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Using Biphenyl and Diphenyl Oxide Substances in the Heat Exchange Process in the Oil Industry

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Abstract
Biphenyl and diphenyl oxide substances are organic compounds and they have a variety of applications, including but not limited to dye carriers, food preservatives, raw materials, heat transfer, and chemical synthesis. In this study, a production bank with a 50,000 barrel per day capacity was simulated using the Aspen Hysys program. The mixture of the diphenyl oxide and biphenyl was used as the heat transfer fluid and then entered the closed system heat exchanger in order to increase the oil temperature. Also, the importance of utilizing these substances in heat exchange processes was explained through interpreting the behavior of different parameters (pressure, density, viscosity, entropy, heat flow, actual liquid flow, and thermal conductivity) with temperature. The results were provided in this research in the form of curves, with explanations of the relationships between heat and various properties of a substance. Finally, the mixture of biphenyl and diphenyl oxide has good efficiency in heat exchange processes; consequently, it can be used in the oil industry.

Keywords: Biphenyl, Diphenyl oxide, Viscosity, Density, Thermal conductivity.

1. Introduction

Phenylbenzene, sometimes referred to as biphenyl or diphenyl, is an organic chemical that crystallizes as colorless particles. Compounds with the functional group biphenyl less one hydrogen may use the prefixes xenyl or diphenylyl, especially in older literature. It smells quite pleasantly and distinctly [1]. The chemical formula for biphenyl is $(C_6H_5)_2$, and it is an aromatic hydrocarbon. It is noteworthy for serving as the raw material for the creation of polychlorinated biphenyls (PCBs), which were once often utilized as dielectric fluids and heat transfer agents[2]. Additionally, the synthesis of a wide range of other chemical compounds, including optical brighteners, crop protection agents, emulsifiers, and polymers, using biphenyl as an intermediary. However, biphenyl is soluble in common organic solvents while being insoluble in water. Two phenyl rings that are joined together make up the biphenyl molecule [3].
The applications of substituted biphenyls are plenty. Several coupling processes, such as the Ullmann reaction and Suzuki-Miyaura reaction, are used to prepare them. Polybrominated biphenyls are flame retardants, whereas polychlorinated biphenyls were originally utilized as cooling and insulating fluids [4]. Other medications that have the biphenyl motif include telmisartan and diflunisal. However, biphenyl's major use is based on the fact that it lacks functional groups and is relatively non-reactive[5]. Biphenyl is mostly utilized as a heat transfer agent in the laboratory when combined with diphenyl ether to form a eutectic combination. The stability of this combination is 400 °C [6].
The chemical substance with the formula $(C_6H_5)_2O$ is called diphenyl oxide or diphenyl ether. It is a solid with no color. This, the most basic diaryl ether, has several specialized uses[7]. Diphenyl ether is primarily utilized as a heat transfer fluid in eutectic mixtures with biphenyl. Due to the relatively wide temperature range of its liquid form, this combination is ideal for heat transfer applications. Diphenyl oxide is a precursor used in the Ferrario reaction to create phenoxathiin. In the creation of polyimide and polyamide, phenoxathiin is employed[8]. It is also employed in the manufacture of polyesters as a processing aid and is frequently used in soap fragrances due to its stability and inexpensive cost [7]. As the related compound of diphenyl oxide, it is a part of the vital hormone T3, also known as triiodothyronine. There are several PBDEs (Polybrominated

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diphenyl ethers) that are effective flame retardants. The three most prevalent PBDEs are penta-, octa-, and decaBDE; only decaBDE is still widely used after being banned in the European Union in 2003[9].
In this paper, the conventional bank of degassing stations was designed and the substances of the biphenyl and diphenyl oxide were simulated as the heat transfer materials in order to increase the temperature of the crude oil in the heat exchanger process through the close system facility. Also, the effect or the relationship of the other properties of biphenyl and diphenyl oxide on the heat was explained.

