]**.

Specific heat is the ratio of the thermal capacity of the substance to that of water (at 15°C). Therefore, thermal capacity is numerically equal to specific heat. Specific heat is a function of fluid structure and density. In HDL, specific heat is used in the calculation of heat transfer, temperature rise, and other thermal factors in an oil film; the thermal capacity of three materials was given as in table (3.2):

Table (3.2) thermal capacity of materials [5].

Material	**Thermal Capacity ($J.kg^{-1}. °C^{-1}$)**
Water	4184
Mineral Oil	1966
Steel	460

Therefore, more heat is required to raise the temperature of 1 kilogram of water and oil than is required for steel. Specific heat is measured using (ASTM D3947). A sample is introduced into a differential scanning calorimeter by means of a hermetically sealed sample cell. The cell is placed on a thermocouple in a controlled environment programmed to increase temperature at a specific rate. This allows the calculation of the specific heat of the oil **[9]**.

2.1.1.15 Boiling Point.

The first step in the manufacture of petroleum products is the separation of crude oil into the main conventional fractions by distillation. A main distinguishing feature of the various products is their volatility or ability to vaporize. This is associated with the size of the molecule and volatility is related to the boiling point; the higher the boiling temperature rang of a fraction, the higher the molecular weights of the components; the lower the volatility for given crude oil, the greater the viscosity **[1]**.

2.1.1.16Oxidation Resistance.

Lubricants are exposed to oxidation by atmospheric oxygen in practically all of their application. This results in formation of acids and sludge’s which interfere with the primary function of lubricant **[5]**. Oxidation of lubricating oil leads to such difficulties as bearing corrosion, ring sticking, lacquer and sludge **[1]**.

2.1.1.17 Acidity.

The acidity or alkalinity of petroleum products is determined by dissolving the product in a suitable neutral solvent and neutralizing the solution with either standard alkali or standard acid as the case may be. The neutral point may be indicated by a color indicator or electrometrically.

Oxidation of petroleum products more often than not produces acid and the progress of deterioration can be used as a refinery control test or as a measure of change during use **[1]**.

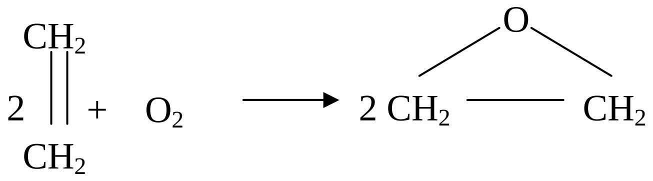
2.1.2 Chemical properties.

2.1.2.1 Oxidation.

All petroleum products under normal condition of storage and use come into contact with air and hence with oxygen, often at high temperature, and sometimes when in a finely divided state, for example as a mist in an engine. Such conditions are very favorable for oxidation to take place. Hydrocarbons vary in their susceptibility to oxidation, paraffin's or saturated chain compounds are generally more resistant than aromatic ring compounds, and unsaturated compounds are readily oxidized **[1]**.

Just as oxygen plays such an important part in controls the life of a lubricating oil. Oxygen may be regarded as the enemy ever eager to destroy it, but, of course, this is not wholly true. Blown are widely used in paints, and lubricating oils is very largely a scheme to render than resistant to oxidation. The study of oxidation is made difficult by the complexity of hydrocarbons in the oils, and the products of oxidation resulting there from. Analysis of compounds produced is tedious and difficult which makes progress slow. Oxidation of oils is of such fundamental interest and practical importance to lubrication that the introduction of antioxidants was a logical escape from a stubborn problem. The interaction of olefins with molecular oxygen is not only a subject of widespread importance, but is one of the most through understood chemical progresses **[3]**.

The reaction of oxygen with a molecule that may or not may already contain oxygen, Oxidation may be partial, resulting incorporation of oxygen into the molecule or in the elimination of hydrogen from it, or it may be complete, forming carbon dioxide and water (combustion) **[1]**.



Partial oxidation (2.1)

Ethylene oxygen ethylene oxide

$2CH_3\,CH_2\,OH + O_2 \longrightarrow CH_3\,CHO + 2H_2O$ Partial oxidation (2.2)

Ethyl alcohol oxygen acetaldehyde water

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$ complete oxidation (2.3)

Methane oxygen carbon dioxide water (combustion)

The inhibitors most used can be divided into two main classes: the first class includes oil-soluble materials containing sulfur or phosphorus, and the second consists of amine or phenolic compounds.

2.1.2.2 Corrosion.

Nearly all petroleum products are used under conditions that bring them into contact with metallic surface, and it is important that these surfaces should not be corroded thereby. Petroleum products must therefore be non-corrosive in them and should not become corrosive during use and, in same instances are also expected to provide positive protection against corrosive even though presents in only small quantities, and products are therefore tested to ensure either its absence or it limitation to relatively harmless amounts. Oxidation with formation of acids is another potential cause of corrosion and this is on reason why oxidation stability is of such great importance **[1]**.

Lubricants must be formulated so as to avoid the promotion of corrosion by any of the ingredients or by their degradation products. They must also be able to prevent corrosion in certain sets of adverse circumstances when potentially corrosive contaminants come in to the oil.

Corrosion is too broad a subjected to be compressed in a limited number of words; suffice it to say that same aspects are within the orbit of the petroleum industries. All coating-fluids should have some ability to check corrosion according to circumstances. But when water is present greater corrosion activity is enticed **[3]**.

The corrosive effect may be minimized in two ways; either the production of harmful peroxides and carboxylic acids can be inhibited, or the reactive metal surfaces can be isolated from the reactive with an appropriate film. In practice the oxidation inhibitors, such as zinc dithiophosphate commonly used in internal combustion engine oils, will function in both ways. The inhibitors will also effective in preventing similar corrosion which might result with some combustion products their way past the piston into the crankcase **[1]**.

Rusting is a special kind of corrosion and both are believed to contribute to wear of moving parts, whereby corrosion products are removed mechanically. Wear caused by friction alone is quite slow where lubrication is adequate. In ordinary automobile use, the wear of cylinder bores and piston rings is usually of the mixed corrosion explains the fact that bore wear is always greater at the top of ring travel. The protection of metals against corrosion is important because corrosion, especially rusting, can cause very considerable losses to industry in both materials from coming into contact with the metal, and the application of an impervious coating is a convenient and effective means.

Since water is a common contaminant in mineral oil lubricated systems used on earth, anti-rust additives are used. Rust inhibitors prevent the formation of rust (hydrated iron oxide) on iron surfaces by the formation of protective films, or by the neutralization of acids. Typical anti-rust compounds are highly basic compounds, sulfonates, phosphates, organic acids, esters or amines. The rusting of ferrous parts in a lubricated system is undesirable. The rust contributes to sludge, causes loss of metal, sticking of metal parts, and the formation of solid particles of rust that are abrasive. Rust indicates the presence of water in the system. The ability of a treated oil to prevent rusting may be measured by (ASTM D 665), entitled Rust Prevention Characteristics. A 300 ml sample of lubricant is introduced into a beaker containing 30 ml of either salt or fresh water. A specially prepared bullet-shaped steel rod is placed in the beaker along with the oil/ water mixture. The mixture is heated and stirred for 24 to 48 hours to promote rust on the steel bullet. At the end of the test time the bullet is carefully inspected and rated for any sign of rust.

2.2 Lubricating Oil Additives (LOAS).

2.2.1 General.

Straight mineral oils, together with compounded oils, were once able to meet normal lubrication requirements of automotive and industrial practice. As these requirements become more severe with the progressive development of engineers and general machinery it becomes necessary firstly to improve the quality of lubricating oils by new methods of refining and eventually to use (additives) either to reinforce existing qualities or to confer additional properties **[4]**.

Additives are substances that, in small quantities-from a few parts per million to a few percent-confer specific properties on the lubricant. The progressive increase in the severity of engine operating conditions for motor oils have made necessary the use of chemical additives. Additives are usually called after their particular function, but many additives are multi-functional; it will give some idea of their multiplicity to name the chief functions they fulfill: to improve the viscosity index (VI improves); to increase oxidation stability (anti-oxidants); to keep contaminants in suspension (dispersants); to depress the pour point (pour point depressant); to prevent rusting (anti-rust); and to prevent foaming (anti-foam).

2.2.2 Types Of Additives.

Table (2.4) Commonly used lubricant Additives [4].

Type of additive	Type of compounds Used	Reasons of use	Mechanism of action
Viscosity Index	Polymerized Olefins or iso Olefins.Butylenes polymers, Methacrylic acid ester polymers,alkylated styrene polymers	To lower rate of change of Viscosity with temperature	Improvers are less affected by temperature change than oil. They raise viscosity at 200° F more in proportion than at 100° F because of their change in solubility's.
Dispersants	Metallo-organic compounds such as naphthenates and sulfonates. Organic salts contaning metals, like calcium,cobalt, and strontium.	To keep potential sludge-forming in-soluble in suspension to prevent their depositing on metal parts	Agglomeration and deposition of fuel soot and insoluble-oil decomposition products is prevented by break down into finely divided state. In colloidal from contaminating

Continued….

			particles remain suspended in oil.
Antioxidant or Oxidation Inhibitor	Organic compound containing sulfur,phosphorus, or nitrogen such as organic amines, sulfides, hydroxyl sulfide, phenols. Metals like tin zinc , or barium often incorporated.	To prevent varnish and sludge formation on metals parts. To prevent corrosion of alloy bearings.	Decreases amount of oxygen taken up by the oil, thereby reducing formation of acidic bodies. Terminates oil oxidation reactions by formation of inactive soluble compound or by taking up oxygen. Additive may by oxidized in preference to oil.
Anticorrosive, Corrosion Preventing or Catalyst (Poisons)	Organic compounds containing active sulfur,phosphorus , or nitrogen such as organic sulfides, phosphites, metals solts of thiophos-phoric	To prevent failure of alloy bearings by corrosive action. To prevent corrosive attack on other metals surfaces.	Inhibits oxidation so that no acidic bodies are formed or enables a protective film to form on bearing or other metals surfaces. Chemical film formation on metal

Continued….

	acid,and sulfurized waxes.		surfaces decreases catalytic oxidation of the oil.
Detergents	Metallo- organic compounds such as naphthanates,phenolates, sulfonates, alcoholates. High-molecular-weight soaps containing metals,like magnesium, barium, calcium,tin.	To keep metal surfaces clean and prevent deposit formation of all type.	By chemical reaction or oxidation direction, oil-soluble oxidation products are prevented from becoming insoluble and depositing on various engine parts.
Oiliness, Film Strength, Extreme Pressure (EP), and Anti-Wear Agents	Organic compound containing chlorine,phosphoruse, and sulpher such as chlorinated waxes, organic phosphates, and phosphitessuch as tricersyl phosphate and zinc, dithiophosphate, and lead soaps such as lead	To reduce friction, prevent galling,scoring, and seizure. to reduce wear.	By chemical reaction film is formed on metal contacting surfaces which has lower shear strengh than base meta,thereby reducing friction and preventing welding and seizure of contacting surfaces when oil

Continued….

	naphthenate.		film ruptured.
Rust Preventives	Solfonates, amines, fatty oils, and certain fatty acids, oxidized wax acids, phosphates, halogenated derivatives of certain fatty acids.	To prevent rust of metal parts during shout down periods, storage,or shipment of new or overhauled equipment.	Preferential adsorption of polar-type surface active materials on metal surface. This film repels attack of water.Neutralizing corrosive acids
Metal Deactivators	Complex organic nitrogen and sulfer containing compounds such as certain complex amines and sulfides. Some soaps.	Passify, prevent, or counteract catalytic effect of metals on oxidation.	Form inactive protective film by physical or chemical adsorption or absorption.Form catalytically inactive complex with soluble or insoluble metal ions.
Stringiness and Tackiness Agents	Certain high-molecular-weight polymers and aluminum soaps of unsaturated fatty acids.	To increase adhiesiveness of lubricant on metal surfaces, from protective coating.	Increases viscosity of lubricating and imparts adhesive and tackiness characteristics.

Continued….

Water Repellents	Organosilicon and other polymers, certain higher aliphatic amines, and hydroxyl fatty acids.	To provide water repellent or resistant properties to non-soap-thickened greases and other lubricants.	Surface active agents from protective film on grease thickeners or other components of lubricats to reduce their affinity for water.
Dyes	Oil-soluble organic compounds with high coloring power.	To provide distinctive or attractive color.	The organic compounds with high coloring power (dyes) dissolve to impart color.
Emulsifiers	Certain soaps of fats and fatty acids,sulfonic acids, or naphthenic acids.	To emulsify soluble oils with water to give coolant-lubricant- type fluid.	Surface-active chemical agents reduce interfacial tensions so oil can be finally dispersed in water.
Color Stabilizers	Certain hydroquinones, dithiocarbamates, aliphatic Amines, dicyclohexylamines.	To stabilize color and prevent formation of undesirable color.	Certain chemical can destroy color-forming bodies by stopping or changing -ical reaction forming .chem

Continued….

			them .sometimes accomplished by oxidation inhibitors functioning as indicated above.
Odor-Control Agents	Certain oil- soluble synthetic perfumes, sometimes nitrobenzene.	To provide distinctive or pleasant odor or mask undesirable odors.	Small amounts of highly odoriferous substances impart fragrant or pleasant odor when mixed with lubricants.
Antiseptics (bactericide or disinfectant)	Certain alcohols, aldehydes, phenols, mercuric compounds, and chlorine-containing compounds.	To control odor, foaming, metal staining, emulsion breaking in emulsion- type lubricants.	Used insoluble oil to reduce or prevent growth of bacteria causing deleterious effect in emulsion lubricants.
Pour Point	Wax alkylated naphthalene or phenol and their polymers. Methacrylate polymers.	To lower pour point of lubricating oils.	Wax crystals in oils coated to prevent growth and oil absorption at reduce temperature.

Continued….

Foam Inhibitors	Silicone polymers	To prevent formation of stable foam.	.Reduce interfacial tension So small air bubblets can combine to form larger bubbles that separated faster.

Continued….

2.3 Blending.

Blending is a physical process in which accurately measured or weighed quantities of two or more components are mixed together form a homogeneous blend. The components may all be petroleum fractions or may include other materials, for example fatty oils, dyes functional additives, referred to collectivity as (additives), in properties from a few parts per million to 10 or 20% W. the blends will be formulated to have required properties for particular applications and will usually be required to meet appropriate marketing specification **[2]**.

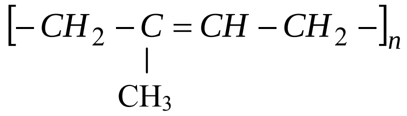
Blending is required for oil product of all kinds. Gasoline as marketed is usually a blend of several refinery grades derived from different processes, generally contains lead anti knock compounds, and may contain other additives, e.g. to prevent spark- plug fouling, carburetor icing, etc. Kerosene may be a blend of two or more refinery grades. Most lubricating oils are blends of two or more base oils with or without additives, ranging from the simplest two-oil blends to quite complex formulations containing several non-petroleum ingredients. Petroleum waxes are blended together and with natural waxes or polyolefin. Bitumens are blended together, or with volatile solvents to form cutbacks **[1]**.

In principle the process of blending is the same all these instance but the details will vary according to the nature of the components and the complexity of the mixture, for example gasoline components can be blended readily by very simple mixing, lubricating oils may require moderate heating (60-80 °C). Blending can be carried out either intermittently by (batch blending) or continuously by (in-line blending).

2.4 Polyisoprene Properties.

2.4.1 Microstructure.

The Structure of natural rubber (cis1, 4 Polyisoprene) as shown below.



$$\left[-CH_2-\underset{\substack{|\\ CH_3}}{C}=CH-CH_2-\right]_n$$

When n= No. of repeated monomer units. All these polymer have similar crystal structures except that the repeat distance of the trans polymers corresponds to one monomer unit and that of the cis polymer to two. The chain is slightly out of plane at the single bound and in plane around the double bound **[11].**

2.4.2 Physical Properties.

Physical Properties of Polyisoprene as given in table (2.5).

Table (2.5) Physical Properties of Polyisoprene [11]

Property	**Value**
Density	0.92 gm /cm^3
Heat Combustion	44770 J/gm
Thermal Conductivity	0.00134 J/sec / cm.^{o}C
Volumetric expansion factor	0.00062 ^{o}C
Molecular weight	200000-400000

2.4.3 Solubility.

Can be see that (benzene) is an excellent solvent while cyclo hexane is a moderate solvent and decaline dioxin is a non-solvent for Polyisoprene, so that (benzene) solvent use in this investigating **[11].**

2.5 Previous Work. [37].

The previous work is to fined additives for oil base stocks which have the ability to raise its viscosity. Three polymers (polyisoprene 1502, 1320, Butile) where selected for that purpose. The three type of polyisoprene have been used and succeeded to raise the viscosity.

Measurement were made of the dynamic viscosities of three types of base lube oil stocks with a wide range of API gravities (34.97 for stock 40, 29.29 for stock 60 and 20.65 for stock 150) with three types of additives (polyisoprene 1502, 1320 and Butile) at different weight percent of polyisoprene (0, 0.5, 1, 2, 4, 6, 8 %) and different temperature in the range of 298 to 353 K.

Viscosities of oil-stocks and their mixtures were measured at seven different temperatures, namely 298 , 303 , 313 , 323 , 343 ,and 353 °K with a Rheology International Viscometer (Model RI: 1:M), and was placed in a water bath (memmert type), which was capable of maintaining the temperature within ± 0.1°C of the selected temperature.

A model used to estimate the dynamic viscosity of oil stocks with additives at different temperature for binary mixtures. The method is based upon concentration (wt %) of the additive, as follows:

$$\left[\frac{\log(\mu)+k}{\log(\mu_{o})+c}\right]=\left[\frac{T^{o}}{T}\right]^{s}$$

Where:

$$k = E * wt_a + B$$
$$s = A * wt_a + D * \log(\mu_o)$$

Comparison between the measured and calculated viscosities of all the studied Iraqi-oil stock blends for different temperature was found to be satisfactory, with an over all average absolute error of 8.2 % for the 363 data points used.

CHAPTER THREE
EXPERIMENTAL WORK

3.1 Oil-Stock

Three Base-Stocks were obtained from Al-Durra Refinery, namely **40 stock**, **60 stock**, and**150 stock**.40 stock is the lightest one with °API gravity 34.97 while 60 stock is middle type with °API gravity 29.29 and 150 stock is heaviest one with °API gravity 20.65.

The main properties of oil stocks (**40 stock**, **60 stock**, and **150 stock**) were measured in Al-Durra Refinery laboratories according to API and ASTM specification, as listed in table (3.1).

Table (3.1) Properties of Oil Stocks.

Specification	40 stock	60 stock	150 stock
Kinamatic Viscosity at 40 °C, cS	18.11	56.12	501.98
Kinamatic Viscosity at 100°C,cS	3.14	7.69	33.38
Viscosity index (VI)	95	95	93
Specific gravity at (**15.6°C/15.6°C)**	0.85	0.88	0.93
°API gravity	34.97	29.29	20.65
Cleveland Open Cup Flash,°C	n.d.	200-300	290-300
Penesky Martenz Flash,°C	160	n.d.	n.d.
Pour point,°C	-24	-6	-3
Sulfur content, wt.%	0.62	1.40	2.00

3.2 Additives.

Lubricating oil additives (LOAs) impart desirable properties to base stocks to satisfy standards for high-performance engines. Each additive is selected for its ability to perform one or more specific functions, for example: to restrict oxidation, to modify the viscosity-temperature characteristics, to act as detergents, to depress the pour point, or to inhibit rust. Although (LOAs) are used in petroleum-based lubricants, they are themselves not typical petroleum products; they are considered specialty chemicals.

The group of polyisoprene (1502 and 1320) used as additives for lubrication oils with various weight ratios additives are originally hard materials used after solving it in benzene and white spirit materials respectively when the amount of the solvent depends on its solving to the whole parts of the solved materials.

The additives are tested before the use as by discovering its ability to the blending with the lubrication oils and the formation of a homogenous solution without impurities or sediment and with various temperatures.

Two materials are blended with the lubrication oils forming homogenous solution at different temperature degree and there are no sediments. These materials are the group of polyisoprene (1502 and 1320).

According to this result, it has been decided that the materials of group polyisoprene (1502 and 1320) should be used because they are conceded with the conditions. And the material of group will be used because it passes the test appositionally.

3.3 Procedure of mixing.

The lubrication oils are prepared, the two types, with the material which decided to be used to study the effect of this on the properties of lubricating oils.

The following binary mixtures were prepared in this study: -

A). Binary mixtures of each oil-stock type (40 stocks, 60 stocks, and 150 Stocks) with (0-8) wt% of polyisoprene 1502.

B). Binary mixtures of each oil-stock type (40 stocks, 60 stocks, and 150 Stocks) with (0-8) wt% of polyisoprene 1320.

3.4 Test Method.

3.4.1 Viscosity Measurements.

Viscosities of oil-stocks and their mixtures were measured at eleven different temperatures, namely 298, 303, 313, 323, 333, … and 393°K with a "U" shaped tube as shown in Fig. (3.1).