2. Materials and Methods

2.1. Biphenyl and Diphenyl Oxide Preparation

It is possible to separate biphenyl from these sources, which include natural gas, crude oil, and coal tar, using distillation. When toluene is dealkylated to create methane, it is generated industrially as a byproduct [1]:

$$C_6H_5CH_3 + C_6H_6 \rightarrow C_6H_5 - C_6H_5 + CH_4$$

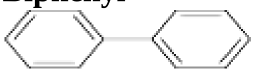
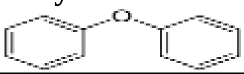
The second main method uses benzene's oxidative dehydrogenation:

$$2\ C_6H_6 + \frac{1}{2}\ O_2 \rightarrow C_6H_5 - C_6H_5 + H_2O$$

Biphenyl can also be created in a lab setting by reacting copper (II) salts with phenyl magnesium bromide[6].
Diphenyl oxide was initially described in 1901, along with several of its characteristics[10]. It is created using a variation of the Williamson ether synthesis, namely through the reaction of phenol and bromobenzene with base and catalytic copper:

$$PhONa + PhBr \rightarrow PhOPh + NaBr$$

Diphenyl oxide, which involves comparable processes, is a substantial byproduct of the high pressure hydrolysis of chlorobenzene to produce phenol[11].
It is necessary to have knowledge about the formula and other properties of the biphenyl and diphenyl oxide substances. Consequently, these properties are considered the basis for any process related to heat transfer, as illustrated in Table 1.
Table 1. Shows the properties of the biphenyl and diphenyl oxide substances.

Properties	**Biphenyl** 	**Diphenyl Oxide** 
Chemical formula	$C_{12}H_{10}$	$C_{12}H_{10}O$
Odor	Pleasant	Geranium-like
Appearance	Colorless to pale-yellow crystals	Colorless solid or liquid
Density	1.04 g/cm^3	1.08 g/cm^3 (20°C)
Molar mass	154.212 g·mol^{-1}	170.211 g·mol^{-1}
Boiling point	255 °C	257 °C at 1 bar
Melting point	69.2 °C	25-26 °C
Vapor pressure	0.005 mmHg (20°C)	0.02 mmHg (25°C)
Magnetic susceptibility	−103.25·10^{-6} cm^3/mol	-108.1·10^{-6} cm^3/mol
Solubility in water	4.45 mg/L	unsolvable
Autoignition temperature	540 °C	-
Flash point	113 °C	115 °C
Explosive limits	0.6-5.8 %	0.7-6.0 %
LD_{50} (median dose)	2400 mg/kg (oral, rabbit) 3280 mg/kg (oral, rat) 1900 mg/kg (oral, mouse) 2400 mg/kg (oral, rat)	3370 mg/kg (rat, oral) 4000 mg/kg (rat, oral) 4000 mg/kg (guinea pig, oral)
IDLH	100 mg/m^3	100 ppm

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2.2. Degassing Station Design

In this study, the Aspen Hysys program was used to simulate and design the production bank of the degassing station with a capacity of reaching 50,000 barrels per day. This bank consists of first stage oil separators (V-100), pre-heater, heater (E-100), second stage oil separator (V-101), dehydrator separator (V-102), desalter separator (V-103), gas boot vessel, flow tank (V-104), export pump (P-100), and a fan cooler for exported crude oil (AC-100). Also, the crucial input parameters of this process were inserted as shown in Figure 1. The heat exchange process occurs through a multi-stage: in the first stage (pre-heater), the heat exchange happens between the out-let crude oil from V-100 and out-let crude oil from V-103. This stage raises the temperature of the crude oil to 70°C. In the second stage (E-100), the heat exchange process takes place between the oil leaving from the primary heat exchanger (pre-heater) and the hot oil substance (Biphenyl and Diphenyl Oxide), which is heated by a thermal furnace. This stage causes the temperature of the crude oil to rise to 83 °C.