3.4.1.1Viscometer.

Viscosity is measured by ASTM method (D 445) using a common cross arm viscometer. The sample is introduced into a "U" shaped, calibrated, glass tube, submerged in a water bath (memmert type), which was capable of maintaining the temperature within ± 0.1°C of the selected temperature.and allowed to flow via gravity down the tube and up the opposite side. The number of seconds the oil takes to flow through the calibrated region is measured. The oil's viscosity in cSt is the flow time in seconds multiplied by the apparatus constant.

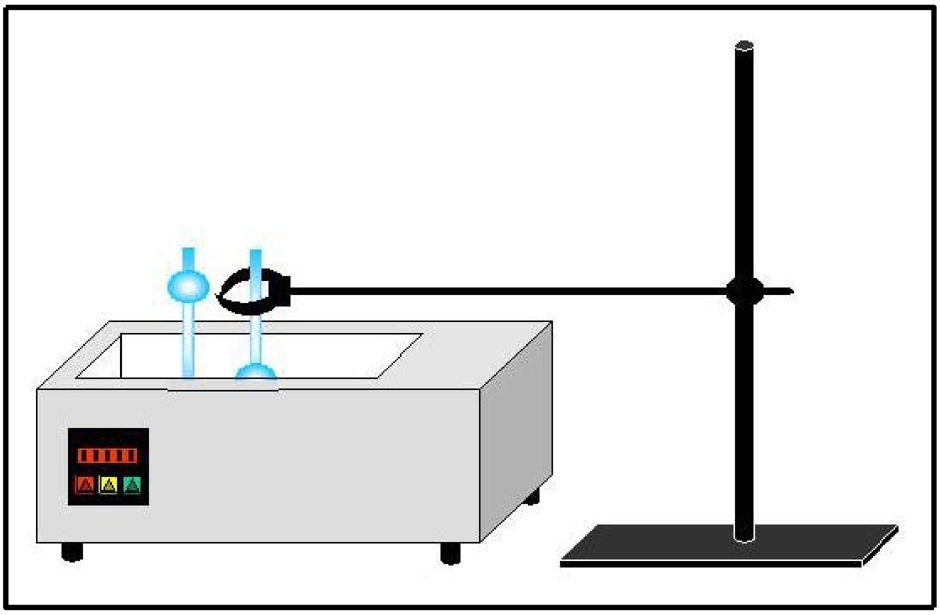


Fig. (3.1) Viscosity Measurement.

3.4.2 Rust Measurement.

Weight lost (corrosion rate) of oil-stocks and their mixtures were measured at seven different concentrations (Wt.%), namely 0, 0.5, 1, 2, 4, 6 and 8 with a Rust Preventing Characteristics Tester Of Inhibited Mineral Oil in the Presence Of Water (ASTM D665) shown in Fig. (3.2).

3.4.2.1 Rust Preventing Characteristics Of Inhibited Mineral Oil in the Presence Of Water (ASTM D665)

This method is used to evaluate the ability of inhibited mineral oils, particularly steam-turbine oils, to aid in preventing the rusting of ferrous parts should water become mixed with the oil. This method is also used for testing other oils, such as hydraulic oil and circulating oils.

Fig. (3.2) Rust Preventing Tester of Inhibited Mineral Oil in the Presence of Water.

3.4.2.2 Standard Test Method for Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water

1. Summary of Test Method.

1.1 A mixture of 300 ml of the oil under test is stirred with 30 ml of or synthetic sea water, as required, at a temperature of 60 ± 1°C with a cylindrical steel test rod completely immersed therein. It is recommended to run the test for 4h; however, the test period may, at the discretion of the contracting parties, be for a shorter or longer period. The test rod is observed for signs of rusting and, if desired, degree of rusting.

2. Apparatus.

2.1 Oil Bath- A thermostatically controlled liquid bath capable of maintaining the test sample at a temperature of 60 ± 1°C. An oil having a viscosity of approximately ISO VG 32 is suitable for the bath. The bath shall have a cover with holes to accommodate the test beakers.

2.2 Beaker- A 400-ml, Berzelius-type, tall-foam heat-resistant glass beaker without pourout, approximately 127 mm in height measured from the inside bottom center and approximately 70 mm in inside diameter measured at the middle.

2.3 Beaker Cover- A flat beaker cover of glass or poly (methyl methacrylate) (PMMA), kept in position by suitable means such as a rim or groove. Two holes shall be provided on any diameter of the cover; and the other, on the opposite side of the center of the cover, for the test rod assembly, 18mm in diameter with its center 16 mm from the center of the cover. In addition, a third hole 12 mm in diameter shall be provided for a temperature measuring device, with its center 22.5 mm from the center of the cover and on a diameter of the cover at right angles to the diameter through the other two holes.

2.4 The plastic holder shall be made of PMMA resin in accordance with the dimensions (two types of holders are illustrated). When testing synthetic fluids, the plastic holder should be made from chemically resistant material such as polytetrafluoroethylene (PTFE).

2.5 Stirrer- A stirrer constructed entirely from stainless steel in the form of an inverted T. A flat blade 25 by 6 by 0.6 mm shall be attached to a 6-mm rod in such a way that the blade is symmetrical with the rod and has its flat surface in the vertical plane.

2.6 Stirring Apparatus – Any convenient form of stirring apparatus of maintaining a speed of 1000 ± 50 rpm.

2.7 Grinding and Polishing Equipment- A (99- µm) and a (53.5- µm) in accordance with BS 871 or its equivalent, metalworking aluminum oxide abrasive cloth coat on a jeans backing, a suitable chuck for holding the test rod, and a means of rotating the test rod at a speed of 1700 to 1800 rpm.

2.8 Oven, capable of maintaining a temperature of 65 ^{o}C.

3. Test Rod and Its Preparation.

3.1 For each test oil, prepare two steel test rods. These may either be new or from a previous test and shall be prepared in accordance with 5.2 and 5.3.

3.2 The test rod assembly shall consist of a round steel test rod fitted to a plastic holder. The round steel test rod, when new, shall be 12.7 mm in diameter and approximately 68 mm in length exclusive of the threaded portion which screws into the plastic holder and shall be tapered at one end. It shall be made of steel. If these steels are not available, other equivalent steels may be used, provided they are found to be satisfactory by comparative test using this Test Method D665.

3.3 Preliminary Grinding- If the test rod has been used previously and is free of rust or other irregularities, the preliminary grinding may be omitted, and it may be subjected only to final polishing as prescribed in 5.4. If the test rod is new or if any part of its surface shows rust or other irregularities, clean it with ASTM precipitation naphtha or isooctane or petroleum spirit and grind with medium (99- µm) aluminum oxide cloth to remove all irregularities, pits, and scratches, as determined by visual inspection. Perform the grindings by mounting the test rod in the chuck of the grinding and polishing apparatus, and turning it at a speed of 1700 to 1800 rpm while applying the (99- µm) aluminum oxide cloth. Old (99- µm) Aluminum oxide cloth may be used to remove rust or major irregularities, but complete the grinding with new cloth. Proceed at once with, or remove the test rod from the chuck and store in isooctane until needed. Discard reused test rods when the diameter is reduced to 9.5mm.

4.4 Final Polishing:

4.4.1 Just before the test is to be made, subject the test rod to final polishing with (53.5- µm) aluminum oxide cloth. If the preliminary grinding has just been completed, stop the motor that rotates the test rod. Otherwise, remove the test rod from the isooctane (previously used unrusted test rods shall be stored in this reagent), dry with a clean cloth, and place in the chuck. Rub a new piece of (53.5- µm) aluminum oxide cloth longitudinally over the static test rod until the rounded end, and the entire surface show visible scratches. Rotate the test rod at a speed of 1700 to 1800 rpm. Take the cloth and place it halfway around the test rod, and apply a firm but gentle downward pull to the loose ends of the cloth for about 1 to 2 min so as to produce a uniform finely scratched free of longitudinal scratches. Carry out the final stages of the polishing with new cloth.

4.4.2 To ensure that the flat shoulder (that portion of the test rod perpendicular to the threaded stem) is free of rust, polish this area. This can be done by holding a strip of (53.5- µm) aluminum oxide cloth between the chuck and the shoulder while rotating the test rod for a brief period.

4.4.3 Remove the test rod from the chuck without touching with the fingers; wipe lightly with a clean, dry lintless cloth or tissue (or brush the test rod lightly with a camel's hair brush); attach to the plastic holder; and immediately immerse in the oil to be tested.

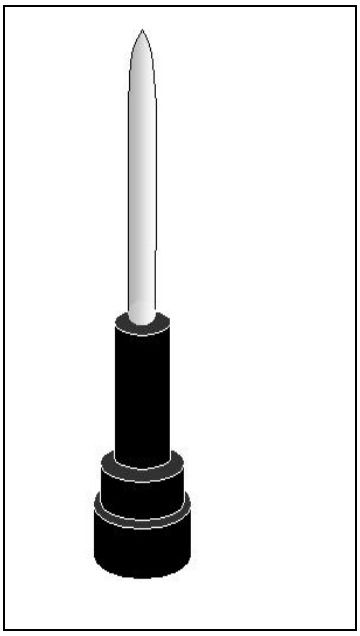


Fig. (3.3) Test Rod

5. Procedure for Synthetic Sea Water.

5.1 Clean the beaker in accordance with good laboratory procedure, wash with distilled water, and dry in an oven. Clean glass beaker cover and a glass stirrer by the same procedure. To clean a stainless steel stirrer and a PMMA cover, use ASTM precipitation naphtha or isooctane or petroleum spirit, wash thoroughly with hot water and finally with distilled water, and dry in an oven at a temperature not over 65 °C. Pour 300 ml of the oil to be tested into the beaker and place the beaker in the oil bath held at a temperature that will maintain the oil sample at 60 ± 1 °C. Insert the beaker into a hole of the bath cover and suspend in the hole with the beaker rim resting on the bath cover. The oil level in the bath shall not be below the oil level in the test beaker. Cover the beaker with the beaker cover with the stirrer in position in the proper opening. Adjust the stirrer so that the shaft is 6 mm off center in the beaker containing the oil sample and the blade is not more than 2 mm from the bottom of the beaker. Then suspend a temperature measuring device through the hole in the cover intended for that purpose so that it is immersed to a depth of about 56 mm. Start the stirrer and when the temperature reading reaches 60 ± 1 °C, insert the steel test rod prepared in accordance with section 5.

5.2 Insert the test rod assembly through the test rod hole in the beaker cover and suspend so that its lower end is 13 to 15 mm from the bottom of the beaker. Either type of plastic test rod holder may be used. The hole through which the test rod is suspended shall be unobstructed.

5.3 continue stirring for 30 min to ensure complete wetting of the steel test rod. With the stirrer in motion, remove the temperature measuring device (if applicable) temporarily and add 30 ml of synthetic sea water through this hole, discharging the water on the bottom of the beaker, and replace the temperature measuring device (if applicable). Continue stirring at a speed of 1000 ± 50 rpm for 4 h from the time water was added, maintaining the temperature of the oil- water mixture at 60 ± 1 ^oC. Stop stirring at the end of the 4-h period, remove the test rod, allow to drain, and then wash with ASTM precipitation naphtha or isooctane, or petroleum spirit. If desired, the test rod may be preserved by lacquering.

3.4.3 Pour Point Measurement.

Pour Point of oil-stocks and their mixtures were measured at seven different concentrations (Wt. %), namely 0, 0.5, 1, 2, 4, 6 and 8 with a Pour Point tester (ASTM D97) using two types of tester shown in Fig. (3.4) and Fig. (3.5).

Fig. (3.4) Computerized Pour Point Tester
Test six samples simultaneously for pour point (ASTM D97).

Fig. (3.5) Pour Point Tester of Petroleum Products

3.4.4 Standard Test Method for Pour Point of petroleum Products

1. Summary of test Method.

1.1 After preliminary heating, the sample is cooled at a specified rate and examined are intervals of 3°C for flow characteristics. The lowest temperature at which movement of the specimen is observed is recorded as the pour point.

2. Apparatus.

2.1 Test Jar, cylindrical, of clear glass, flat bottom, 33.2 to 34.8-mm outside diameter, and 115 to 125-mm in height. The inside diameter of the Jar can range from 30.0 to 32.4 mm, within the constraint that the wall thickness be no greater than 1.6 mm. The jar shall have a line to indicate a sample height 54 ± 3 mm above the inside bottom.

2.2 Thermometers.

2.2.1 Since separation of liquid column thermometers occasionally occurs and may escape detection; thermometers should be checked immediately prior to the test and used only if they prove accurate within ± 1°C (for example ice point).

2.3 Cork, to fit the test Jar, bored centrally for the test thermometer.

2.4 Jacket, watertight, cylindrical, metal, flat bottomed, 115± 3mm depth, with inside diameter of 44.2 to 45.8mm.It shall be supported in a vertical position in the cooling bath so that not more than 25mm projects out of the cooling medium, and shall be capable of being cleaned.

2.5 Disk, cork or felt, 6 mm thick to fit loosely inside the jacket.

2.6 Gasket, to fit snugly around the outside of the test jar and loosely inside the jacket. The gasket may be made of rubber, leather, or other material that is elastic enough to cling to the test jar and hard enough to hold its shape. Its purpose is to prevent the test jar from touching the jacket.

2.7 Bath or Baths, maintained at prescribed temperatures with a firm support to hold the jacket vertical. The required bath temperatures may be obtained by refrigeration if available, otherwise by suitable freezing mixtures. Freezing mixtures commonly used for temperatures down.

3. Procedure.

3.1 Pour the specimen into the test jar to the level mark. When necessary, heat the specimen in a water bath until it is just sufficiently fluid to pour into the test jar.

3.2 Close the test jar with the cork carrying the high-pour thermometer. In the case of pour points above 36°C, use a higher range thermometer such as ASTM 61C. Adjust the position of the cork and thermometer so the cork fits tightly, the thermometer and the jar coaxial, and the thermometer bulb is immersed so the beginning of the capillary is 3 mm below the surface of the specimen.

3.3 For the measurement of the pour point, subject the specimen in the test jar to the following preliminary treatment:

3.3.1 Specimens Having Pour Points Above –33°C, Heat the specimen without stirring to 9°C above the expected pour point, but to at least 48°C. Transfer the test jar to a water bath maintained at 24°C and commence observations for pour point.

3.3.2 Specimens Having Pour Points of -33°C and Below Heat the specimen without stirring to 45°C in a bath maintained at 6°C. Remove the high Pour thermometer and place the low Pour thermometer in position.

3.4 See that the disk, gasket, and the inside of the jacket are clean and dry. Place the disk in the bottom of the jacket. Place the gasket around the test jar, 25 mm from the bottom. Insert the test jar in the jacket. Never place a jar directly into the cooling medium.

3.5 After the specimen has cooled to allow the formation of paraffin wax crystals, take great care not to disturb the mass of specimen; any disturbance of the spongy network of wax crystals will lead to low and erroneous results.

3.6 Pour points are expressed in integers that are positive or negative multiples of 3 °C. Begin to examine the appearance of the specimen when the temperature of the specimen is 9°C above the expected pour point (estimated as a multiple of 3°C). At each test thermometer reading that is a multiple of 3°C below the starting temperature remove the test jar from the jacket. To remove condensed moisture that limits visibility wipe the surface with a clean cloth moistened in alcohol (ethanol or methanol). Tilt the jar just enough to ascertain whether there is a movement of the specimen in the test jar. The complete operation of removal, wiping, and replacement shall require not more than 3s.

3.6.1 If the specimen has not ceased to flow when its temperature has reached 27°C, transfer the test jar to the next lower temperature bath per the following schedule:

Specimen is at +27°C, move to 0°C bath,
Specimen is at +9°C, move to -18°C bath,
Specimen is at -6°C, move to -33°C bath,

Specimen is at -24°C, move to -51°C bath,
Specimen is at -42°C, move to -69°C bath.

3.6.2 As soon as the specimen in the jar does not flow when titled, hold the jar in a horizontal position for 5s, as noted by an accurate timing device and observe carefully. If the specimen shows any movement, replace the test jar immediately in the jacket and repeat a test for flow at the next temperature, 3°C lower.

3.7 Continue in this manner until a point is reached at which the specimen shows no movement when the test jar is held in a horizontal position for 5s. Record the observed reading of the test thermometer.

4. Calculation and Report.

4.1 Add 3°C to the temperature recorded in 6.7 and report the result as the Pour Point, ASTM D97.

3.4.4 Flash Point Measurement.

Flash point of oil-stocks and their mixtures were measured at seven different concentration (Wt.%), namely 0, 0.5, 1, 2, 4, 6 and 8 with a Flash Point tester (ASTM D92) shown in Fig.(3.6).

Fig. (3.6) Flash Point Tester, Cleveland Open Cup (COC)

3.4.4.1 Standard Test Method for Flash and Fire Points by Cleveland Open Cup

This standard is issued under the fixed designation D92. This flash point test method is a dynamic method and depends on definite rates of temperature increases to control the precision of the test method. Its primary use is for viscous materials having flash point of 79°C and above.

1. Summary of Method.

1.1 Approximately 70ml of test specimen is filled into a test cup. The temperature of the test specimen is increased rapidly at first and then at a slower constant rate as the flash point is approached. At specified intervals a test flame is passed across the cup. The flash point is the lowest liquid temperature at which application of the test flame causes the vapors of the test specimen of the sample to ignite.

2. Apparatus.

2.1 Cleveland Open Cup Apparatus (manual)- This apparatus consists of the test cup, heating plate, test flame applicator, heater.

2.2 Cleveland Open Cup Apparatus (automated)- This apparatus is an automated flash point instrument that shall perform the test.

2.3 Temperature Measuring Device- A thermometer having the range (-6 to + 400 °C).

2.4 Test Flame- Natural gas (methane) flame and bottled gas (butane, propane) flame have been found acceptable for use as the ignition source.

3. Sampling.

3.1 Obtain a sample at least 70 ml of sample is required for each test.

3.2 Erroneously high flash points may be obtained if precautions are not taken to avoid the loss of volatile material. Do not open containers unnecessarily; this will prevent loss of volatile material and possible introduction of moisture. Do not make a transfer of the sample unless the sample temperature is at least 56 °C below the expected flash point. When possible, flash point should be the first test performed on a sample and the sample should be stored at low temperature.

3.3 Do not store samples in gas-permeable containers since volatile material may diffuse through the walls of the enclosure. Samples in leaky containers are suspect and not a source of valid results.

3.4 Light hydrocarbons may be present in the form of gasses, such as propane or butane, and may not be detected by testing because of losses during sampling and filling of the test cup. This is especially evident on heavy residuums or asphalts from solvent extraction processes.

3.5 Samples of very viscous materials can be warmed until they are reasonably fluid before they are tested. However, no sample shall be heated more than absolutely necessary. It shall never be heated above a temperature of 56 °C below the expected flash point before transferring.

3.6 Samples containing dissolved or free water can be dehydrated with calcium chloride or by filtering through a qualitative filter paper or a loose plug of dry absorbent cotton. Samples of very viscous materials can be warmed until they are reasonably fluid before they are filtered, but they shall not be heated for prolonged periods or above a temperature of 56 °C below the expected flash point.

4. Preparation of Apparatus.

4.1 Support the manual or automated apparatus on a level steady surface.

4.2 Tests are to be performed in a draft-free room or compartment. Tests made in a laboratory hood or in any location where drafts occur are not be relied upon.

4.3 Wash the test cup with the cleaning solvent to remove any test specimen or traces of gum or residue remaining from a previous test.

If any deposits of carbon are present, they should be removed with a material such as a very fine grade of steel wool. Ensure that the test cup is completely clean and dry before using again. If necessary, flush the test cup with cold water and dry for a few minutes over an open flame or a hot plate to remove the last traces of solvent and water. Cool the test cup to at least 56 °C below the expected flash point before using.

4.4 Support the temperature measuring device in a vertical position with the bottom of the device located 6.4 ± 0.1 mm up from of the bottom of the inside of the test cup on a diameter perpendicular to the arc (or line) of the sweep of the test flame and on the side opposite to the test flame and on the side opposite to the test flame applicator mounting position.

4.5 Prepare the manual apparatus or the automated apparatus for operation according to the manufacturers instructions for calibrating, checking, and operating the equipment.

5. Procedure.

5.1 Manual Apparatus:

5.1.1 Fill the test cup with the sample so that the top of the meniscus of the test specimen is exactly at the filling mark, and place the test cup on the center of the heater. The temperature of the test cup and the sample not exceed 56 °C below the expected flash point. If too much test specimen has been added to the cup, remove the excess using a syringe or similar device for withdrawal of fluid. However, if there is test specimen on the outside of the test cup, empty, clean, and refill it. Destroy any air bubbles or foam on the surface of the test specimen with a sharp knife or other suitable device and maintain the required level of test specimen. If a foam persists during the final stages of the test, terminate the test and disregard any results.

5.1.2 Solid material shall not be added to the test cup. Solid or viscous samples shall be until they are fluid before being poured into the test cup; however, the temperature of the sample during heating shall not exceed 56 °C below the expected flash point.

5.1.3 Light the test flame and adjust it to a diameter of 3.2 to 4.8 mm or to the size of the comparison bead, if one is mounted on the apparatus.

5.1.4 Apply heat initially at such a rate that the temperature as indicated by the temperature measuring device increases 14 to 17°C/min. When the test specimen temperature is approximately 56 °C below the expected flash point is 5 to 6°C / min.

5.1.5 Apply the test flame when the temperature of the test specimen is approximately 28°C below the expected flash point and each time thereafter at a temperature reading that is a multiple of 2°C. Pass the test flame across the center of the test cup at right angles to the diameter, which passes through the temperature measuring device. With a smooth, continuous motion, apply the test flame either in a straight line or along the circumference of a circle having a radius of at least 150 ± 1 mm. The center of the test flame shall move in a horizontal plane not more than 2 mm above the plane of the upper edge of the test cup and passing in one direction only. At the time of the next test flame application, pass the test flame in the opposite direction of the preceding application. The time consumed in passing the test flame across the test cup in each case shall the approximately 1± 0.1 s.

5.1.6 During the last 28°C rise in temperature prior to the expected flash point, care shall be taken to avoid disturbing the vapors in the test cup with rapid movements or drafts near the test cup.

5.1.7 When a foam persists on top of the test specimen during the last 28°C rise in temperature prior to the expected flash point, terminate the test and disregard any results.

5.1.8 Meticulous attention to all details relating to the test flame, size of the test flame, rate of temperature increase, and rate of passing the test flame over the test specimen is required for proper results.

5.1.9 when testing materials where the expected flash point temperature is not known, bring the material to be tested and the test cup to a temperature no greater than 50°C, or when the material to that temperature. Apply the test flame, in the manner described in 9.1.5, beginning at least 5°C above the starting temperature. Continue heating the test specimen at 5 to 6°C /min and testing the material every 2°C as described in 9.1.5 until the flash point is obtained.

5.1.10 Record, as the observed flash point, the reading on the temperature measuring device at the time the test flame causes a distinct flash in the interior of the test cup.

5.1.11 When a flash point is detected on the first application of the test flame, the test shall be discontinued, the result discarded, and the test repeated with a fresh test specimen shall be at least 28°C below the temperature found when the flash point was detected on the first application.

5.1.12 When the apparatus has cooled down to a safe handling temperature, less than 60°C, remove the test cup and clean the test cup and the apparatus as recommended by the manufacture.

3.4.5 Viscosity Index Measurements.

Viscosity index of oil-stocks and their mixtures were measured at seven different concentrations (Wt.%), namely 0, 0.5, 1, 2, 4, 6 and 8 with a Standard practice for calculating viscosity index from kinematic viscosity at 40 and 100°C (ASTM D2270).

3.4.5.1 Standard practice for calculating viscosity index from Kinematic viscosity at 40 and 100°C

1. Procedure A-for oils of viscosity index up to and including 100.

1.1 Calculation:

1.1.1 if the kinematic viscosity of the oils at 100°C is less than or equal to 70 mm^2/s (cSt), extract from table 1(Appendix A) the corresponding values for L and H. measured values that are not listed, but are within the range of table 1(Appendix A), may be obtained by linear interpolation. The viscosity index is not defined and may not be reported for oils of kinematic viscosity of less than 2.0 mm^2/s(cSt) at 100°C.

1.1.2 If the kinematic viscosity is above 70mm^2/s (cSt) at 100°C, calculate the values of L and H as follows:

$$L = 0.8353Y^2 + 14.67Y - 216 \quad \ldots (3.1)$$

$$H = 0.1684Y^2 + 11.85Y - 97 \quad \ldots (3.2)$$

Where:

L = kinematic viscosity at 40°C of an oil of 0 viscosity index having the same kinematic viscosity at 100°C as the oil whose viscosity index is to be calculated, mm^2/s (cSt),

Y =kinematic viscosity at 100°C of the oil of 100 viscosity index is to be calculated, mm^2/s (cSt), and

H =kinematic viscosity at 40°C of an oil of 100 viscosity index having the same kinematic viscosity at 100°C as the oil whose viscosity index is to be calculated mm^2/s (cSt).

1.1.3 Calculate the viscosity index, VI, of the oil as follows:

$$VI = \left[\frac{(L-U)}{(L-H)}\right] * 100 \quad \ldots (3.3)$$

Where:

U = kinematic viscosity at 40°C of the oil whose viscosity index is to be calculated mm^2/s (cSt).

2. Procedure B-for oils of viscosity index of 100 and greater.

2.1 Calculation:

2.1.1 If the kinematic viscosity of the oil at 100°C is less than or equal to 70 mm^2/s (cSt), extract the corresponding value for H from table1. Measured values that are not listed, but are within the range of table1, can be obtained by linear interpolation. The viscosity index is not defined and may not be reported for oils of kinematic viscosity of less than 2.0 mm^2/s (cSt) at 100°C.

2.1.2 If the measured kinematic viscosity at 100°C greater than 70 mm^2/s (cSt), calculate the value of follows:

$$H = 0.1684Y^2 + 11.85Y - 97 \qquad \dots (3.4)$$

Where:

Y = kinematic viscosity at 100°C of the oil whose kinematic viscosity is to be calculated, mm^2/s (cSt)

H =kinematic viscosity at 40°C of an oil of 100 viscosity index having the same kinematic viscosity at 100°C as the oil whose viscosity index is to be calculated mm^2/s (cSt).

2.1.3 Calculate the viscosity index, VI, of the follows:

$$VI = \left[\frac{((antiLogN) - 1)}{0.00715}\right] + 100 \qquad \dots (3.5)$$

Where:

$$N = \frac{(log\, H - log\, U)}{log\, Y} \qquad \dots (3.6)$$

Or

$$Y^N = H / U \qquad \ldots (3.7)$$

Where:

U = kinematic viscosity at 40°C of the oil whose viscosity index is to be calculated mm^2/s (cSt).

3.4.6 Foaming Measurement.

Foaming of oil-stocks and their mixtures were measured at seven different concentration (Wt. %), namely 0, 0.5, 1, 2, 4, 6 and 8 with a foaming characteristics tester of lubricating oils (ASTM D892) shown in Fig. (3.7).

3.4.6.1 Foaming characteristics of lubricating oils (ASTM D892).

This test method covers the determination of the foaming characteristics of lubricating oils at 24°C and 93.5°C.

Fig. (3.7) Foaming Tester

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Effect of Blending of Oil-Stocks with Polyisoprene on Viscosity.

The dynamic viscosities of the three types of oil-stocks of 40 stock, 60 stock, 150 stock in the range of (20.65-34.97) °API gravity, were mixed with different concentrations in the range of (0-8) wt.% of Polyisoprene 1502 and Polyisoprene 1320, which have 0.789 and 0.853 specific gravity respectively at different temperature, as follows:

- Each one of 40 stocks, 60 stocks, and 150 stocks was mixed with Polyisoprene 1502 the efforts are represented graphically in Figs. (4.1) to (4.3).
- Each one of 40 stocks, 60 stocks, and 150 stocks was mixed with Polyisoprene 1320 the efforts are represented graphically in Figs. (4.4) to (4.6).

The blending of the three types of oil-stocks with Polyisoprene resulted in a noticeable increase in the viscosity when the weight percent of Polyisoprene increased. Because each type of Polyisoprene has higher viscosity than the viscosities of the three types of oil-stocks. The effect of Polyisoprene 1320 on viscosity of oil-stocks is higher than the effect of Polyisoprene 1502.

The increase in the viscosity for lighter oil-stock is greater than that of the medium and heavier one, i.e. the effect of Polyisoprene on 40 stock is higher than on 60 and 150 stock respectively, as shown in the Figures (4.1) to (4.6).

Figures (4.1) to (4.6) shows the effect of increasing temperature on dynamic viscosities of oil-stocks with Polyisoprene. It can be noted that the increase in temperature will decrease the value of the dynamic viscosity of the oil-stocks for all values of weight percentages of Polyisoprene.

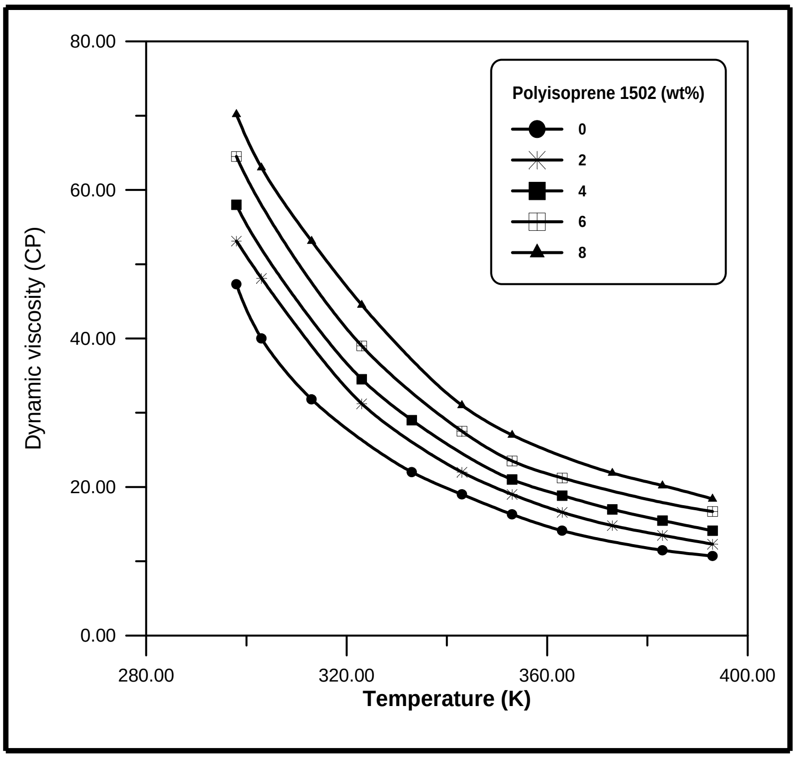


Fig. (4.1) Dynamic Viscosity of 40 Stock Versus Temperature of Different Wt% Polyisoprene 1502.

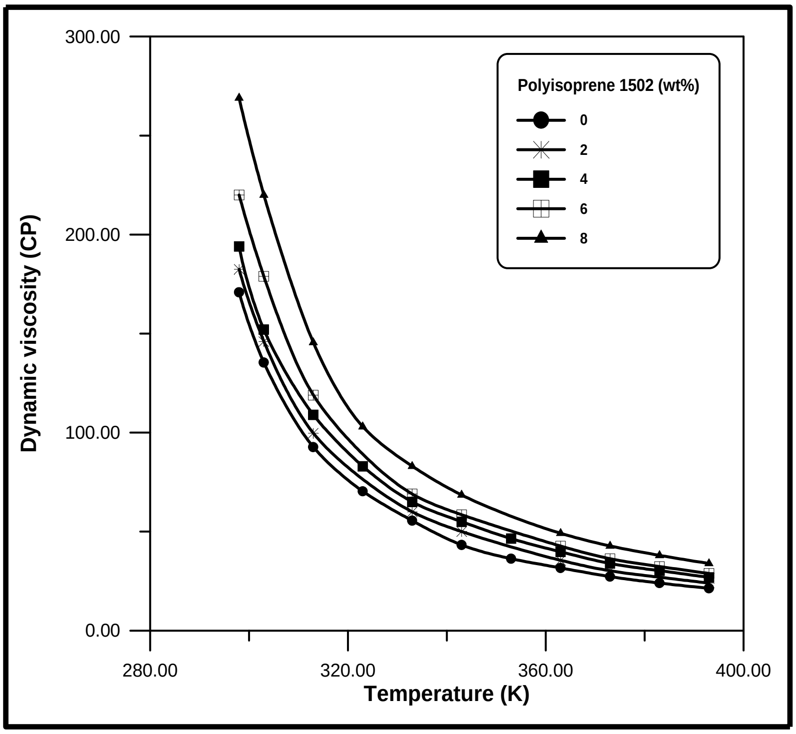


Fig. (4.2) Dynamic Viscosity of 60 Stock Versus Temperature of Different Wt% Polyisoprene 1502.

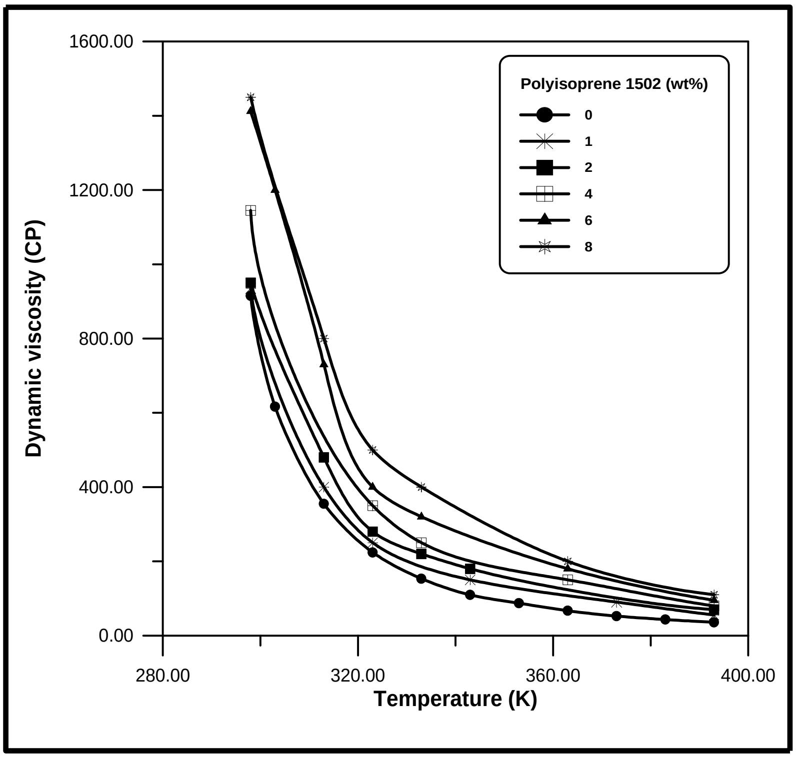


Fig. (4.3) Dynamic Viscosity of 150 Stock Versus Temperature of Different Wt% Polyisoprene 1502.

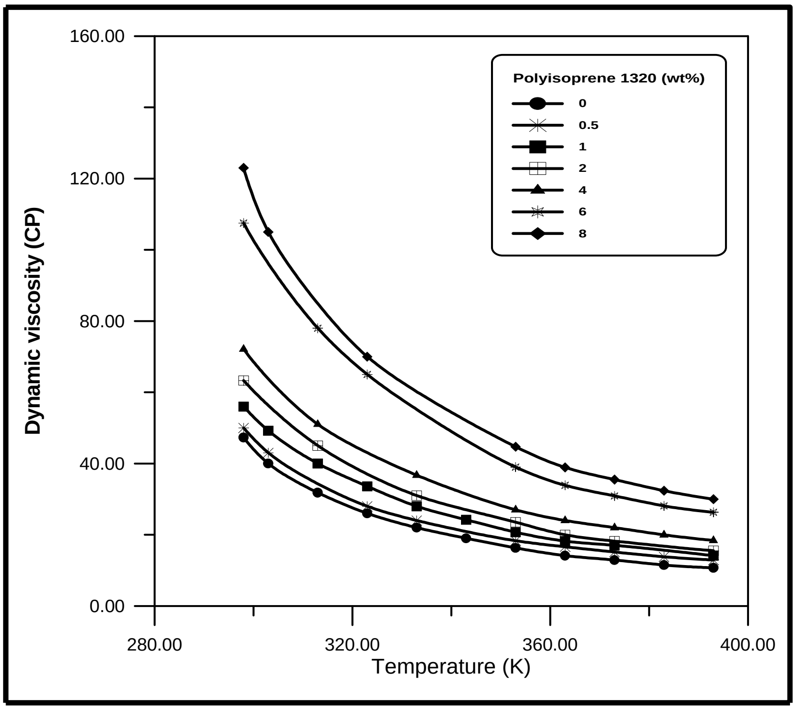


Fig. (4.4) Dynamic Viscosity of 40 Stock Versus Temperature of Different Wt% Polyisoprene 1320.

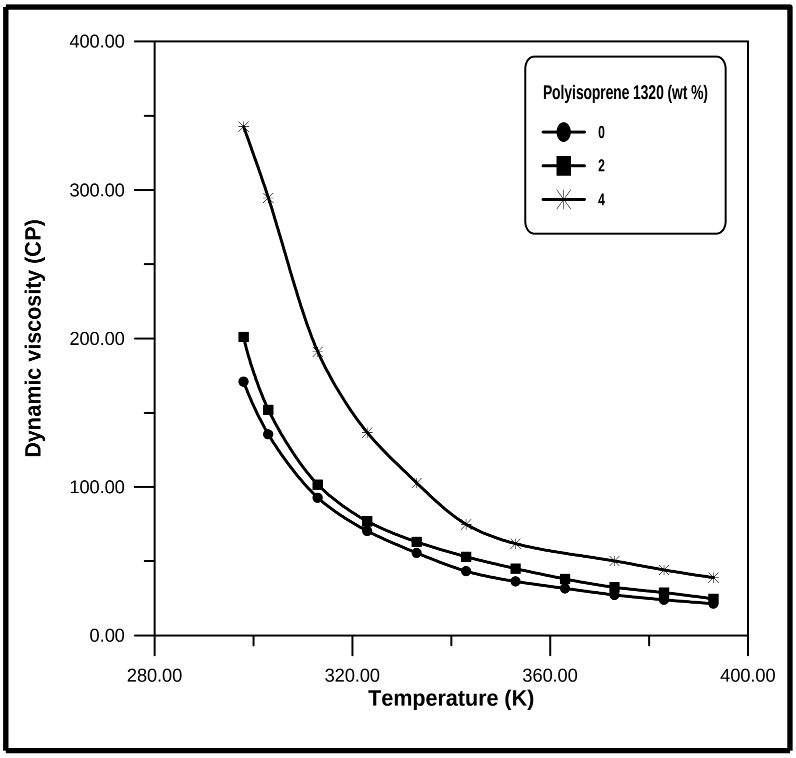


Fig. (4.5) Dynamic Viscosity of 60 Stock Versus Temperature of Different Wt% Polyisoprene 1320.

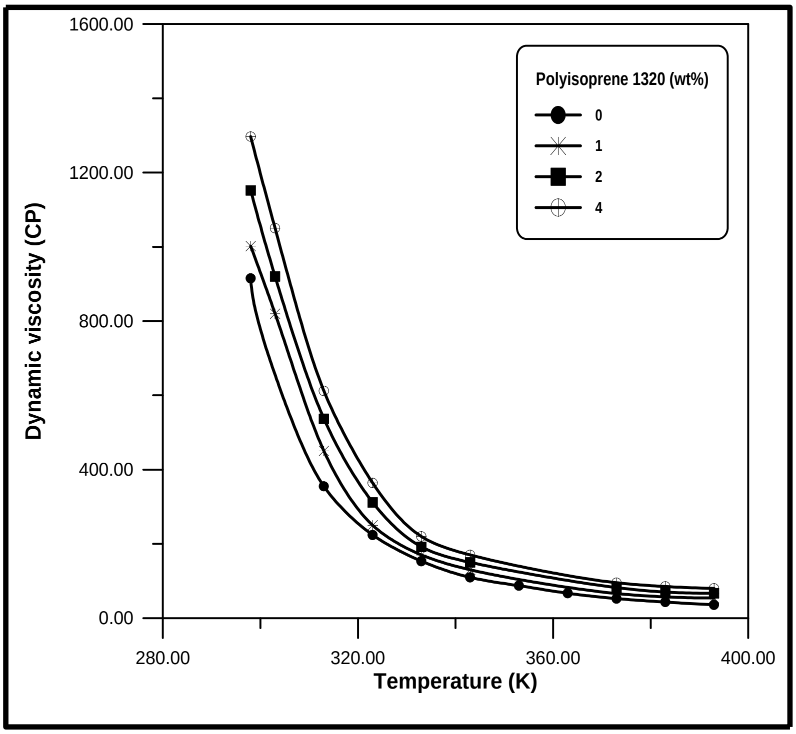


Fig. (4.6) Dynamic Viscosity of 150 Stock Versus Temperature of Different Wt% Polyisoprene 1320.

4.2 Effect of Blending of Oil-Stocks with Polyisoprene on Rust (corrosion rate).

The weight lost (corrosion rate) is measured of the three types of oil-stocks of 40 stock, 60 stock, 150 stock in the range of (20.65-34.97) °API gravity,which were mixed with different concentrations in the range of (0-8) wt. % of Polyisoprene 1502 and Polyisoprene 1320, as follows:

- Each one of 40 stocks, 60 stocks, and 150 stocks was mixed with Polyisoprene 1502 the efforts are represented graphically in Fig. (4.7).

- Each one of 40 stocks, 60 stocks, and 150 stocks was mixed with Polyisoprene 1320 the efforts are represented graphically in Fig. (4.8).