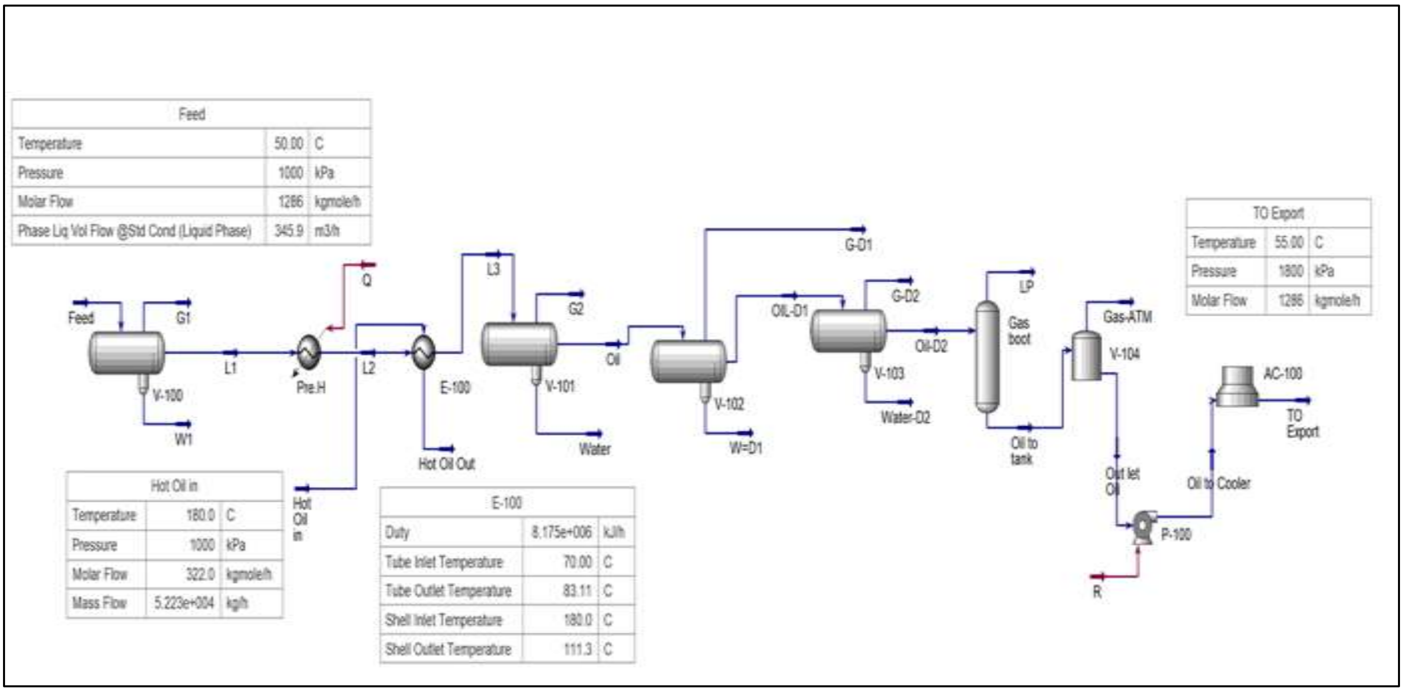

Figure 1. Design of the production bank using the Aspen Hysys program.

3. Results and Discussions

3.1. Temperature and Viscosity Relationship

Each fluid has a unique resistance to flow, which varies from one fluid to another, and this resistance is known as the fluid's viscosity. As temperature rises, the viscosity of gases increases, whereas that of liquids rapidly reduces. As a result, liquids flow more freely when heated, but gases flow more slowly.

The molecules become more mobile when the temperature rises because the kinetic or thermal energy also rises. Reduced viscosity results from a decrease in the attractive binding energy. Due to the increased movement of the particles caused by an increase in temperature, the viscosity reduces as the temperature rises. As a result, the forces of attraction between the particles are comparatively reduced. On the other hand, the forces of attraction between the liquid's particles grow as pressure on the liquid increases, slightly increasing viscosity. Also, the viscosity of the liquid is significantly influenced by the configuration and composition of its component particles. Large, asymmetrical particles in a liquid have a higher viscosity than tiny, symmetrical ones. Figure 2 shows the relationship between the temperatures and viscosity. With increasing temperature, viscosity clearly decreases, while pressure has minimal impact on it (Figure 2).

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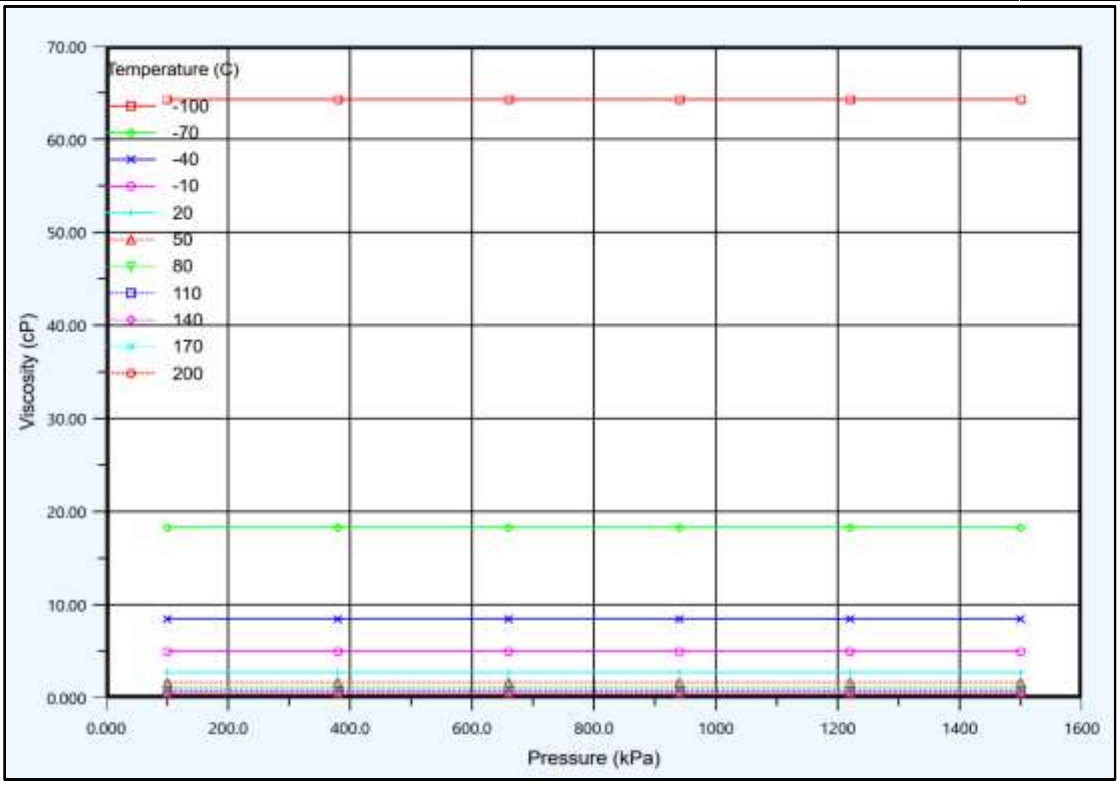

Figure 2. Relation between Temperature and Viscosity.

3.2. Temperature and Density Relationship

The two characteristics of matter are temperature and density. The quantity of heat in a material is assessed by its temperature. A substance or material's density is one of its physical properties. However, how much mass is contained in a specific volume may be determined by density. Moreover, temperature and density have an inversely proportionate relationship. Temperature changes will be manifested in alterations in density, and vice versa.

Figure 3 display the relationship between the temperatures and density. In this figure, the density decreases as the temperature rises while the pressure remains constant.