The blending of the three types of oil-stocks with Polyisoprene resulted in a noticeable decrease in the weight lost (corrosion rate) when the weight percent of Polyisoprene increased. The effect of Polyisoprene 1320 on weight lost of oil-stocks is higher than the effect of Polyisoprene 1502, the efforts are represented graphically in Fig. (4.9) to Fig. (4.11). The decrease in the weight lost for lighter oil-stock is less than that of the medium and heavier one, i.e. the effect of Polyisoprene on 40 stock is lower than on 60 and 150 stock respectively, as shown in the Figures (4.7) to (4.11). Figures (4.7) to (4.11) shows the effect of increasing weight percent of Polyisoprene on corrosion rate of oil-stocks with Polyisoprene. It can be noted that the increase in weight percent of Polyisoprene will decrease the value of the corrosion rate of the oil-stocks for all values of weight percentages of Polyisoprene.

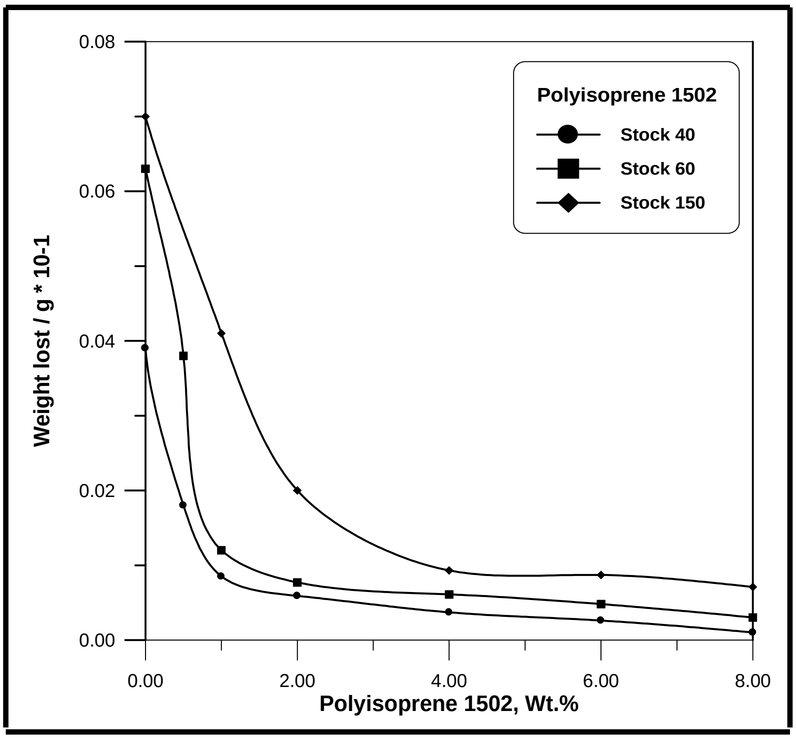


Fig. (4.7) Weight Lost of Stock (40,60 and 150) Versus Wt.% of Polyisoprene 1502.

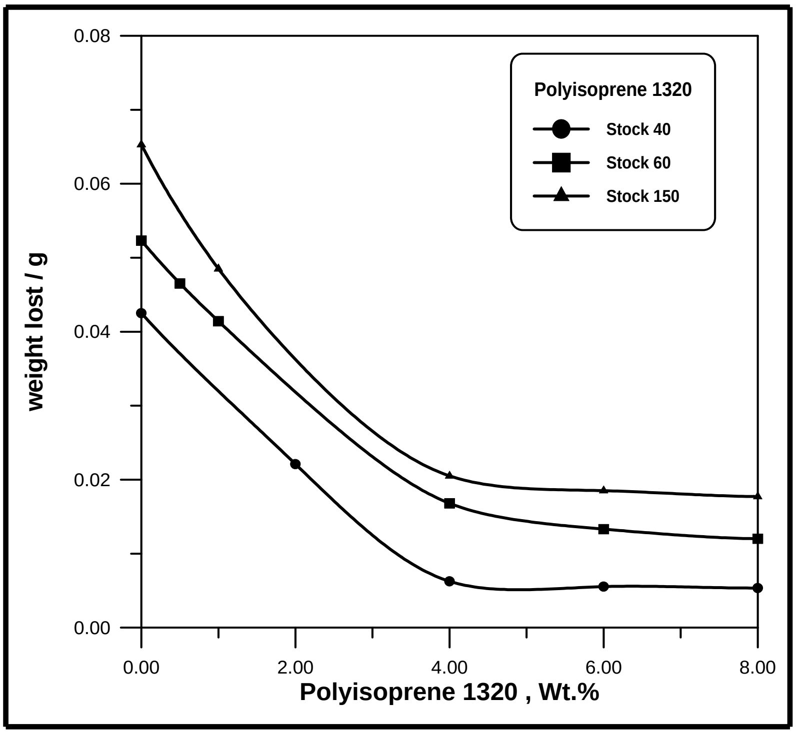


Fig. (4.8) Weight Lost of Stock (40,60 and 150) Versus Wt.% of Polyisoprene 1320.

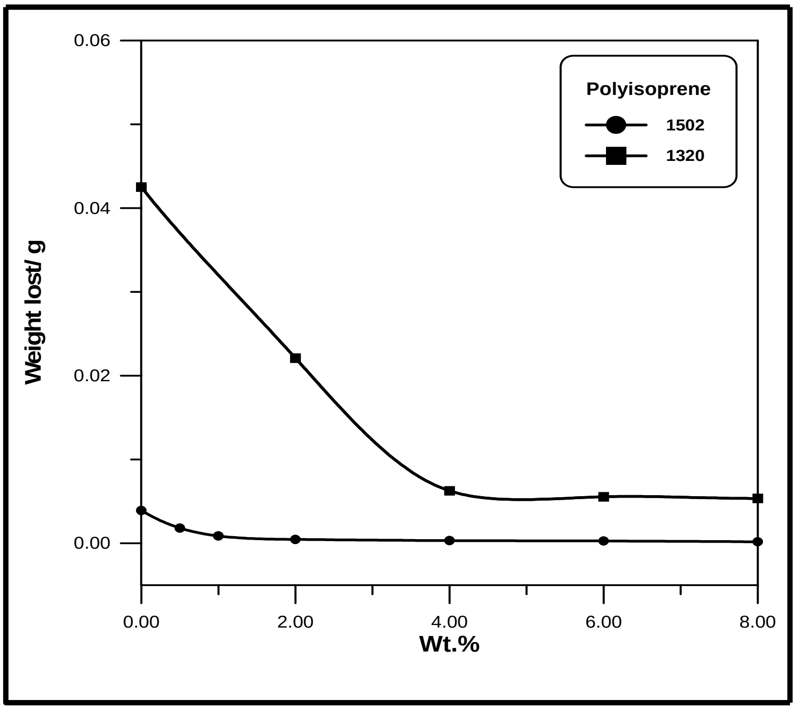


Fig. (4.9) Weight Lost Versus Wt.% of 40 Stock of Different Additives.

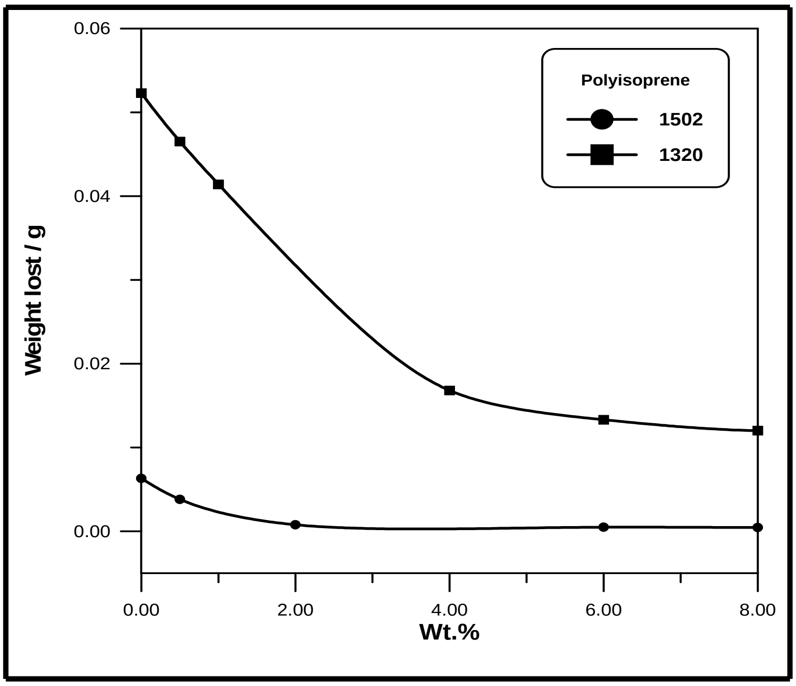


Fig. (4.10) Weight Lost Versus Wt.% of 60 Stock of Different Additives.

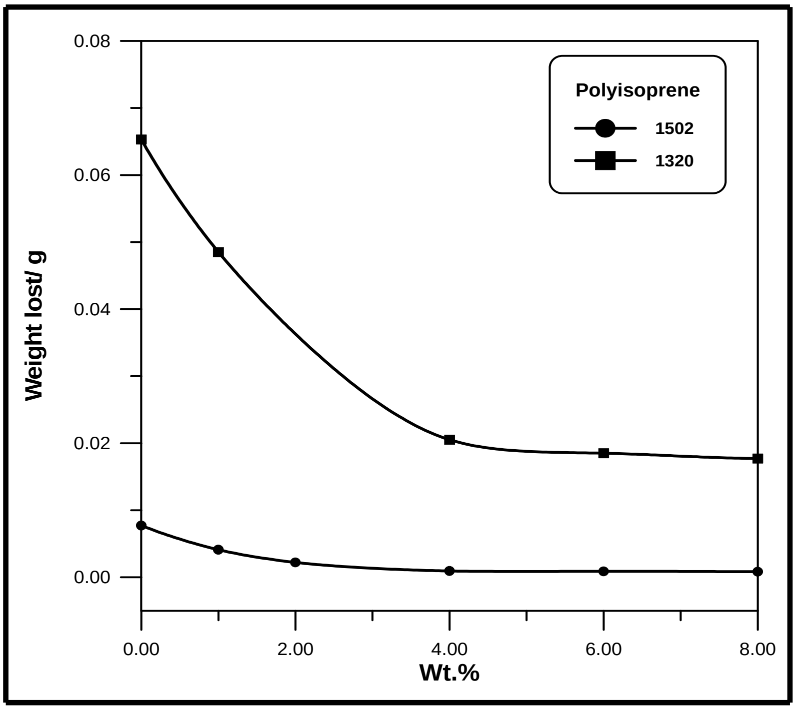


Fig. (4.11) Weight Lost Versus Wt.% of 150 Stock of Different Additives.

4.3 Effect of Blending of Oil-Stocks with Polyisoprene on Flash Point.

The Flash Point is measured of the three types of oil-stocks of 40 stock, 60 stock, 150 stock in the range of (20.65-34.97) °API gravity, which were mixed with different concentrations in the range of (0-8) wt. % of Polyisoprene 1502 and Polyisoprene 1320, as follows:

- Each one of 40 stocks, 60 stocks, and 150 stocks was mixed with Polyisoprene 1502 the efforts are represented graphically in Fig. (4.12).

- Each one of 40 stocks, 60 stocks, and 150 stocks was mixed with Polyisoprene 1320 the efforts are represented graphically in Fig. (4.13).

The blending of the three types of oil-stocks with Polyisoprene resulted in a noticeable decrease in the Flash Point when the weight percent of Polyisoprene increased because of benzene used as solvent to Polyisoprene, therefore flash point decrease because benzene has flash point less than each type of oil-stocks. The effect of Polyisoprene 1320 on Flash Point of oil-stocks is higher than the effect of Polyisoprene 1502.

The decrease in the flash point for lighter oil-stock is less than that of the medium and heavier one, i.e. the effect of Polyisoprene on 40 stock is lower than on 60 and 150 stock respectively, the efforts are represented graphically in Fig. (4.14) to Fig. (4.16).

Figures (4.12) to (4.16) shows the effect of decreasing Flash Point of oil-stocks with Polyisoprene. It can be noted that the increase in weight percent of Polyisoprene will decrease the value of the Flash Point of the oil-stocks for all values of weight percentages of Polyisoprene.

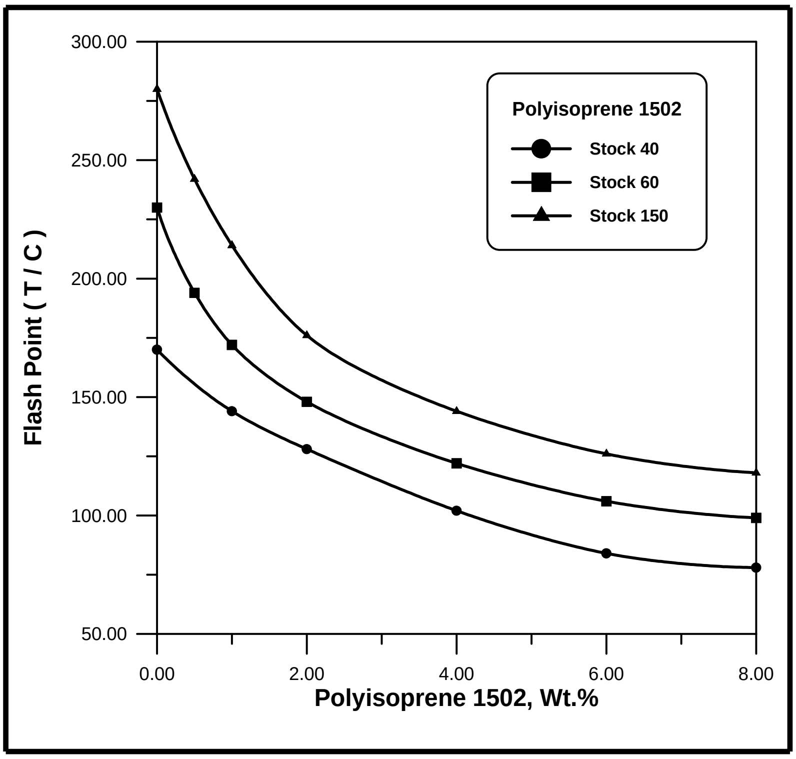


Fig. (4.12) Flash Point of Stock (40,60 and 150) Versus Wt.% of Polyisoprene 1502.

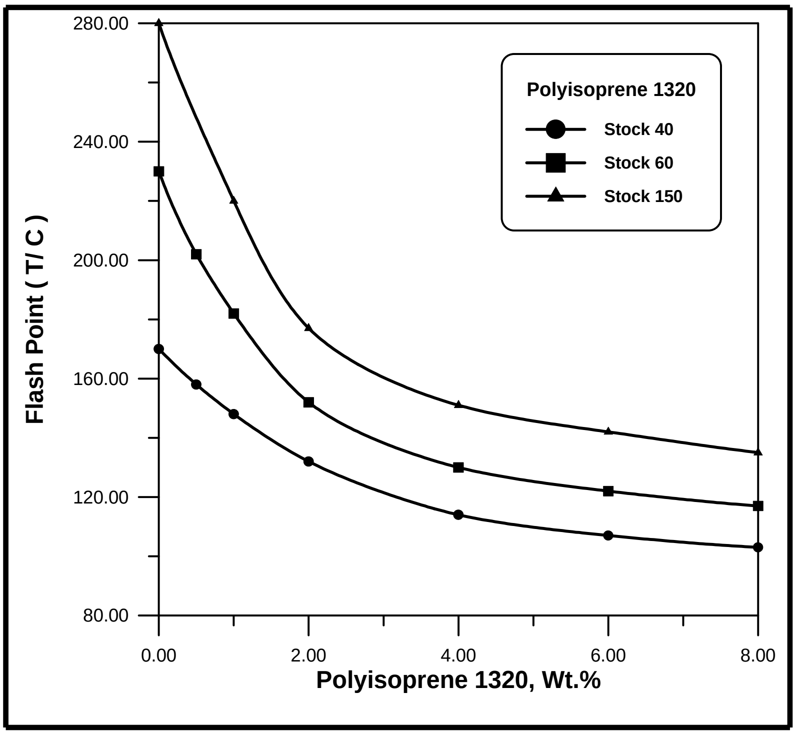


Fig. (4.13) Flash Point of Stock (40,60 and 150) Versus Wt.% of Polyisoprene 1320.

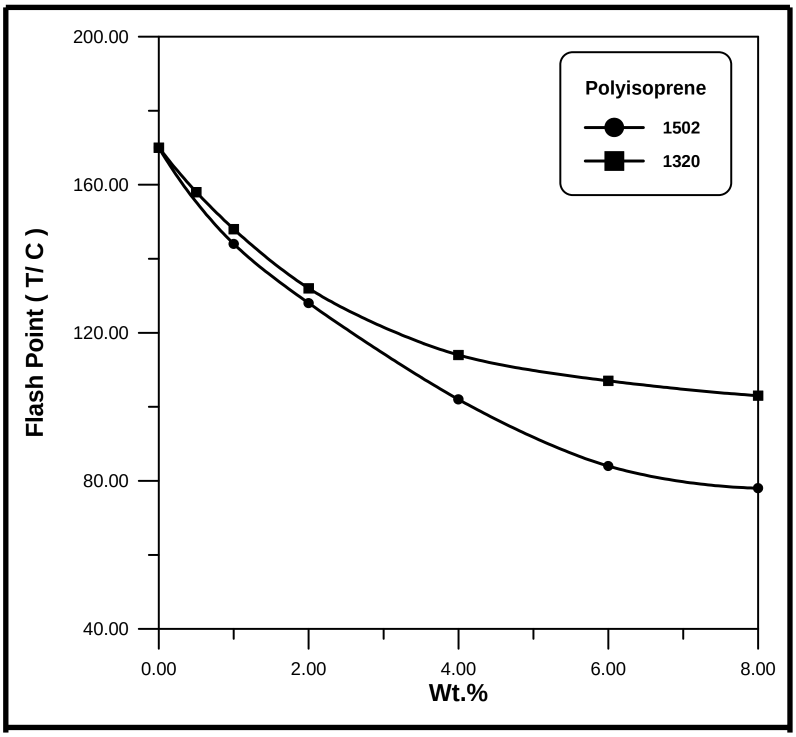


Fig. (4.14) Flash Point Versus Wt.% of 40 Stock of Different Additives.

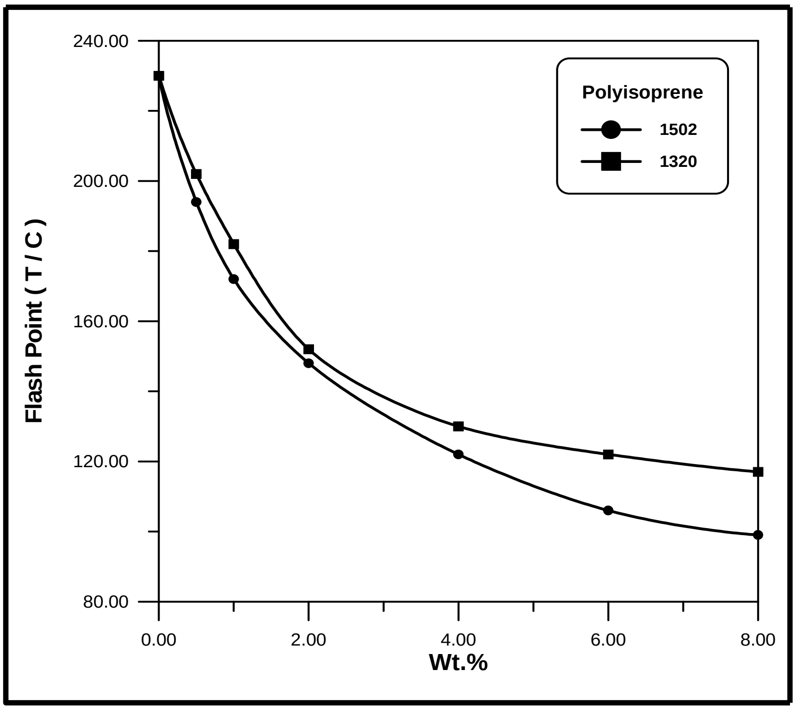


Fig. (4.15) Flash Point Versus Wt.% of 60 Stock of Different Additives.