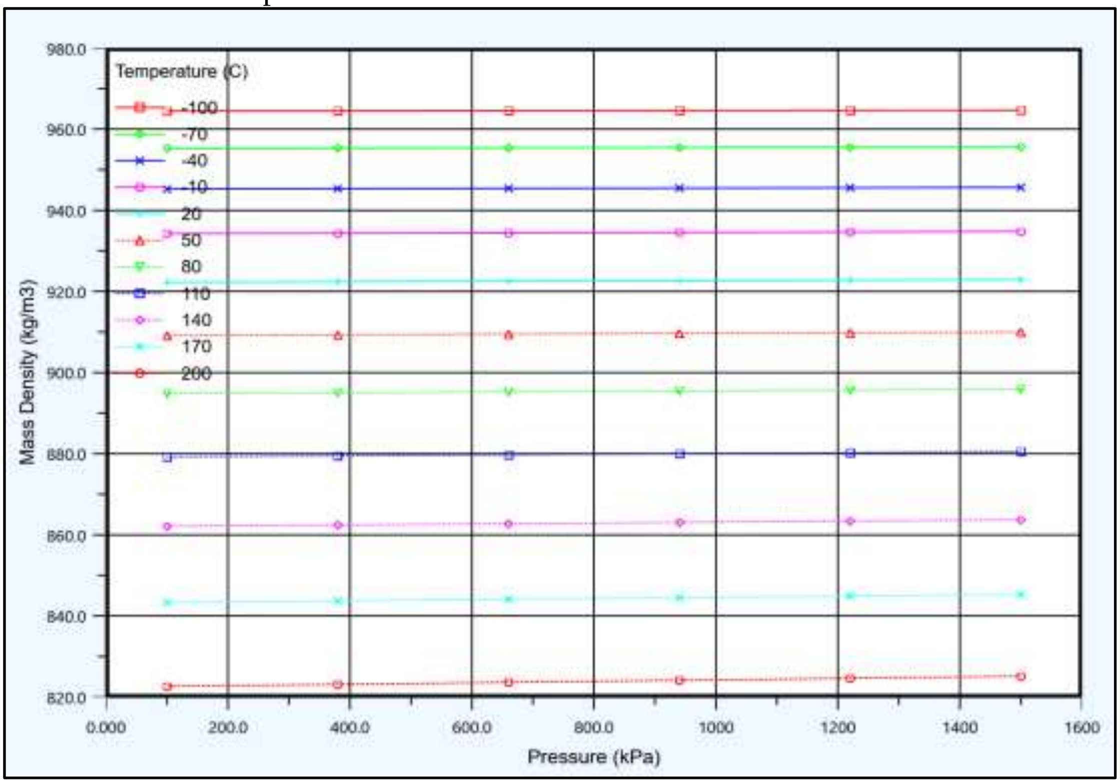

Figure 3. Shows the relationship between temperature, pressure, and density.

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3.3. Temperature and Entropy Relationship

Entropy is a closed system's propensity to change spontaneously until all of its components are distributed equally in terms of temperature, density, and pressure. It is a one of the most essential ideas in physics and chemistry. It may also be used in many other disciplines, including astronomy and economics, where it plays a crucial role in thermodynamics. Entropy is a particular technique for assessing chaos and unpredictability in any system. The mass of the system has a significant impact on the entropy value.

Figure 4 depicts the relationship between the temperature and mass enthalpy. When the temperature rises, the system's randomness increases (Figure 4).

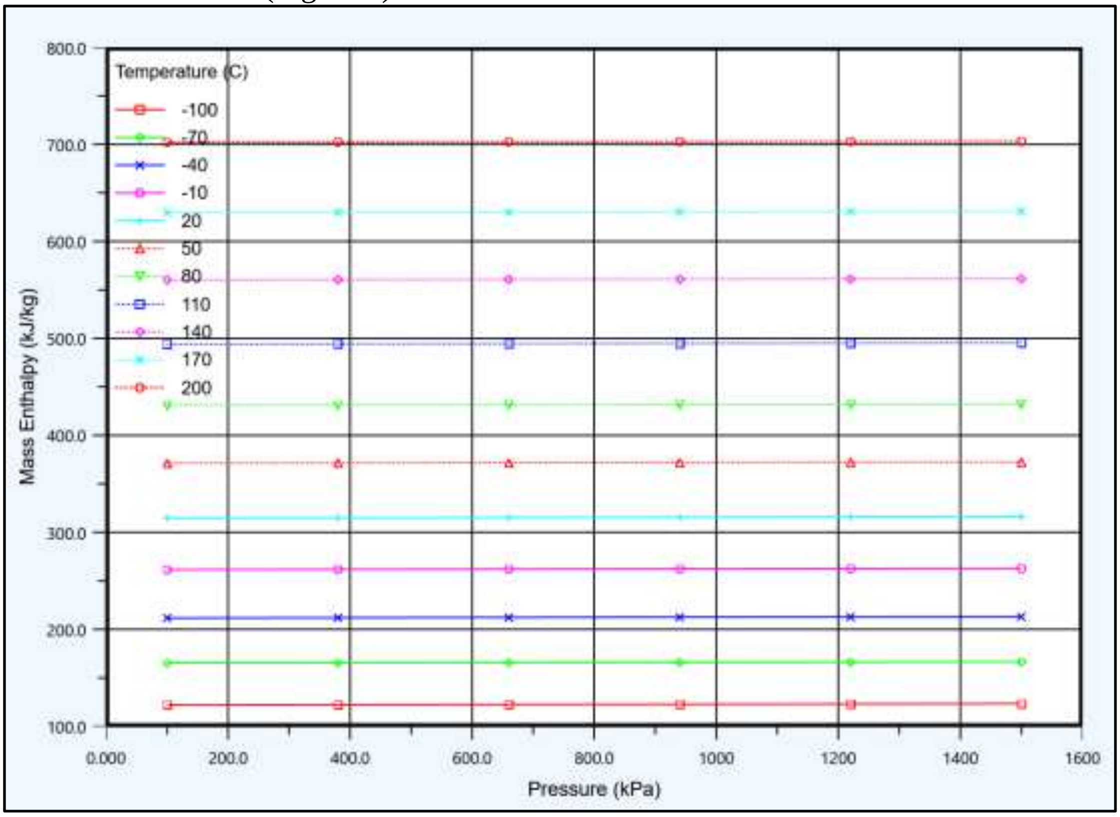

Figure 4. Relationship between entropy and temperature.

3.4. Temperature and Thermal Conductivity Relationship

The rate at which heat is transported by conduction through a material's unit cross-section area when a temperature gradient emerges orthogonal to the area is known as thermal conductivity. As a liquid expands and its molecules separate with temperature, its thermal conductivity diminishes. Density, moisture content, and operating temperature are the three key variables that have a significant impact on thermal conductivity. As the temperature rises, molecules scatter, causing the liquid to expand. Consequently, the capacity to transport heat is reduced as a result.

Figure 5 depicts the relationship between temperature and thermal conductivity. Because of the liquid's expansion and the molecules' movement apart, the thermal conductivity of liquids diminishes as temperature rises (Figure 5).

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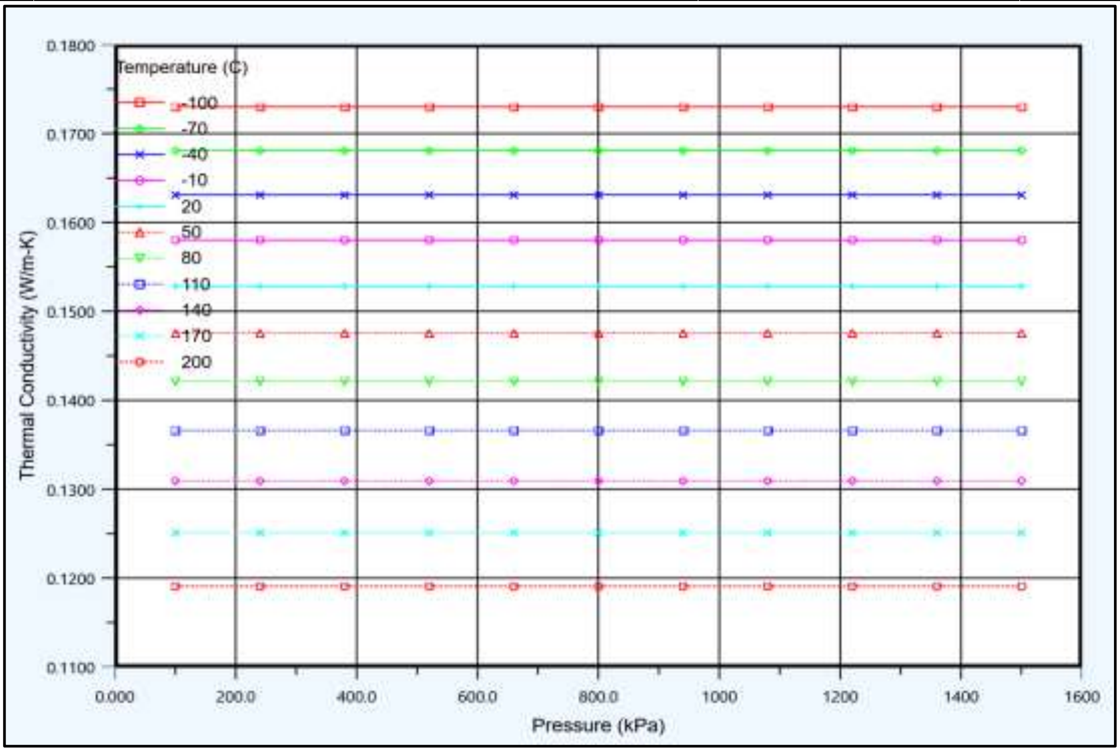

Figure 5. Depicts the relationship between temperature and thermal conductivity.