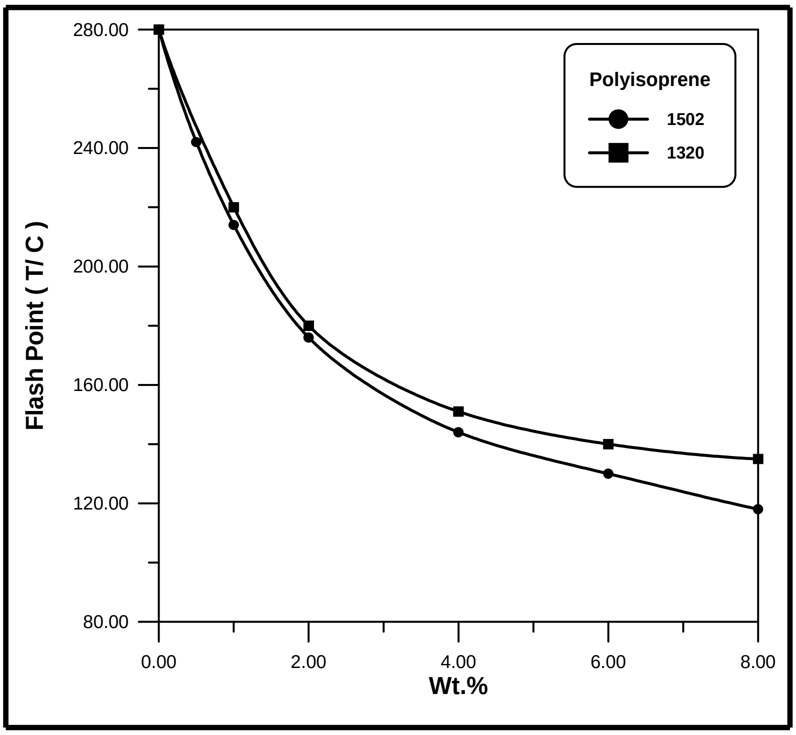


Fig. (4.16) Flash Point Versus Wt.% of 150 Stock of Different Additives.

4.4 Effect of Blending of Oil-Stocks with Polyisoprene on Pour Point.

The Pour Point is measured of the three types of oil-stocks of 40 stock, 60 stock, 150 stock in the range of (20.65-34.97) °API gravity, which were mixed with different concentrations in the range of (0-8) wt. % of Polyisoprene 1502 and Polyisoprene 1320, as follows:

- Each one of 40 stocks, 60 stocks, and 150 stocks was mixed with Polyisoprene 1502 the efforts are represented graphically in Fig. (4.17).

- Each one of 40 stocks, 60 stocks, and 150 stocks was mixed with Polyisoprene 1320 the efforts are represented graphically in Fig. (4.18).

The blending of the three types of oil-stocks with Polyisoprene resulted in a noticeable increase in the Pour Point when the weight percent of Polyisoprene increased. The effect of Polyisoprene 1502 on Pour Point of oil-stocks is higher than the effect of Polyisoprene 1320.The increase in the Pour Point for lighter oil-stock is greater than that of the medium and heavier one, i.e. the effect of Polyisoprene on 40 stock is higher than on 60 and 150 stock respectively, the efforts are represented graphically in Fig. (4.19) to Fig. (4.21).

Figures (4.17) to (4.21) shows the effect of increasing weight percent of Polyisoprene on Pour Point of oil-stocks with Polyisoprene. It can be noted that the increase in weight percent will increase the value of the Pour Point of the oil-stocks for all values of weight percentages of Polyisoprene.

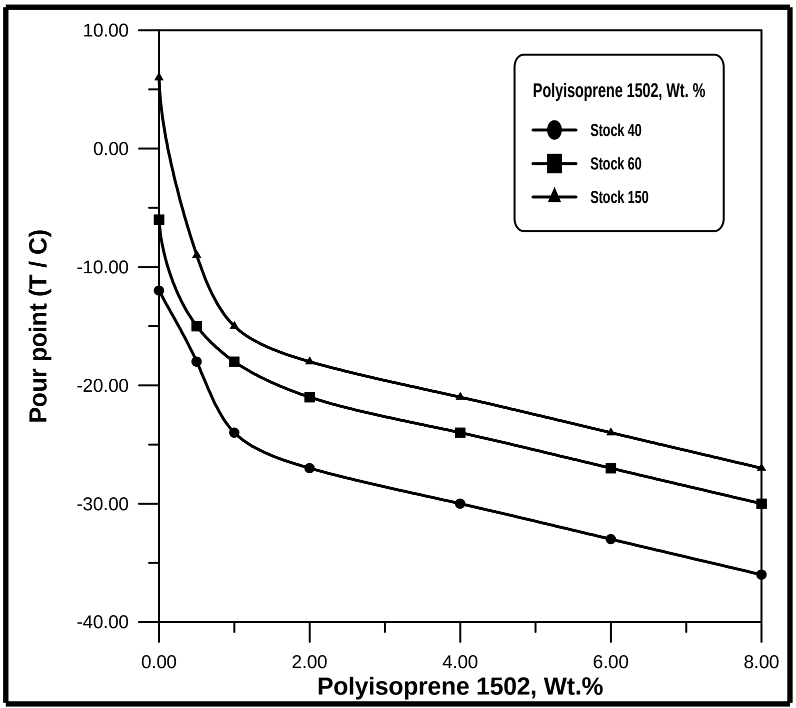


Fig. (4.17) Pour Point of Stock (40,60 and 150) Versus Wt.% of Polyisoprene 1502.

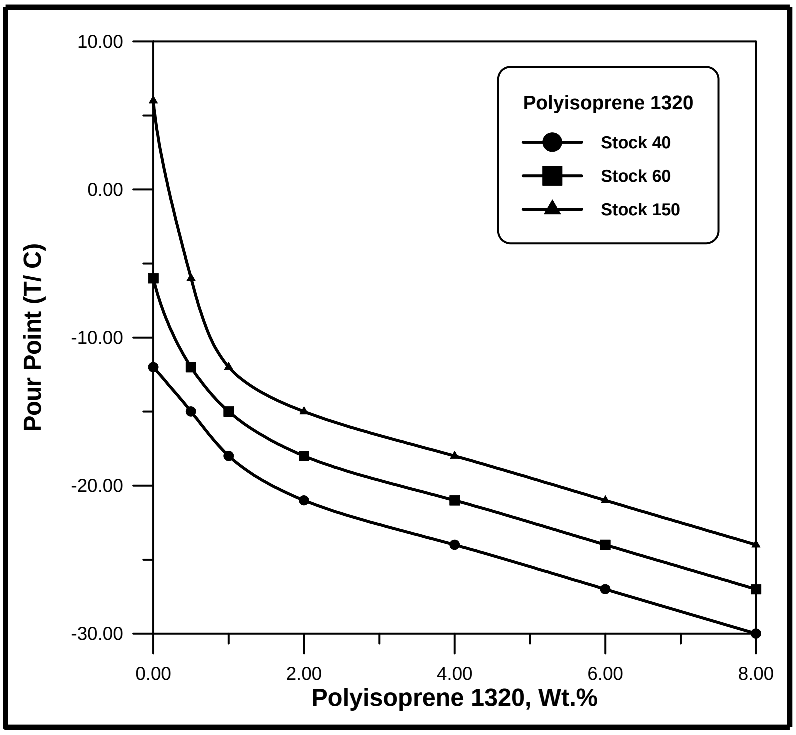


Fig. (4.18) Pour Point of Stock (40,60 and 150) Versus Wt.% of Polyisoprene 1320.

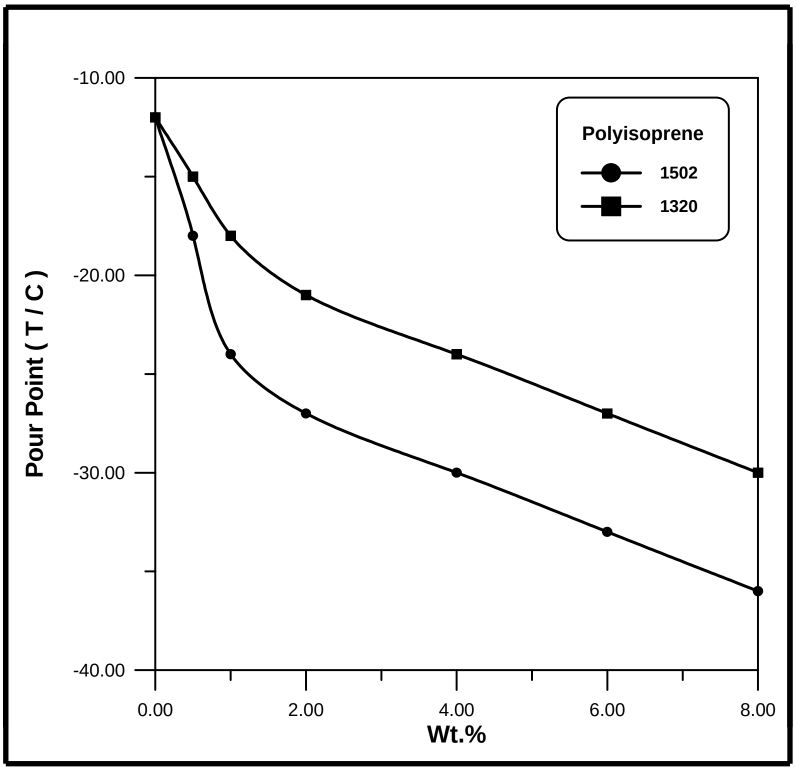


Fig. (4.19) Pour Point Versus Wt.% of 40 Stock of Different Additives.

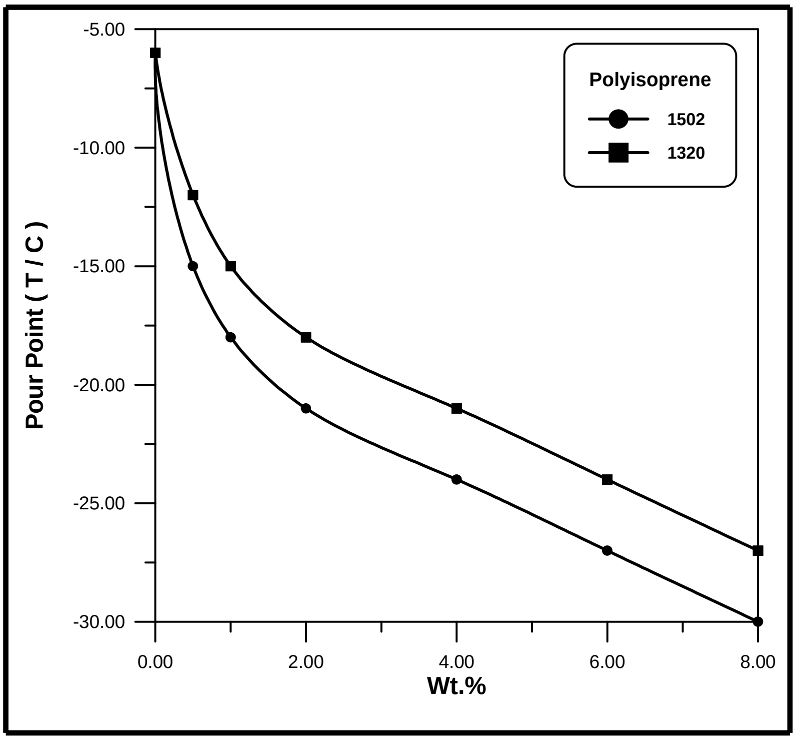


Fig. (4. 20) Pour Point Versus Wt.% of 60 Stock of Different Additives.

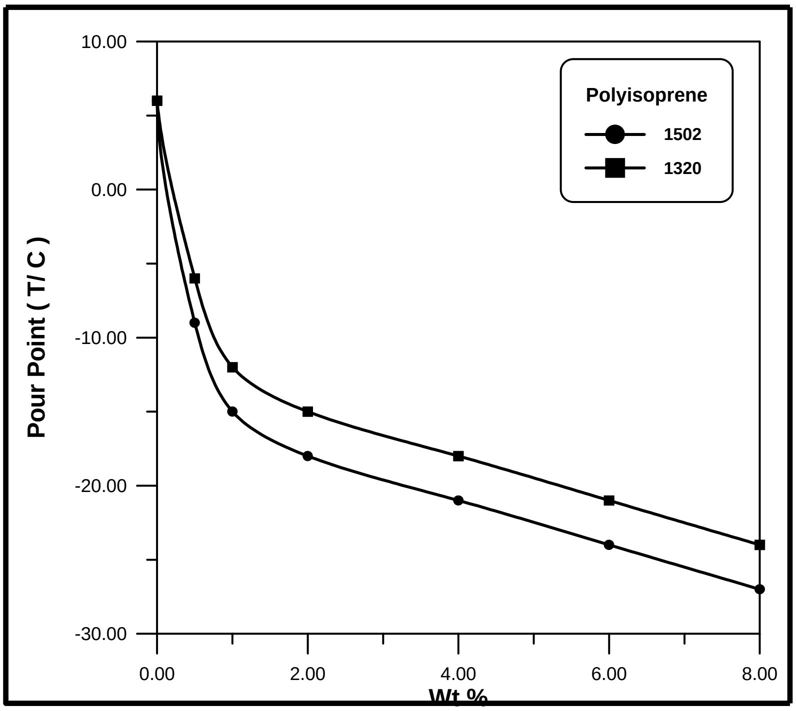


Fig. (4.21) Pour Point Versus Wt.% of 150 Stock of Different Additives.

4.5 Effect of Blending of Oil-Stocks with Polyisoprene on Viscosity Index.

The viscosity index of the three types of oil-stocks of 40 stock, 60 stock, 150 stock in the range of (20.65-34.97) °API gravity, were mixed with different concentrations in the range of (0-8) wt. % of Polyisoprene 1502 and Polyisoprene 1320, as follows:

- Each one of 40 stocks, 60 stocks, and 150 stocks was mixed with Polyisoprene 1502 the efforts are represented graphically in Fig. (4.22).

- Each one of 40 stocks, 60 stocks, and 150 stocks was mixed with Polyisoprene 1320 the efforts are represented graphically in Fig. (4.23).

The blending of the three types of oil-stocks with Polyisoprene resulted in a noticeable increase in the viscosity index when the weight percent of Polyisoprene increased. Because each type of Polyisoprene has higher viscosity than the viscosities of the three types of oil-stocks. The effect of Polyisoprene 1502 on viscosity index of oil-stocks is higher than the effect of Polyisoprene 1320.

The increase in the viscosity index for lighter oil-stock is greater than that of the medium and heavier one, i.e. the effect of Polyisoprene on 40 stock is higher than on 60 and 150 stock respectively, the efforts are represented graphically in Fig. (4.24) to Fig. (4.26)

Figures (4.22) to (4.26) shows the effect of increasing concentration on viscosity index of oil-stocks with Polyisoprene. It can be noted that the increase in weight percent of Polyisoprene will increase the value of the viscosity index of the oil-stocks for all values of weight percentages of Polyisoprene.

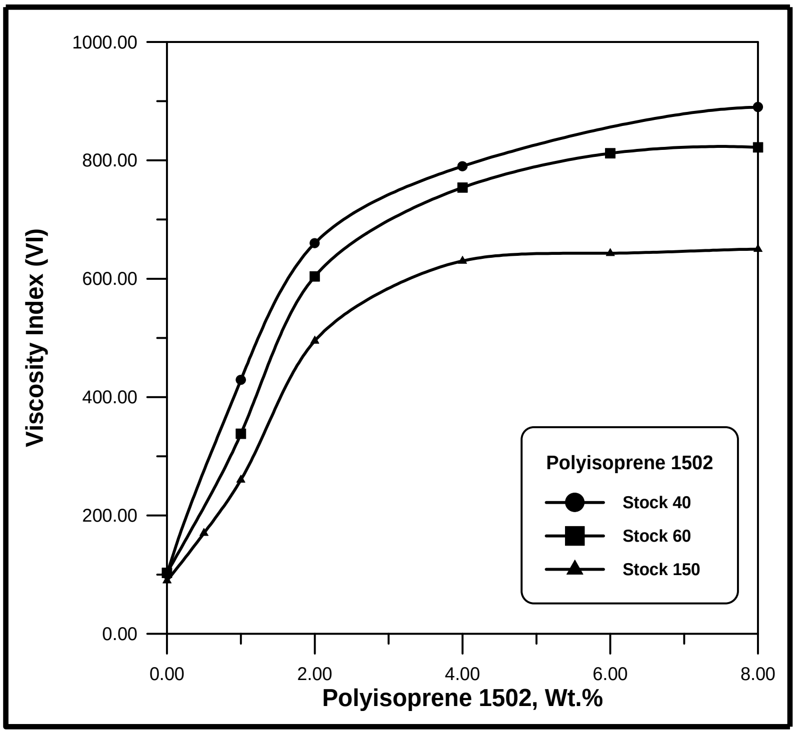


Fig. (4.22) Viscosity Index of Stock (40,60 and 150) Versus Wt.% of Polyisoprene 1502.

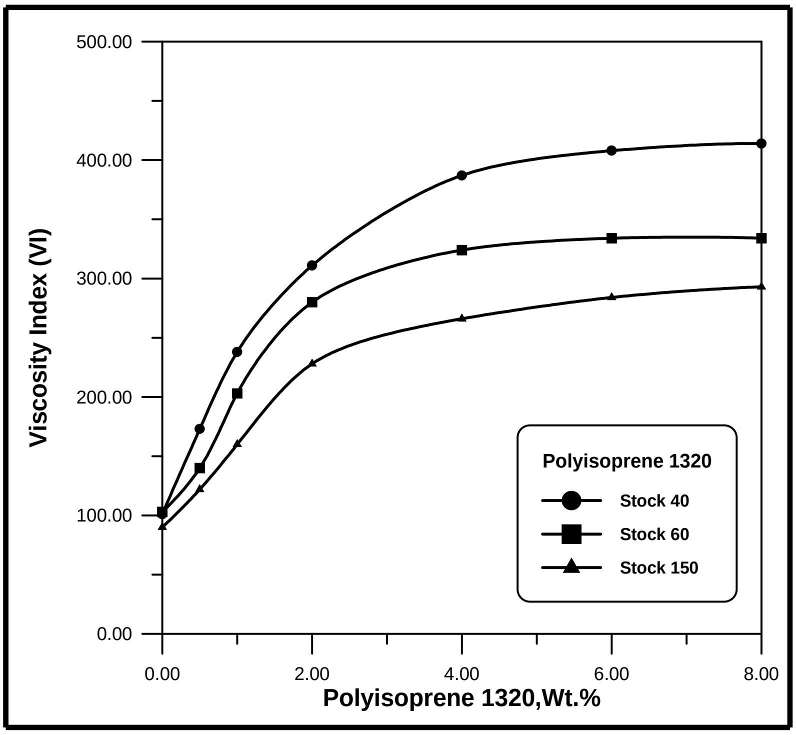


Fig. (4.23) Viscosity Index of Stock (40,60 and 150) Versus Wt.% of Polyisoprene 1320.

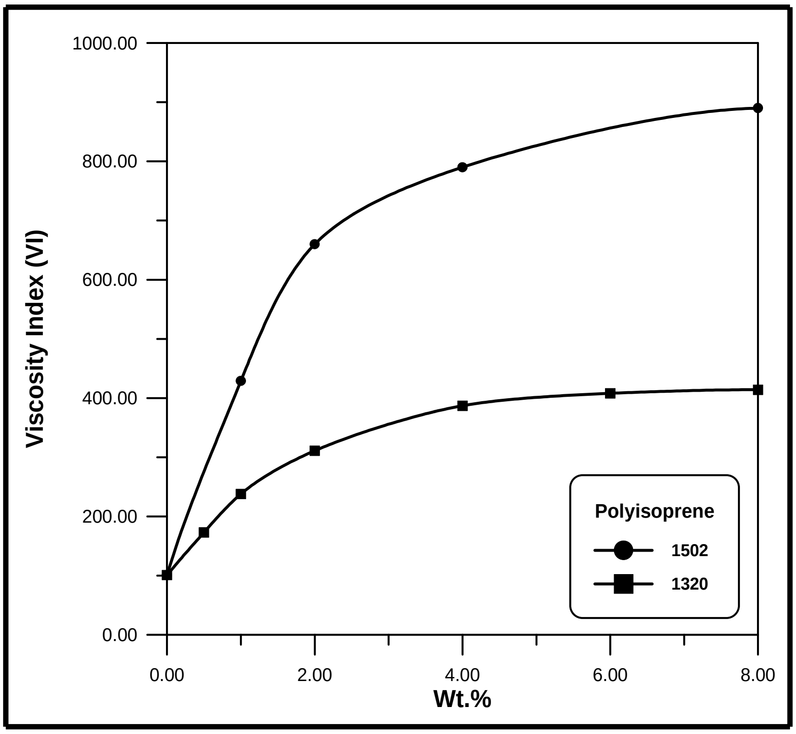


Fig. (4.24) V.I. Versus Wt.% of 40 Stock of Different Additives.