3.5. Temperature and Heat Flow Relationship

The higher-temperature element always transfers heat to the lower-temperature element; this process is known as heat flow, while the temperature is an indicator of the system's atoms' or molecules' average kinetic energy. The average molecular kinetic energy will fluctuate when a system gains or loses heat. As long as the system is not going through a phase change, heat transfer causes a change in temperature in the system.

It is necessary to know at least two factors in order to determine how the heat added to a system will affect the system's temperature: the number of molecules present in the system and the system's heat capacity. Assuming no phase transitions are taking place, the heat capacity informs us how much energy is required to change the temperature of a specific substance. Figure 6 shows the relationship between temperature and heat flow. The heat flow in this figure is directly proportional to the temperature.

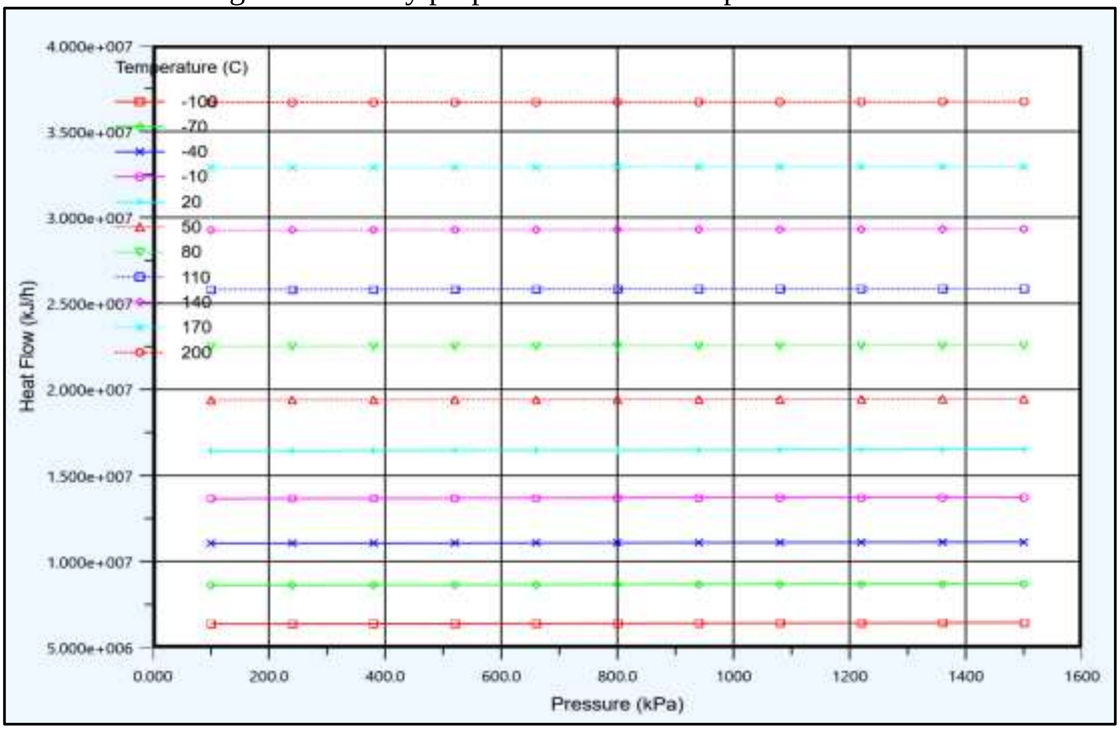

Figure 6. Shows the relationship between temperature and heat flow.

4. Conclusions

The following statements can be used to summarize the study's findings:

1. Biphenyl and diphenyl oxide substances can be utilized in heat exchange processes, especially in degassing stations, so they give high efficiency.
2. The process of heat exchange is unaffected by the ratio of biphenyl to diphenyl oxide, as it can be observed that when the ratio of biphenyl to diphenyl oxide changes, the heat exchange process remains almost constant.
3. The efficiency of heat exchange increases as the flow rate of biphenyl and diphenyl oxide increases.
4. It was observed that the behavior of the substance is the same as the rest of the other fluids, where:

- The viscosity decreases with increasing temperature.
- As temperature rises, density decreases.
- As the temperature rises, thermal conductivity decreases.
- As the temperature drops, heat flow decreases.
- As the temperature rises, so does the level of randomness.
- The volume increases with the increase in temperature.

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