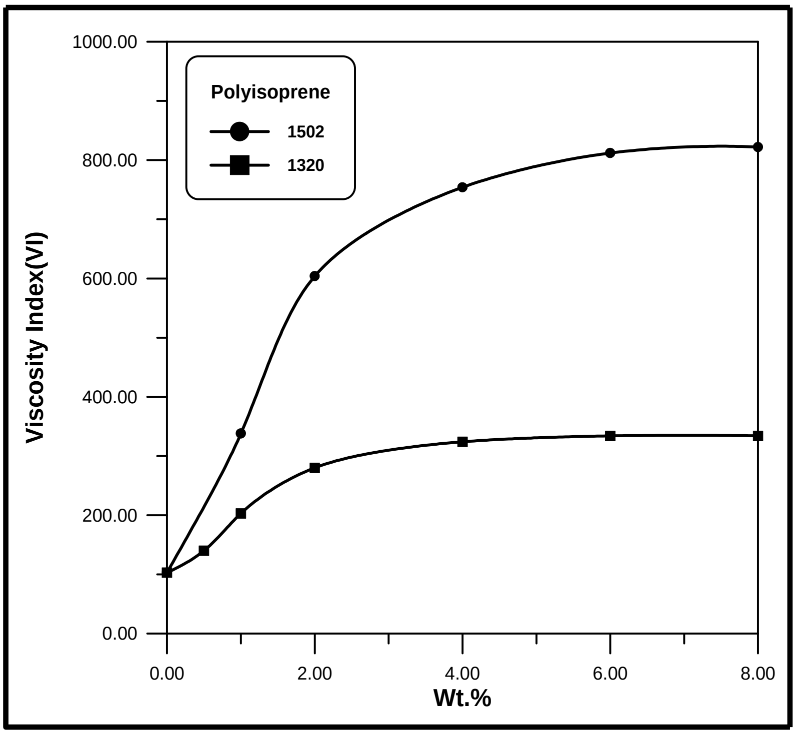


Fig. (4.25) V.I. Versus Wt.% of 60 Stock of Different Additives.

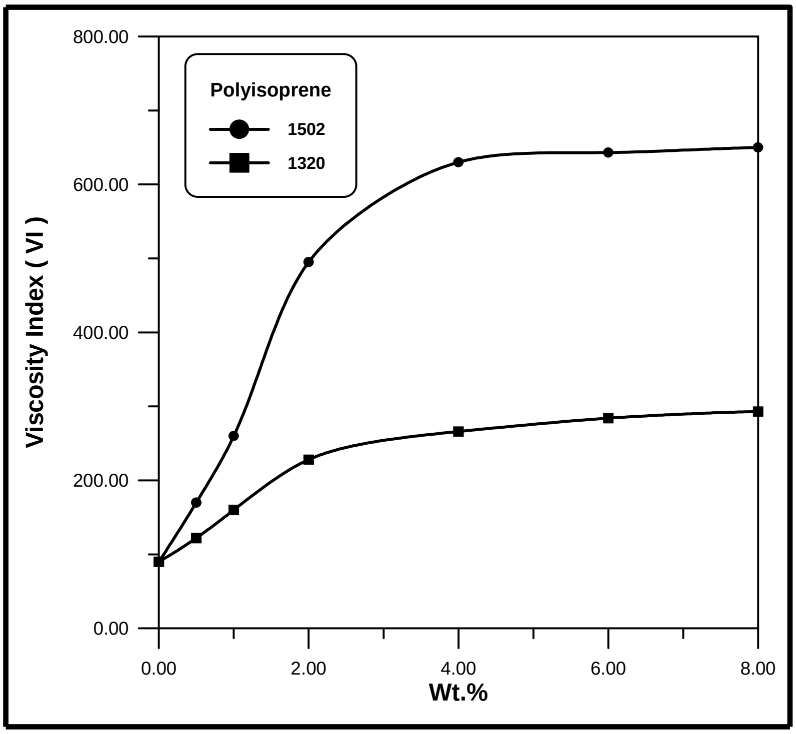


Fig. (4.26) V.I. Versus Wt.% of 150 Stock of Different Additives.

4.6 Flash Point-Concentration Relationship.

1. Blending of Polyisoprene 1502 with Stock 40.

A complete computer program performs a linear least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 1.95 %, the final constants of Eq. (4.1) are listed in table (4.1).

$$(T_f) = a + b(C_{on.}) \qquad \ldots (4.1)$$

Table (4.1) Constant of equation (4.1)

a = 156.49353	b = -11.369987

Where:

T_f = flash point of blending Polyisoprene with base oil, (°C).

$C_{on.}$ = weight percent of polyisoprene, (%).

2. Blending of Polyisoprene 1502 with Stock 60.

A complete computer program performs a linear least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 5.30 %, the final constants of Eq. (4.2) are listed in table (4.2).

$$(T_f) = a + b(C_{on.}) \qquad \ldots (4.2)$$

Table (4.2) Constant of equation (4.2)

a = 198.36869	b = -14.910737

Where:

T_f = flash point of blending Polyisoprene with base oil, (°C).

$C_{on.}$ = weight percent of polyisoprene, (%).

3. Blending of Polyisoprene 1502 with Stock 150.

A complete computer program performs a linear least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 5.20 %, the final constants of Eq. (4.3) are listed in table (4.3).

$$(T_f) = a + b(C_{on.}) \qquad \ldots (4.3)$$

Table (4.3) Constant of equation (4.3)

a = 243.79043	b = -19.187581

Where:

T_f = flash point of blending Polyisoprene with base oil, (°C).

$C_{on.}$ = weight percent of polyisoprene, (%).

4. Blending of Polyisoprene 1320 with Stock 40.

A complete computer program performs a linear least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 1.71 %, the final constants of Eq. (4.4) are listed in table (4.4).

$$(T_f) = a + b(C_{on.}) \qquad \ldots (4.4)$$

Table (4.4) Constant of equation (4.4)

a = 159.69599	b = -9.389392

Where:

T_f = flash point of blending Polyisoprene with base oil, (°C).

$C_{on.}$ = weight percent of polyisoprene, (%).

5. Blending of Polyisoprene 1320 with Stock 60.

A complete computer program performs a <u>linear</u> least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 4.52 %, the final constants of Eq. (4.5) are listed in table (4.5).

$$(T_f) = a + b(C_{on.}) \qquad \ldots (4.5)$$

Table (4.5) Constant of equation (4.5)

a = 204.39327	b = -15.104787

Where:

T_f = flash point of blending Polyisoprene with base oil, (°C).

$C_{on.}$ = weight percent of polyisoprene, (%).

6. Blending of Polyisoprene 1320 with Stock 150.

A complete computer program performs a <u>linear</u> least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 4.74 %, the final constants of Eq. (4.6) are listed in table (4.6).

$$(T_f) = a + b(C_{on.}) \qquad \ldots (4.6)$$

Table (4.6) Constant of equation (4.6)

a = 252.07245	b = -18.256145

Where:

T_f = flash point of blending Polyisoprene with base oil, (°C).

$C_{on.}$ = weight percent of polyisoprene, (%).

4.7 Pour Point-Concentration Relationship.

1. Blending of Polyisoprene 1502 with Stock 40.

A complete computer program performs a <u>Quadratic</u> least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 8.11 %, the final constants of Eq. (4.7) are listed in table (4.7).

$$(T_p) = a + b(C_{on.}) + c(C_{on.})^2 \qquad \ldots(4.7)$$

Table (4.7) Constant of equation (4.7)

a = -15.222654	b = -5.7452318	c = 0.41303968

Where:

T_p = pour point of blending Polyisoprene with base oil, (°C).

$C_{on.}$ = weight percent of polyisoprene, (%).

2. Blending of Polyisoprene 1502 with Stock 60.

A complete computer program performs a <u>Quadratic</u> least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 8.60 %, the final constants of Eq. (4.8) are listed in table (4.8).

$$(T_p) = a + b(C_{on.}) + c(C_{on.})^2 \qquad \ldots(4.8)$$

Table (4.8) Constant of equation (4.8)

a = -10.320443	b = -5.3198947	c = 0.37625435

Where:

T_p = pour point of blending Polyisoprene with base oil, (°C).

$C_{on.}$ = weight percent of polyisoprene, (%).

3. Blending of Polyisoprene 1502 with Stock 150.

A complete computer program performs a Polynomial least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 8.1 %, the final constants of Eq. (4.9) are listed in table (4.9).

$$(T_p) = a + b(C_{on.}) + c(C_{on.})^2 + d(C_{on.})^3 \qquad \text{…(4.9)}$$

Table (4.9) Constant of equation (4.9)

a = 2.3776646	b = -18.133433	c = 4.0413775	d = -0.28059524

Where:

T_p = pour point of blending Polyisoprene with base oil, (°C).

$C_{on.}$ = weight percent of polyisoprene, (%).

4. Blending of Polyisoprene 1320 with Stock 40.

A complete computer program performs a Quadratic least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 4.55 %, the final constants of Eq. (4.10) are listed in table (4.10).

$$(T_p) = a + b(C_{on.}) + c(C_{on.})^2 \qquad \text{…(4.10)}$$

Table (4.10) Constant of equation (4.10)

a = -13.285469	b = -3.6980561	c = 0.21036278

Where:

T_p = pour point of blending Polyisoprene with base oil, (°C).

$C_{on.}$ = weight percent of polyisoprene, (%).

5. Blending of Polyisoprene 1320 with Stock 60.

A complete computer program performs a Polynomial least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 6.75 %, the final constants of Eq. (4.11) are listed in table (4.11).

$$(T_p) = a + b(C_{on.}) + c(C_{on.})^2 + d(C_{on.})^3 \quad \ldots(4.11)$$

Table (4.11) Constant of equation (4.11)

a = -7.139724	b = -8.4962342	c = 1.6468337	d = -0.11238131

Where:

T_p = pour point of blending Polyisoprene with base oil, (°C).

$C_{on.}$ = weight percent of polyisoprene, (%).

6. Blending of Polyisoprene 1320 with Stock 150.

A complete computer program performs a Polynomial least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 10.04 %, the final constants of Eq. (4.12) are listed in table (4.12).

$$(T_p) = a + b(C_{on.}) + c(C_{on.})^2 + d(C_{on.})^3 \quad \ldots(4.12)$$

Table (4.12) Constant of equation (4.12)

a = 3.272197	b = -15.829107	c = 3.4514758	d = -0.23850339

Where:

T_p = pour point of blending Polyisoprene with base oil, ($^{\circ}$C).

$C_{on.}$ = weight percent of polyisoprene, (%).

4.8 Rust (Weight Lost)-Concentration Relationship.

1. Blending of Polyisoprene 1502 with Stock 40.

A complete computer program performs a <u>Polynomial</u> least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 14.22 %, the final constants of Eq. (4.13) are listed in table (4.13).

$$(wt_{lost}) = a + b(C_{on\cdot}) + c(C_{on\cdot})^2 + d(C_{on\cdot})^3 \qquad \ldots(4.13)$$

Table (4.13) Constant of equation (4.13)

a = 0.00338607	b = -0.002610625	c = 0.0006119488	d = 4.2318152 $*10^{-5}$

Where:

wt_{lost} = weight lost of blending Polyisoprene with base oil, (g).

$C_{on.}$ = weight percent of polyisoprene, (%).

2. Blending of Polyisoprene 1502 with Stock 60.

A complete computer program performs a <u>Polynomial</u> least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 8.74 %, the final constants of Eq. (4.14) are listed in table (4.14).

$$(wt_{lost}) = a + b(C_{on.}) + c(C_{on.})^2 + d(C_{on.})^3 \qquad \ldots(4.14)$$

Table (4.14) Constant of equation (4.14)

a = 0.005805971	b = -0.00452152	c = 0.001056308	d = -7.2456231 $*10^{-5}$

Where:

wt_{lost} = weight lost of blending Polyisoprene with base oil, (g).

$C_{on.}$ = weight percent of polyisoprene, (%).

3. Blending of Polyisoprene 1502 with Stock 150.

A complete computer program performs a Polynomial least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 10.62 %, the final constants of Eq. (4.15) are listed in table (4.15).

$$(wt_{lost}) = a + b(C_{on.}) + c(C_{on.})^2 + d(C_{on.})^3 \qquad \ldots(4.15)$$

Table (4.15) Constant of equation (4.15)

a = 0.007881534	b = -0.004185576	c = 0.000790934	d = -4.7522612 $* 10^{-5}$

Where:

wt_{lost} = weight lost of blending Polyisoprene with base oil, (g).

$C_{on.}$ = weight percent of polyisoprene, (%).

4. Blending of Polyisoprene 1320 with Stock 40.

A complete computer program performs a Quadratic least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 7.75 %, the final constants of Eq. (4.16) are listed in table (4.16).

$$(wt_{lost}) = a + b(C_{on.}) + c(C_{on.})^2 \qquad \ldots(4.16)$$

Table (4.16) Constant of equation (4.16)

a = 0.034764718	b = -0.0089871494	c = 0.0006604593

Where:

wt_{lost} = weight lost of blending Polyisoprene with base oil, (g).

$C_{on.}$ = weight percent of polyisoprene, (%).

5. Blending of Polyisoprene 1320 with Stock 60.

A complete computer program performs a Quadratic least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 7.25 %, the final constants of Eq. (4.17) are listed in table (4.17).

$$(wt_{lost}) = a + b(C_{on.}) + c(C_{on.})^2 \qquad \ldots(4.17)$$

Table (4.17) Constant of equation (4.17)

a = 0.051916125	b = -0.010879447	c = 0.0006682493

Where:

wt_{lost} = weight lost of blending Polyisoprene with base oil, (g).

$C_{on.}$ = weight percent of polyisoprene, (%).

6. Blending of Polyisoprene 1320 with Stock 150.

A complete computer program performs a Quadratic least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 7.11 %, the final constants of Eq. (4.18) are listed in table (4.18).

$$(wt_{lost}) = a + b(C_{on.}) + c(C_{on.})^2 \qquad \ldots(4.18)$$

Table (4.18) Constant of equation (4.18)

a = 0.061838396	b = -0.012342174	c = 0.0007685605

Where:

wt_{lost} = weight lost of blending Polyisoprene with base oil, (g).

$C_{on.}$ = weight percent of polyisoprene, (%).

4.9 Viscosity Index (V.I.) - Concentration Relationship.

1. Blending of Polyisoprene 1502 with Stock 40.

A complete computer program performs a Quadratic least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 9.98 %, the final constants of Eq. (4.19) are listed in table (4.19).

$$(V.I.) = a + b(C_{on.}) + c(C_{on.})^2 \qquad \ldots(4.19)$$

Table (4.19) Constant of equation (4.19)

a = 185.12525	b = 239.75854	c = -19.420085

Where:

V.I. = viscosity index of blending Polyisoprene with base oil.

$C_{on.}$ = weight percent of polyisoprene, (%).

2. Blending of Polyisoprene 1502 with Stock 60.

A complete computer program performs a Quadratic least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 8.82 %, the final constants of Eq. (4.20) are listed in table (4.20).

$$(V.I.) = a + b(C_{on.}) + c(C_{on.})^2 \qquad \ldots(4.20)$$

Table (4.20) Constant of equation (4.20)

a = 149.28235	b = 227.04863	c = -18.024924

Where:

V.I. = viscosity index of blending Polyisoprene with base oil.

$C_{on.}$ = weight percent of polyisoprene, (%).

3. Blending of Polyisoprene 1502 with Stock 150.

A complete computer program performs a Quadratic least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 7.06 %, the final constants of Eq. (4.21) are listed in table (4.21).

$$(V.I.) = a + b(C_{on.}) + c(C_{on.})^2 \qquad \ldots(4.21)$$

Table (4.21) Constant of equation (4-21)

a = 107.62643	b = 151.39313	c = -9.5532973

Where:

V.I. = viscosity index of blending Polyisoprene with base oil.

$C_{on.}$ = weight percent of polyisoprene, (%).

4. Blending of Polyisoprene 1320 with Stock 40.

A complete computer program performs a Polynomial least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 1.52 %, the final constants of Eq. (4.22) are listed in table (4.22).

$$(V.I.) = a + b(C_{on.}) + c(C_{on.})^2 + d(C_{on.})^3 \qquad \ldots(4.22)$$

Table (4.22) Constant of equation (4.22)

a = 99.217402	b = 168.72359	c = -35.046174	d = 2.5891958

Where:

V.I. = viscosity index of blending Polyisoprene with base oil.

$C_{on.}$ = weight percent of polyisoprene, (%).

5. Blending of Polyisoprene 1320 with Stock 60.

A complete computer program performs a Polynomial least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 8.71 %, the final constants of Eq. (4.23) are listed in table (4.23).

$$(V.I.) = a + b(C_{on.}) + c(C_{on.})^2 + d(C_{on.})^3 \qquad \ldots(4.23)$$

Table (4.23) Constant of equation (4.23)

a = 92.305715	b = 141.04749	c = -26.234877	d = 1.5494683

Where:

V.I. = viscosity index of blending Polyisoprene with base oil.

$C_{on.}$ = weight percent of polyisoprene, (%).

6. Blending of Polyisoprene 1320 with Stock 150.

A complete computer program performs a Polynomial least square fitting of proposed function of a given set of data with over all average absolute error between experimental and calculated values is not greater than 3.85 %, the final constants of Eq. (4.24) are listed in table (4.24).

$$(V.I.) = a + b(C_{on.}) + c(C_{on.})^2 + d(C_{on.})^3 \qquad \ldots(4.24)$$

Table (4.24) Constant of equation (4.24)

a = 91.977475	b = 68.890566	c = -8.6614272	d = 0.40094687

Where:

V.I. = viscosity index of blending Polyisoprene with base oil.

$C_{on.}$ = weight percent of polyisoprene, (%).

4.10 Viscosity -Temperature Relationship.

The following viscosity correlation is particulary relevant to present study [6]:

$$\left[\frac{\log(\mu)+c}{\log(\mu_o)+c}\right] = \left[\frac{T_o}{T}\right]^s \qquad \ldots(4.25)$$

Where s= 0.06690*log (μ_o) + 3.5565, when T_o is K

Equation (4.25) was originally proposed as generalized dynamic viscosity-temperature correlation for unrefined bitumens and heavy oils [6].

In deriving the correlation shown in Eq. (4.25), consideration was given to limiting the number of adjustable parameters.

The modified form is as shown in Eq. (4.26) [6].

$$Log\mu = B*[303.15/(t+273.15)]^{s} - C \quad \ldots(4.26)$$

$$B = \log(\mu_{o}) + C \quad \ldots(4.27)$$

Where:

$S=0.0066940 * B + 3.5565$

The parameter B is indicative of the viscosity of the particular oil at 30°C and one atmosphere pressure. The parameters were measured of the variation of viscosity with temperature.

Modification was done in Eq. (4.25) for calculated the dynamic viscosity (μ), to get more accurate data on the effect of temperature on viscosity of oil stocks. Introducing a new parameter, namely the weight fraction of the additives for the base lubricating oil (40 stock, 60 stock, 150 stock), made the modification possible. The new formula of Eq. (4.25) is proposed to predict the dynamic viscosity of oil-stock with additive at different concentration, and temperature range of 298-393 K with an average absolute error 8.4% applying it to 330 experimental data points (R= 0.9946).

The problem is to formulate the dynamic viscosity as a function of the main property of additive to base lubricating oil, as concentration (weight fraction).

Regression analysis has been used to give a functional relationship between the viscosity and concentration of each additive, as follows:

$$\left[\frac{\log(\mu)+k}{\log(\mu_o)+c}\right]=\left[\frac{T_o}{T}\right]^s \quad \ldots(4.28)$$

$$K=(E*wt_a+B) \quad \ldots(4.29)$$

$$S=D*\log(\mu_o)+A*wt_o \quad \ldots(4.30)$$

μ = the dynamic viscosity of blends in cP at different temperature (T).
wt_a = weight fraction of additive.
μ_o = the dynamic viscosity of blends in cP at T_o= 303.15 k

A complete program performs a non linear least square fitting of proposed function of a given set of data the final constant of Eqs. (4.28), (4.29), and (4.30) are listed in Table (4.25).

Table (4.25) Constant of equation (4.28), (4.29), and (4.30).

A	B	C	D	E
-2.33319	-0.417146	-0.424021	1.064617	-0.063691

As can be seen from tables (4.25) to (4.30) the overall average absolute error between experimental and calculated values is not greater than 10.6%, which is obviously quite acceptable for engineering purposes.

The analyses of the proposed correlation fitted the experimental data consisting for viscosity measurements of the two types of additives (polyisoprene 1502, polyisoprene 1320).

This result was very acceptable comparing with previous search [37], where it’s used the same equation of this search at 231 measuring point. At absolute mean error was 7.6% and greater mean error between experimental and theoretical not exceeding 12.134% whiles in this search uses 330 measuring point at absolute mean error 8.4% and greater mean error between experimental and theoretical was not exceeding 10.6%, from this comparing this search is very acceptable.

Table (4.1) Comparison Between Measured and Calculated Pour Point for the Blends of 40 Stocks With Polyisoprene 1502.

Polyisoprene 1502, Wt.%	Pour Point (T/°C) Experimental	Pour Point (T/°C) Calculation
0	-12	-9.50
0.5	-18	-17.99
1	-24	-20.55
2	-27	-25.06
4	-30	-31.60
6	-33	-34.82
8	-36	-34.75
Average Absolute Error % = 8.11		

Table (4.2) Comparison Between Measured and Calculated Pour Point for the Blends of 60 Stocks With Polyisoprene 1502.

Polyisoprene 1502, Wt.%	Pour Point (T/°C) Experimental	Pour Point (T/°C) Calculation
0	-6	-5.60
0.5	-15	-12.87
1	-18	-15.26
2	-21	-19.45
4	-24	-25.58
6	-27	-28.70
8	-30	-28.80
Average Absolute Error % = 8.6		

Table (4.3) Comparison Between Measured and Calculated Pour Point for the Blends of 150 Stocks With Polyisoprene 1502.

Polyisoprene 1502, Wt.%	Pour Point (T/°C) Experimental	Pour Point (T/°C) Calculation
0	6	4.83
0.5	-9	-8.43
1	-15	-12.00
2	-18	-15.48
4	-21	-23.90
6	-24	-27.01
8	-27	-24.84
Average Absolute Error % = 8.1		

Table (4.4) Comparison Between Measured and Calculated Pour Point for the Blends of 40 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt.%	Pour Point (T/°C) Experimental	Pour Point (T/°C) Calculation
0	-12	-13.28
0.5	-15	-15.08
1	-18	-16.77
2	-21	-19.84
4	-24	-24.71
6	-27	-27.90
8	-30	-29.41
Average Absolute Error % = 4.55		

Table (4.5) Comparison Between Measured and Calculated Pour Point for the Blends of 60 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt.%	Pour Point (T/°C) Experimental	Pour Point (T/°C) Calculation
0	-6	-5.81
0.5	-12	-10.98
1	-15	-13.02
2	-18	-16.65
4	-21	-22.30
6	-24	-25.30
8	-27	-26.10
Average Absolute Error % = 6.75		

Table (4.6) Comparison Between Measured and Calculated Pour Point for the Blends of 150 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt.%	Pour Point (T/°C) Experimental	Pour Point (T/°C) Calculation
0	6	4.84
0.5	-6	-5.53
1	-12	-9.34
2	-15	-12.68
4	-18	-20.46
6	-21	-23.62
8	-24	-22.14
Average Absolute Error % = 10.04		

Table (4.7) Comparison Between Measured and Calculated Viscosity Index for the Blends of 40 Stocks With Polyisoprene 1502.

Polyisoprene 1502, Wt.%	Viscosity Index Experimental	Viscosity Index Calculation
0	101	185
0.5	344	300
1	429	405
2	660	587
4	790	833
6	882	840
8	890	860
Average Absolute Error % = 9.98		

Table (4.8) Comparison Between Measured and Calculated Viscosity Index for the Blends of 60 Stocks With Polyisoprene 1502.

Polyisoprene 1502, Wt.%	Viscosity Index Experimental	Viscosity Index Calculation
0	103	149
0.5	290	258
1	338	358
2	604	531
4	754	769
6	812	863
8	840	812
Average Absolute Error % = 8.82		

Table (4.9) Comparison Between Measured and Calculated Viscosity Index for the Blends of 150 Stocks With Polyisoprene 1502.

Polyisoprene 1502, Wt.%	Viscosity Index Experimental	Viscosity Index Calculation
0	90	108
0.5	170	181
1	260	249
2	415	372
4	548	560
6	643	672
8	724	707
Average Absolute Error % = 7.06		

Table (4.10) Comparison Between Measured and Calculated Viscosity Index for the Blends of 40 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt.%	Viscosity Index Experimental	Viscosity Index Calculation
0	101	98
0.5	173	175
1	238	235
2	311	305
4	387	379
6	404	399
8	533	532
Average Absolute Error % = 1.52		

Table (4.11) Comparison Between Measured and Calculated Viscosity Index for the Blends of 60 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt.%	Viscosity Index Experimental	Viscosity Index Calculation
0	103	115
0.5	140	156
1	203	197
2	301	257
4	324	338
6	334	359
8	334	319
Average Absolute Error % = 8.17		

Table (4.12) Comparison Between Measured and Calculated Viscosity Index for the Blends of 150 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt.%	Viscosity Index Experimental	Viscosity Index Calculation
0	90	98
0.5	122	124
1	160	149
2	197	192
4	250	255
6	284	288
8	293	290
Average Absolute Error % = 3.85		

Table (4.13) Comparison Between Measured and Calculated Weight Lost for the Blends of 40 Stocks With Polyisoprene 1502.

Polyisoprene 1502, Wt.%	Weight lost/g Experimental	Weight lost/g Calculation
0	0.0039	0.0034
0.5	0.0018	0.0022
1	0.00085	0.00071
2	0.00059	0.00048
4	0.00037	0.00030
6	0.00026	0.00015
8	0.0001	0.00008
Average Absolute Error % = 14.22		

Table (4.14) Comparison Between Measured and Calculated Weight Lost for the Blends of 60 Stocks With Polyisoprene 1502.

Polyisoprene 1502, Wt.%	Weight lost/g Experimental	Weight lost/g Calculation
0	0.0063	0.0058
0.5	0.0038	0.0039
1	0.0012	0.0010
2	0.00077	0.00065
4	0.00061	0.00050
6	0.00048	0.00046
8	0.0003	0.00028
Average Absolute Error % = 8.74		

Table (4.15) Comparison Between Measured and Calculated Weight Lost for the Blends of 150 Stocks With Polyisoprene 1502.

Polyisoprene 1502, Wt.%	Weight lost/g Experimental	Weight lost/g Calculation
0	0.0077	0.0072
0.5	0.0065	0.0059
1	0.0041	0.0049
2	0.0022	0.0021
4	0.00093	0.00075
6	0.00087	0.00076
8	0.00071	0.00068
Average Absolute Error % = 10.62		

Table (4.16) Comparison Between Measured and Calculated Weight Lost for the Blends of 40 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt.%	Weight lost/g Experimental	Weight lost/g Calculation
0	0.03208	0.0348
0.5	0.03114	0.0304
1	0.02831	0.0264
2	0.02208	0.0194
4	0.00573	0.0055
6	0.00553	0.0046
8	0.00534	0.0051
Average Absolute Error % = 7.75		

Table (4.17) Comparison Between Measured and Calculated Weight Lost for the Blends of 60 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt.%	Weight lost/g Experimental	Weight lost/g Calculation
0	0.0523	0.0520
0.5	0.04651	0.0466
1	0.0414	0.0420
2	0.0335	0.0330
4	0.0168	0.0190
6	0.0133	0.0107
8	0.00672	0.0076
Average Absolute Error % = 7.25		

Table (4.18) Comparison Between Measured and Calculated Weight Lost for the Blends of 150 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt.%	Weight lost/g Experimental	Weight lost/g Calculation
0	0.0653	0.0620
0.5	0.0533	0.0560
1	0.0485	0.0503
2	0.0407	0.0402
4	0.0235	0.0222
6	0.0185	0.0154
8	0.0109	0.0123
Average Absolute Error % = 7.11		

Table (4.19) Comparison Between Measured and Calculated Flash Point for the Blends of 40 Stocks With Polyisoprene 1502.

Polyisoprene 1502, Wt.%	Flash Point (T/°C) Experimental	Flash Point (T/°C) Calculation
0	170	165.56
0.5	152	154.82
1	144	144.77
2	123	126.72
4	102	98.84
6	84	81.91
8	76	75.94
Average Absolute Error % = 1.95		

Table (4.20) Comparison Between Measured and Calculated Flash Point for the Blends of 60 Stocks With Polyisoprene 1502.

Polyisoprene 1502, Wt.%	Flash Point (T/°C) Experimental	Flash Point (T/°C) Calculation
0	230	215.45
0.5	194	198.49
1	172	182.84
2	148	155.46
4	122	116.40
6	106	98.28
8	96	101.08
Average Absolute Error % = 5.30		

Table (4.21) Comparison Between Measured and Calculated Flash Point for the Blends of 150 Stocks With Polyisoprene 1502.

Polyisoprene 1502, Wt.%	Flash Point (T/°C) Experimental	Flash Point (T/°C) Calculation
0	280	265.87
0.5	242	243.98
1	214	223.80
2	176	188.49
4	144	138.18
6	126	114.93
8	112	118.74
Average Absolute Error % = 5.20		

Table (4.22) Comparison Between Measured and Calculated Flash Point for the Blends of 40 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt.%	Flash Point (T/°C) Experimental	Flash Point (T/°C) Calculation
0	170	166.84
0.5	158	158.17
1	148	150.05
2	132	135.44
4	114	112.80
6	102	98.91
8	92	93.788
Average Absolute Error % = 1.71		

Table (4.23) Comparison Between Measured and Calculated Flash Point for the Blends of 60 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt.%	Flash Point (T/°C) Experimental	Flash Point (T/°C) Calculation
0	230	219.40
0.5	202	203.50
1	182	188.74
2	152	162.68
4	130	124.36
6	112	104.43
8	98	102.89
Average Absolute Error % = 4.52		

Table (4.24) Comparison Between Measured and Calculated Flash Point for the Blends of 150 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt.%	Flash Point (T/°C) Experimental	Flash Point (T/°C) Calculation
0	280	267.57
0.5	252	249.82
1	220	233.25
2	192	203.68
4	166	158.78
6	142	132.89
8	120	125.99
Average Absolute Error % = 4.73		

Table (4.25) Comparison Between Measured and Calculated Dynamic Viscosity Value for the Blends of 40 Stocks With Polyisoprene 1502.

Polyisoprene 1502,Wt%		**Temperature, K**										
		298	**303**	**313**	**323**	**333**	**343**	**353**	**363**	**373**	**383**	**393**
0	**μ exp.**	**47.3**	**40**	**31.8**	**25**	**22**	**19**	**16.3**	**14.12**	**12.88**	**11.48**	**10.7**
	μ cal.	**42.6**	**39.4**	**34**	**29.8**	**26.3**	**23.5**	**21.1**	**19.2**	**17.5**	**16.1**	**14.9**
2	**μ exp.**	**53.1**	**48.1**	**41.6**	**31.2**	**25.5**	**22**	**18.1**	**16.59**	**14.79**	**13.49**	**12.3**
	μ cal.	**51.7**	**47.5**	**40.5**	**34.9**	**30.6**	**27**	**24.1**	**21.7**	**19.7**	**17.9**	**16.5**
4	**μ exp.**	**58**	**52**	**48**	**34.5**	**29**	**25**	**23**	**18.83**	**16.98**	**15.48**	**14.12**
	μ cal.	**56.3**	**51.6**	**43.8**	**37.7**	**32.9**	**29**	**25.8**	**23.1**	**20.9**	**19.1**	**17.5**
6	**μ exp.**	**64.5**	**55.2**	**45.4**	**39**	**33.6**	**27.5**	**26**	**22.38**	**19.95**	**18.19**	**16.7**
	μ cal.	**60**	**54.9**	**46.6**	**40**	**34.9**	**30.7**	**27.2**	**24.2**	**22.1**	**20.1**	**18.4**
8	**μ exp.**	**70.2**	**63**	**53.1**	**44.5**	**37.5**	**31**	**27**	**24.54**	**21.87**	**20.18**	**18.4**
	μ cal.	**69**	**62.9**	**52.9**	**45.1**	**39**	**34.1**	**30.1**	**26.8**	**24.1**	**21.8**	**19.9**
Average Absolute Error % = 9.4												

Table (4.26) Comparison Between Measured and Calculated Dynamic Viscosity Value for the Blends of 60 Stocks With Polyisoprene 1502.

Polyisoprene 1502,Wt%		**Temperature, K**										
		298	**303**	**313**	**323**	**333**	**343**	**353**	**363**	**373**	**383**	**393**
0	**μ exp.**	**170.8**	**135.4**	**92.7**	**70.3**	**55.5**	**43.2**	**36.3**	**31.62**	**27.22**	**23.98**	**21.37**
	μ cal.	**155.7**	**133.8**	**101.2**	**78.6**	**62.6**	**50.9**	**42.2**	**35.6**	**30.4**	**26.3**	**23.1**
2	**μ exp.**	**182.5**	**146**	**99.7**	**72**	**58**	**48**	**40.5**	**35.48**	**30.19**	**26.91**	**23.98**
	μ cal.	**168.8**	**144.7**	**109**	**84.4**	**67**	**54.3**	**44.9**	**37.7**	**32.2**	**27.8**	**24.3**
4	**μ exp.**	**194**	**152**	**109**	**83**	**65**	**55**	**46.4**	**39.8**	**33.88**	**30.2**	**26.9**
	μ cal.	**176.1**	**151.1**	**113.9**	**88.2**	**70**	**56.8**	**46.9**	**39.4**	**33.6**	**29**	**25.4**
6	**μ exp.**	**220**	**178.9**	**118.9**	**85**	**69**	**58.5**	**47.2**	**42.65**	**36.3**	**32.35**	**28.84**
	μ cal.	**209.7**	**178.4**	**132.4**	**101.2**	**79.4**	**63.7**	**52.1**	**43.4**	**36.7**	**31.5**	**27.4**
8	**μ exp.**	**269**	**220**	**145.5**	**103**	**83**	**68.5**	**52.5**	**50.11**	**42.7**	**38**	**33.88**
	μ cal.	**261.8**	**220.9**	**160**	**120**	**92.6**	**73.2**	**59.2**	**48.7**	**40.8**	**34.7**	**29.9**
Average Absolute Error % = 5.8												

Table (4.27) Comparison Between Measured and Calculated Dynamic Viscosity Value for the Blends of 150 Stocks With Polyisoprene 1502.

Polyisoprene 1502, Wt%		Temperature, K										
		298	303	313	323	333	343	353	363	373	383	393
0	µ exp.	915	616.5	354.8	223.8	153.3	109.6	87	66.8	52.48	43.15	35.48
	µ cal.	806.5	611.7	370.4	238.1	161.1	113.9	83.6	63.4	49.5	39.6	32.4
1	µ exp.	935	645.6	371.5	234.4	165.9	114.8	91.2	72.4	57.5	48.97	40.73
	µ cal.	847.7	641.6	387	247.9	167.2	117.8	86.3	65.3	50.9	40.7	33.25
2	µ exp.	950	708	398	251.1	175.7	123	97.72	77.62	61.65	51.28	42.17
	µ cal.	937.3	704.7	420.1	266.4	178.1	124.6	90.6	68.3	52.98	42.16	34.31
4	µ exp.	1145	775	446.7	278.6	195	138	111	87.1	69.1	58.2	47.86
	µ cal.	1033	773.7	457.8	288.4	191.7	133.4	96.6	72.4	55.9	44.37	35.99
6	µ exp.	1412	875	545	323	218	166	136	102.3	80.35	67.3	54.95
	µ cal.	1178	876	511.9	318.9	209.9	144.8	104.1	77.55	59.55	46.97	37.93
8	µ exp.	1450	1100	570	380	252	181	154.5	114.8	91.2	75.8	63
	µ cal.	1513	1105	625.6	379.3	244	165.1	116.7	85.64	64.93	50.65	40.51
Average Absolute Error % = 10.6												

Table (4.28) Comparison Between Measured and Calculated Dynamic Viscosity Value for the Blends of 40 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt%		Temperature, K										
		298	303	313	323	333	343	353	363	373	383	393
0	µ exp.	47.3	40	31.8	25	22	19	16.3	14.12	12.88	11.48	10.7
	µ cal.	42.6	39.4	34	29.8	26.3	23.5	21.1	19.2	17.5	16.1	14.9
0.5	µ exp.	50	43	36.1	28	25	23	18.3	16.59	15.13	13.8	12.88
	µ cal.	46	42.4	36.4	31.7	27.9	24.8	22.2	20.1	18.3	16.7	15.4
1	µ exp.	56	49.2	40	33.6	28	24.2	20.7	18.19	17	15	14.1
	µ cal.	53	48.6	41.2	35.5	30.5	27.2	24.2	21.7	19.7	17.9	16.4
2	µ exp.	63.3	51	43.5	35.5	31	25	23.5	20	18.2	16	15.5
	µ cal.	55.1	50.4	42.7	36.7	32	28.1	25	22.4	20.2	18.4	16.9
4	µ exp.	72.1	60.7	51	43.9	36.7	33	27	24	22	19.95	18.4
	µ cal.	66.3	60.2	50.4	42.8	36.8	32.1	28.3	25.2	22.6	20.4	18.6
6	µ exp.	107.5	92.9	78	67.4	51.6	42.9	39	33.88	30.9	28.1	26.3
	µ cal.	104.1	92.5	74.3	60.9	50.8	43	36.9	32	28.2	25	22.4
8	µ exp.	123	96	83	72	59	51	44.7	38.9	35.48	32.35	30
	µ cal.	107.8	95.9	77.1	63.3	52.8	44.7	38.4	33.4	29.3	26	23.3
Average Absolute Error % = 9.25												

Table (4.29) Comparison Between Measured and Calculated Dynamic Viscosity Value for the Blends of 60 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt%		Temperature, K										
		298	303	313	323	333	343	353	363	373	383	393
0	μ exp.	170.8	135.4	92.73	70.3	55.5	43.2	36.3	31.62	27.22	23.98	21.37
	μ cal.	155.7	133.8	101.2	78.6	62.6	50.9	42.25	35.6	30.4	26.4	23.1
2	μ exp.	201	151.9	101.5	76.8	63	55	47	38	32.35	28.8	25.7
	μ cal.	176.1	150.6	112.8	87	68.8	55.6	45.8	38.4	32.7	28.2	24.6
4	μ exp.	342.7	294.6	187.8	136.6	102.7	74.8	61.8	58.2	50.1	44.1	38.9
	μ cal.	359.5	293.4	202.1	144.9	107.5	82.2	64.5	51.8	42.5	35.4	30.1
Average Absolute Error % = 5.4												

Table (4.30) Comparison Between Measured and Calculated Dynamic Viscosity Value for the Blends of 150 Stocks With Polyisoprene 1320.

Polyisoprene 1320, Wt%		Temperature, K										
		298	303	313	323	333	343	353	363	373	383	393
0	μ exp.	915	616.5	354.8	223.8	153.3	109.6	87	66.8	52.48	43.15	35.48
	μ cal.	806.4	611.7	370.4	238.1	161.1	113.9	83.6	63.4	49.5	39.6	32.4
1	μ exp.	1002	820	425	287	148	112	84.4	76.73	59.56	43	35
	μ cal.	1102	815.4	472.2	292.3	191.6	131.8	94.6	70.3	54.04	42.6	34.4
2	μ exp.	1152	920	537	311.2	164.8	115.5	92.9	83.1	64.55	53	43.45
	μ cal.	1250	916.4	522.2	318.9	206	140.7	100.1	73.9	56.42	44.2	35.6
4	μ exp.	1297	1050	612	363.9	219.7	145.6	103.8	96.6	75.58	61.65	51.28
	μ cal.	1444	1049	588.8	354.9	227.3	153.3	108.1	79.2	60	46.8	37.5
Average Absolute Error % = 9.97												

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions.

1. Blending the three types of oil-stocks with additives (Polyisoprene 1502and Polyisoprene 1320) results a noticeable increase in the viscosity of the mixture, increase viscosity index, decrease rust, increase pour point and decrease flash point.

2. The effect of Polyisoprene on 40 stocks is higher than on 60 and 150 stocks respectively on viscosity, viscosity index and pour point, while the effect of Polyisoprene on 40 stocks is lower than on 60 and 150 stocks respectively on rust and flash point.

3. The effect of Polyisoprene 1320 on viscosity, rust, and flash point is higher than the effect of Polyisoprene 1502, while the effect of Polyisoprene 1502 on viscosity index and pour point is higher than the effect of Polyisoprene 1320.

4. We notice that no effect of Polyisoprene 1502 and 1320 on foam of stock 40, 60 and 150 respectively.

5. A method has been used to calculate viscosity-temperature correlation of base oil-stocks with additives, based on temperature and concentration (Wt %). The overall average absolute error obtained by this correlation is 8.4%.

$$\left[\frac{\log(\mu)+k}{\log(\mu_o)+c}\right]=\left[\frac{T^o}{T}\right]^s$$

6. Comparison between the measured and calculated values of properties of all the studied Iraqi-oil stock blends for different weight percent were found to be satisfactory, with an average absolute error of (3.9%) for (Flash Point), (8.4%) for (viscosity), (9.28%) for (Rust Test), (7.7%) for (Pour Point) and (6.56%) for (Viscosity Index) for the (498) data points used.

5.2 Recommendations.

1. Study the effect of each Polyisoprene type (Polyisoprene 1502and Polyisoprene 1320) on other properties like thermal expansion of base lubricating oil.

2. Further work can be carried out to study the effect of the temperature and concentration on the properties for types of multi-component mixtures of oil stock containing various concentrations of the oil-stocks blending with various concentrations of each Polyisoprene type (Polyisoprene 1502 and Polyisoprene 1320).

3. Further work can be carried out to study the effect of mixing each Polyisoprene type (Polyisoprene 1502 and polyisoprene 1320) with another type of additives like Methacrylate polymer and test the mixtures by blending its to the oil base-stocks to know if its have the ability to raise the viscosity, viscosity index, decrease rust, increase pour point and decrease flash point.

4. Study the effect of (Polyisoprene Butile) as additives on the properties of lubricating oils.

REFERENCES

1. Brouwer,L.E.J., "The Petroleum Handbook", Fifth Edition, PP.116-235,1966.

2. Zuidema, H.H., "The Performance of Lubricating Oils", Second Edition, 1959.

3. Evans,E.A., "Lubricating and Allied Oils", Forth Edition, 1963.

4. Emerson, W., "Guide to the Chemical Industry", July 1983.

5. Baker, A. E., "Lubricant Properties and Test Methods", Handbook of Lubrication, Theory and Practice of Tribology, Vol. I, Ed. E. R. Booser, CRC Press, (1984), pp.481-515.

6. Gary, J.H., and G.E. Handwork, "Petroleum Refining Technology and Economics", second Edition.

7. Singh, B.A. Miadonye and V.R. Puttagunta, Hydrocarbon processing August, 158-187,1993.

8. Mehrotra, A.K., Can.J.Chem.Eng.72, 554-557,1994.

9. ASTM-D341,"The American Society for Testing and Materials", 1981.

10. Nelson, W.L.," Petroleum Refinery Engineering", Forth Edition, Mc Graw Hill Book Co., New York, 1958.

11. Dr.Korkis A. Addam, Chemical Departement, Al-Basarah University, Polymers Chemistry and Technology, 1994.

12. Gol'dberg, D.O., Khimiya, Moscow-Leningrad, 120, 1964.

13. Eigenson, A.S., Khim. Technol. Masel, 8, 22, 1973.

14. Eigenson, A.S., and E.G. Ivchenko, part1, Zenatene, Riga, 36-40, 1976.

15. Kham, M.A.,A.K. Mehrotra and W.Y. Svrcek, Can.J.Pet.Tech, 47-53, 1984.

16. Letsou, A. and L.I.Steil, AICHE J., 19,409,1973.

17. Amin, M.B. and R.N. Madox, Hydrocarbon processing, 59, 131, 1980.

18. Eyring, H.J. Chem. Phys., 4, 238, 1936.

19. Beg S.A., M.B. Amin and I. Hussein, J. Chem. Eng., 38, 123-136, 1988.

20. Amin, M.B. and Beg-S.A., Can. J. Chem. Eng., New York, 1994.

21. Orbey, H. and S.I. Sandler, Can. J. Chem. Eng., 71, 437-446, 1993.

22. Beggs, H.D. and J.R. Robinson, J.Pet. Tech, Sep., 1140, 1975.

23. Emmanuel, O. Egbogah and T. Jack, J. Pet. Sci.Eng., 5, 197-200, 1990.

24. Allan J. and A.S. Teja, Can. J. Chem. Eng., 69, 984-991, 1991.

25. Al- Mamoory, D.M., “Influence of the additives on the lubricating oil”, Msc. Thesis. Nahrain University 2002.

26. ASTM, Annual Book of ASTM Standards, Sec. 5, Petroleum Products, Lubricants, and Fossil Fuels. American Society For Testing And Materials, 1916 Race Street, Philadelphia, PA, 19103-1187.

27. ASTM. "Standard Practice for Use of the SI International System of Units - The Modernized Metric System", E380-93, (1993), American Society For Testing And Materials, 1916 Race Street Philadelphia PA 19103-1187.

28. Liston T. V., Engine Lubricant Additives, What They Are and How They Work", Lubr. Engr. 48, 5, (1992), pp. 389-397.

29. Rizvi, S. Q. A., "Lubricant Additives and Their Function", Friction, Lubrication and Wear Technology, ASM. (1992), pp. 98-112.

30. Litt, F., Assoc. Editor, "Starting From Scratch: Tribology Basics", STLE, Park Ridge, IL 60068.

31. Klaus, E. E. and Tewksbury, E. J., "Liquid Lubricants", Handbook of Lubrication, Theory and Practice of Tribology, Vol. II, Ed. E. R. Booser, CRC Press, (1984), pp.229-254.

32. Wright, W. A., "Prediction of Bulk Moduli and Pressure-Volume-Temperature Data for Petroleum Oils", ASLE Trans. 10, (1967), pp. 349-356.

33. Fein, R. S., "Liquid Lubricants" Friction, Lubrication, and Wear Technology, ASM (1992), pp.81-88.

34. Kauffman, R. E., "Rapid Determination of Remaining Useful Lubricant Life", Handbook of Lubrication and Tribology, III, Ed. Richard E. Booser, CRC Press, Boca Raton, FL, (1994), pp. 89-100.

35. Herguth, W.R. and Dr. Phillips, S., Comparison of Common Analytical Techniques to Voltammetric Analysis of Antioxidants in Industrial Lubricating Oil, STLE, Annual Meeting, Condition Monitoring, May 19, 1995.

36. Organization For Economic Co-operation and Development, "Glossary of Terms And Definitions In The Field Of Friction, Wear, and Lubrication" Wear Control Handbook, Ed M. B. Peterson and W. O. Winer, ASME, New York, (1980), pp. 1143-1203.

37. Al-Taa’ay, A.H., “Influence of polyisoprene additives on the viscosity of base lubricating oil”, Msc. Thesis. Nahrain University 2003.

Appendix (A)

A. Sample of Calculation

Example1: Estimate the dynamic viscosity of a mixture which contains (6% of polyisoprene 1320 and 94% of 40stock) at 363.15K and 1.01325bar, given μ_o=92.9Cp at T_o=303.15K.

Solution:

$$K = (E * wt._a + B)$$

$$K = (-0.063691 * 0.06 + -0.41746) = -0.42096746$$

$$S = D * \log \mu_o + A * wt._a$$

$$S = 1.064617 * 1.968015 + -2.33319 * 0.06 = 1.9551915$$

$$\left[\frac{\log(\mu) + K}{\log(\mu_o) + C}\right] = \left[\frac{T_o}{T}\right]^s$$

$$\left[\frac{\log(\mu) - 0.42096746}{\log(92.9) - 0.42021}\right] = \left[\frac{303.15}{363.15}\right]^{1.9551915}$$

$$\underline{\mu = 32cP}$$

Example2: Measured kinematic viscosity at 40°C of the oil whose viscosity index is to be calculated = 73.30 mm^2/s (cSt).

Kinematic viscosity at 100°C of the oil whose viscosity index is to be calculated = 8.86 mm^2/s (cSt). Calculate (V.I.)

Solution:

From table (A.1) (by interpolation) L=119.94

From table (A.1) (by interpolation) H=69.48

Substituting in Eq. (3.3) and rounding to the nearest whole number:

$$VI = \left[\frac{(119.94 - 73.30)}{(119.94 - 69.48)}\right] * 100 = 92.43$$

$$VI = 92$$

Example3:

(1) Measured kinematic viscosity at 40°C of the oil whose viscosity index is to be calculated = 22.83 mm^2/s (cSt).

Kinematic viscosity at 100°C of the oil whose viscosity is to be calculated = 5.05 mm^2/s (cSt). Calculate (V.I.)

<u>Solution:</u>

From table (A.1) (by interpolation) H= 28.97

Substituting by Eq. (3.6) (by logarithms):

$$N = \left[\frac{(\log 28.97 - \log 22.83)}{\log 5.05}\right] = 0.14708$$

Substituting in Eq. (3.5) and rounding to the nearest whole number:

$$VI = \left[\frac{((antiLog\, 0.14708) - 1)}{0.00715}\right] + 100$$

$$= \left[\frac{(1.40307 - 1)}{0.00715}\right] + 100$$

$$VI = 156$$

(2) Measured kinematic viscosity at 40°C of the oil whose viscosity index is to be calculated = 53.47 mm^2/s (cSt).

Kinematic viscosity at 100°C of the oil whose viscosity is to be calculated = 7.80 mm^2/s (cSt). Calculate (V.I.)

Solution:

From table (A.1) H= 57.31

Substituting in Eq. (3.6) (by logarithms):

$$N=\left[\frac{(\log 57.31-\log 53.47)}{\log 7.80}\right]=0.03376$$

Substituting in Eq. (3.5) and rounding to the nearest whole number:

$$VI=\left[\frac{((antiLog\,0.03376)-1)}{0.00715}\right]+100$$

$$=\left[\frac{(1.08084-1)}{0.00715}\right]+100$$

$$VI=111$$

B. Tables

Table (A.1) Basic Values for L and H for Kinematic Viscosity in 40-100 °C System [27].

Kinematic viscosity at 100°C, mm^2/s (cSt)	L, mm^2/s (cSt)	H, mm^2/s (cSt)	Kinematic viscosity at 100°C, mm^2/s (cSt)	L, mm^2/s (cSt)	H, mm^2/s (cSt)
2.00	7.994	6.394	5.40	47.31	32.37
2.10	8.640	6.894	5.50	49.09	33.34
2.20	9.309	7.410	5.60	50.87	34.32
2.30	10.00	7.944	5.70	52.64	35.29
2.40	10.71	8.496	5.80	54.42	36.26
2.50	11.45	9.063	5.90	56.20	37.23
2.60	12.21	9.647	6.00	57.97	38.19
2.70	13.00	10.25	6.10	59.74	39.17
2.80	13.80	10.87	6.20	61.52	40.15
2.90	14.63	11.50	6.30	63.32	41.13

3.00	15.49	12.15	6.40	65.18	42.14
3.10	16.36	12.82	6.50	67.12	43.18
3.20	17.26	13.51	6.60	69.16	44.24
3.30	18.18	14.21	6.70	71.29	45.33
3.40	19.12	14.93	6.80	73.48	46.44
3.50	20.09	15.66	6.90	75.72	47.51
3.60	21.08	16.42	7.00	78.00	48.57
3.70	22.09	17.19	7.10	80.25	49.61
3.80	23.13	17.97	7.20	82.39	50.69
3.90	24.19	18.77	7.30	84.53	51.78
4.00	25.32	19.56	7.40	86.66	52.88
4.10	26.50	20.37	7.50	88.85	53.98
4.20	27.75	21.21	7.60	91.04	55.09
4.30	29.07	22.05	7.70	93.20	56.20
4.40	30.48	22.92	7.80	95.43	57.31
4.50	31.96	23.81	7.90	97.72	58.45
4.60	33.52	24.71	8.00	100.0	59.60
4.70	35.13	25.63	8.10	102.3	60.74
4.80	36.79	26.57	8.20	104.6	61.89
4.90	38.50	27.53	8.30	106.9	63.05
5.00	40.23	28.49	8.40	109.2	64.18
5.10	41.99	29.46	8.50	111.5	65.32
5.20	43.76	30.43	8.60	113.9	66.48
5.30	45.53	31.40	8.70	116.2	67.64
8.80	118.5	68.79	12.9	228.8	120.1
8.90	120.9	69.94	13.0	231.9	121.5
9.00	123.3	71.10	13.1	235.0	122.9
9.10	125.7	72.27	13.2	238.1	124.2
9.20	128.0	73.42	13.3	241.2	125.6
9.30	130.4	74.57	13.4	244.3	127.0
9.40	132.8	75.73	13.5	247.4	128.4
9.50	135.3	76.91	13.6	250.6	129.8
9.60	137.7	78.08	13.7	253.8	131.2
9.70	140.1	79.27	13.8	257.0	132.6
9.80	142.7	80.46	13.9	260.1	134.0
9.90	145.2	81.67	14.0	263.3	135.4
10.0	147.7	82.87	14.1	266.6	136.8
10.1	150.3	84.08	14.2	269.8	138.2
10.2	152.9	85.30	14.3	273.0	139.6
10.3	155.4	86.51	14.4	276.3	141.0
10.4	158.0	87.72	14.5	279.6	142.4

10.5	160.6	88.95	14.6	283.0	143.9
10.6	163.2	90.19	14.7	286.4	145.3
10.7	165.8	91.40	14.8	289.7	146.8
10.8	168.5	92.65	14.9	293.0	148.2
10.9	171.2	93.92	15.0	296.5	149.7
11.0	173.9	95.19	15.1	300.0	151.2
11.1	176.6	96.45	15.2	303.4	152.6
11.2	179.4	97.71	15.3	306.9	154.1
11.3	182.1	98.97	15.4	310.3	155.6
11.4	184.9	100.2	15.5	313.9	157.0
11.5	187.6	101.5	15.6	317.5	158.6
11.6	190.4	102.8	15.7	321.1	160.1
11.7	193.3	104.1	15.8	324.6	161.6
11.8	196.2	105.4	15.9	328.3	163.1
11.9	199.0	106.7	16.0	331.9	164.6
12.0	201.9	108.0	16.1	335.5	166.1
12.1	204.8	109.4	16.2	339.2	167.7
12.2	207.8	110.7	16.3	342.9	169.2
12.3	210.7	112.0	16.4	346.6	170.7
12.4	213.6	113.3	16.5	350.3	172.3
12.5	216.6	114.7	16.6	354.1	173.8
12.6	219.6	116.0	16.7	358.0	175.4
12.7	222.6	117.4	16.8	361.7	177.0
12.8	225.7	118.7	16.9	365.6	178.6
17.0	369.4	180.2	22.2	595.0	268.6
17.1	373.3	181.7	22.4	604.3	272.3
17.2	377.1	183.3	22.6	614.2	275.8
17.3	381.0	184.9	22.8	624.1	279.6
17.4	384.9	186.5	23.0	633.6	283.3
17.5	388.9	188.1	23.2	643.4	286.8
17.6	392.7	189.7	23.4	653.8	290.5
17.7	396.7	191.3	23.6	663.3	294.4
17.8	400.7	192.9	23.8	673.7	297.9
17.9	404.6	194.6	24.0	683.9	301.8
18.0	408.6	196.2	24.2	694.5	305.6
18.1	412.6	197.8	24.4	704.2	309.4
18.2	416.7	199.4	24.6	714.9	313.0
18.3	420.7	201.0	24.8	725.7	317.0
18.4	424.9	202.6	25.0	736.5	320.9
18.5	429.0	204.3	25.2	747.2	324.9
18.6	433.2	205.9	25.4	758.2	328.8

18.7	437.3	207.6	25.6	769.3	332.7
18.8	441.5	209.3	25.8	779.7	336.7
18.9	445.7	211.0	26.0	790.4	340.5
19.0	449.9	212.7	26.2	801.6	344.4
19.1	454.2	214.4	26.4	812.8	348.4
19.2	458.4	216.1	26.6	824.1	352.3
19.3	462.7	217.7	26.8	835.5	356.4
19.4	467.0	219.4	27.0	847.0	360.5
19.5	471.3	221.1	27.2	857.5	364.6
19.6	475.7	222.8	27.4	869.0	368.3
19.7	479.7	224.5	27.6	880.6	372.3
19.8	483.9	226.2	27.8	892.3	376.4
19.9	488.6	227.7	28.0	904.1	380.6
20.0	493.2	229.5	28.2	915.8	384.6
20.2	501.5	233.0	28.4	927.6	388.8
20.4	510.8	236.4	28.6	938.6	393.0
20.6	519.9	240.1	28.8	951.2	396.6
20.8	528.8	243.5	29.0	963.4	401.1
21.0	538.4	247.1	29.2	975.4	405.3
21.2	547.5	250.7	29.4	987.1	409.5
21.4	556.7	254.2	29.6	998.9	413.5
21.6	566.4	257.8	29.8	1011	417.6
21.8	575.6	261.5	30.0	1023	421.7
22.0	585.2	264.9	30.5	1055	432.4
31.0	1086	443.2	51.5	2767	962.9
31.5	1119	454.0	52.0	2817	977.5
32.0	1151	464.9	52.5	2867	992.1
32.5	1184	475.9	53.0	2918	1007
33.0	1217	487.0	53.5	2969	1021
33.5	1251	498.1	54.0	3020	1036
34.0	1286	509.6	54.5	3073	1051
34.5	1321	521.1	55.0	3126	1066
35.0	1356	532.5	55.5	3180	1082
35.5	1391	544.0	56.0	3233	1097
36.0	1427	555.6	56.5	3286	1112
36.5	1464	567.1	57.0	3340	1127
37.0	1501	579.3	57.5	3396	1143
37.5	1538	591.3	58.0	3452	1159
38.0	1575	603.1	58.5	3507	1175
38.5	1613	615.0	59.0	3563	1190
39.0	1651	627.1	59.5	3619	10206

39.5	1691	639.2	60.0	3676	1222
40.0	1730	651.8	60.5	3734	1238
40.5	1770	664.2	61.0	3792	1254
41.0	1810	676.6	61.5	3850	1270
41.5	1851	689.1	62.0	3908	1286
42.0	1892	701.9	62.5	3966	1303
42.5	1935	714.9	63.0	4026	1319
43.0	1978	728.2	63.5	4087	1336
43.5	2021	741.3	64.0	4147	1352
44.0	2064	754.4	64.5	4207	1369
44.5	2108	767.6	65.0	4268	1386
45.0	2152	780.9	65.5	4329	1402
45.5	2197	794.5	66.0	4392	1419
46.0	2243	808.2	66.5	4455	1436
46.5	2288	821.9	67.0	4517	1454
47.0	2333	835.5	67.5	4580	1471
47.5	2380	849.2	68.0	4645	1488
48.0	2426	863.0	68.5	4709	1506
48.5	2473	876.9	69.0	4773	1523
49.0	2521	890.9	69.5	4839	1541
49.5	2570	905.3	70.0	4905	1558
50.0	2618	919.6			
50.5	2667	933.6			
51.0	2717	948.2			

شكـر و تقـديـر

اتوجه بالشكر لله على هنئ عطائه و محمود بلائه وتوالي سبوغ نعمائه والى استاذي الدكتور طالب بهجت كشموله لمعاونته ومساندته ايا ي طوال فترة البحث.

اود ايضا ان اشكر جميع اساتذ ة وموظفي قسم الهندسة الكيمياوية في جامعة النهرين لابدائهم المساعدة اللازمة اثناء فترة البحث.

اود ايضا ان اشكر جميع منتسبي مصفى الدورة وبالاخص مختبر الزيوت والدهون الثقيلة لابدائهم المساعدة اللازمة لاجراء جميع الفحوصات اثناء فترة البحث.

لانسى ان اتوجه بالشكر الى كل من ساندني خلال هذا البحث لاسيما والدتي العزيزة و اهلي واصحابي .

لؤي عبد الوهاب رشيد الجاف

حزيران ٢٠٠٦

الخـــــلاصه

يتضمن هذا البحث دراسة تاثير اضافة (البولي ايزوبرين) على خواص زيوت التزييت الاساس . استخدم نوعان من مادة (البولي ايزوبرين) كمضاف لزيوت التزييت الاساس هما (البولي ايزوبرين 1502 &1320).

أن السبب الرئيسي لاستعمال (البولي ايزوبرين) في هذا البحث هو ان (البولي ايزوبرين) يعتبر احد انواع الاضافات المستخدمة لتحسين اللزوجة فضلا عن ذلك ان كلفته رخيصة ومتوفر محليا.

فقد تم خلط الزيوت الاساس (Stock 40 , 60 & 150) اولآ مع (البولي ايزوبرين1502) و ثانيآ مع (البولي ايزوبرين1320) مستخدما النسب الوزنية المئوية التالية لل (البولي ايزوبرين) وهذه النسب هي (0 , 0.5 , 1 , 2 , 4 , 6 ,8 %).

أن سبب استخدام النسب المئوية الوزنية المختلفة لل(البولي ايزوبرين) الى حد 8 % هو لاظهار اكبر تاثيرلل(البولي ايزوبرين) على الزيوت الاساس لكن أكثر الاضافات المستعملة صناعيا تتراوح من بضعة أجزاء لكلّ مليون إلى حد 10 او 20 %.

بعد ذلك تمت عملية قياس الخواص الفيزيائية للخليط , حيث تم قياس الخواص الفيزيائية التالية: (نقطة الوميض) ، (نقطة الانسكاب) ، (فحص الصدأ) ، (معامل اللزوجة) ، (اللزوجة),(فحص الرغوة).

وقد استنتج من خلال ذلك ان مادة (البولي ايزوبرين) قد نجحت بتحسين كل من (نقطة الوميض) ، (اللزوجة) ، (معامل اللزوجة) و (فحص الصدأ) حيث قللت من نسبة (الصدأ) الناتجة عن استعمال زيوت التزييت. اما فحص (نقطة الوميض) فقد كان لها تاثير سلبي حيث وجد انها تقل كلما زاد تركيز (البولي ايزوبرين) والسبب في ذلك هو وجود البانزين المستخدم كمذيب لل(البولي ايزوبرين). اما فحص (الرغوة) فقد وجد ان اضافة (البولي ايزوبرين) ليس له اي تاثير على زيوت التزييت الاساس.

قورنت النتائج التي تم الحصول عليها عمليا مع تلك التي جرى حسابها لزيوت التزييت الاساس مع اضافاتها ولمختلف التراكيز وكانت النتائج مرضية وبمعدل خطأ مطلق مقداره (% 8.4) بالنسبة لفحص(اللزوجة) ، (% 3.9) بالنسبة لفحص (نقطة الوميض) ، (% 7.7) بالنسبة لفحص (نقطة الوميض) ، (% 9.28) بالنسبة لفحص (الصدأ) و (% 6.56) بالنسبة لفحص (معامل اللزوجة) باستخدام (498) نقطة قياس تجريبية, كذلك تم مقارنة النتائج مع بحوث سابقة وجد انها مقبولة.

تاثير المطاط الصناعي المضاف على خواص زيوت التزييت

رسالة

مقدمة الى كلية الهندسة في جامعة النهرين

وهي جزء من متطلبات نيل درجة ماجستير علوم

في الهندسة الكيمياوية

من قبل

لؤي عبد الوهاب رشيد الجاف

بكالوريوس علوم في الهندسة الكيمياوية ٢٠٠٣

جمادى الاخرة ١٤٢٧

حزيران ٢٠٠٦