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EXPERIMENTAL INVESTIGATION AND COMPARATIVE ANALYSIS OF FLASH/FIRE POINTS OF BIO-FUEL BLENDS USING PENSKY-MARTENS CLOSED CUP APPARATUS

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ABSTRACT
The determination of flash point and fire point is critical for assessing the flammability, volatility, storage safety, and transport hazard classification of liquid fuels and lubricating oils. This paper presents an experimental study evaluating the flash point of [Test Samples neat diesel, biodiesel blends (B5, B10, B20), waste cooking oil, or transformer oil] using the Pensky-Martens Closed Cup Apparatus in compliance with ASTM D93 / ISO 2719 standards. Test samples were heated at a controlled rate of 5.5℃/min under continuous stirring (90–120 rpm). An ignition source was periodically applied to the vapours in the cup at 1℃ temperature intervals. Ambient barometric pressure corrections were applied to obtain standardized flash point values. The results indicate that [increase in biodiesel percentage elevated the flash point from 68℃ to 130℃, significantly improving fuel handling safety]. This research provides valuable insights into fuel volatility behaviour and standard quality control parameters required for industrial handling.

KEYWORDS: Flash Point, Fire Point, Pensky-Martens Closed Cup, ASTM D93, Volatility, Flammability Hazards, Fuel Safety.

1. INTRODUCTION

1.1 Background & Significance

Volatility and Safety: Liquids release combustible vapours above their surface when heated. Knowing the temperature at which these vapours form a combustible mixture with air is vital for safety in storage, transport, and engine operation.
Flash Point (Tf): The lowest temperature (corrected to standard barometric pressure of 101.3kPa at which application of an ignition source causes the vapor of the specimen to ignite momentarily across the surface of the cup.
Fire Point (Tr): The lowest temperature at which the vapor continues to burn for at least 5 seconds after ignition. (Note: While fire points are traditionally measured using open-cup methods like Cleveland Open Cup ASTM D92, modified closed-cup protocols or transition to open top after the flash point are often examined in academic research).

1.2 Closed Cup vs. Open Cup Method

Pensky-Martens Closed Cup (PMCC): Used primarily for diesel, heating fuels, biodiesel, lubricating oils, and liquids with suspended solids. The closed lid prevents volatile lighter fractions from escaping prior to testing, yielding a more conservative (lower and safer) flash point compared to open cup methods.
Cleveland Open Cup (COC): Used mainly for viscous liquids and heavy lubricating oils with flash points above 79℃ where vapours can accumulate freely.

2. Penskey Martens Flash Point Apparatus Laboratory test

2.1 Objective: To determine the flash and fire point of a given sample using Pensky-Marten's flash point apparatus and determination of experimental repeatability.

2.2 Apparatus and consumables required:

a) A Pensky-Marten's flash point apparatus.
b) Thermometer of suitable range.
c) Test samples.

2.3 Methodology and procedure

2.3.1 Preparation of samples

a) Samples should be in reasonably fluid state before testing. For asphalts and other viscous materials, preheating should be done to ensure fluidity before testing.
b) Samples may be warmed with constant heating rate. However, under no circumstances, should be heated above a temperature that lies 16ºC below the expected flash point.
c) Samples containing dissolved water may be dehydrated with calcium chloride or by filtering through a suitable filter paper. If the same is not done, its consequence on experimental results and repeatability should be duly inferred.

2.3.2 Generalized procedure

a) Clean and dry all parts of the cup thoroughly.
b) Fill the cup with the sample to be tested to the level indicated by the filling mark.
c) Place the lid on the cup and set the latter on the stove.

d) Insert the thermometer and supply heat with the help of the rheostat switch to ensure temperature rise rate not more than 5 to 6ºC per minute.
e) Turn the stirrer with 90 to 120 rpm in a downward direction.
f) Provide the test flame time to time and start nearly 17ºC below the expected flash point of the sample with 0.5 to 1ºC gap.
g) Lower the test flame to the vapour space of the cup for 5s and allow it to be there for 1s. After that move the test flame up as quickly as possible and shut down the lid for vapour build up.
h) Do not stir the sample while providing the test flame.
i) Denote the flash point and fire point accordingly.
j) For suspension of solids, follow the procedure as mentioned below.
-Bring the materials to be tested to a temperature of 15±5ºC or 11ºC lower than estimated flash point.
-Completely fill the space between the cup and the interior of the air bath with water at the temperature of the tester and the sample.
-Turn the stirrer at 250±10 rpm in a downward direction.
Raise the temperature throughout the duration of the test at a rate not less than 1ºC or more than 1.5ºC per minute.
-The rest of the procedures same as the generalized one.

Observation Table:

Fuel Sample	Blend Ratio (%)	Ambient Pressure (kPa)	Observed Flash Point To (℃)	Corrected Flash Point C (℃)	Fire Point	Standard Limit (ASTM D975 / D6751)
Pure Diesel (B0)	100/0	95.2	64.0	64.8	70℃	>=52.0 ℃
Biodiesel Blend (B10)	91/09	95.2	72.5	73.3	77℃	>=52.0 ℃
Biodiesel Blend (B20)	81/19	95.2	84.0	84.8	90℃	>=52.0 ℃
Neat Biodiesel (B100)	0/100	95.2	142.0	142.8	150℃	>=130.0 ℃

Experimental Procedure (ASTM D93)
Preparation: Clean and thoroughly dry the brass cup. Fill the cup up to the internal fill line with the test sample (56 mL).
Assembly: Place the lid on the cup, insert the thermometer, attach the drive shaft, and position the assembly inside the heating jacket.
Heating & Stirring: Apply heat to achieve a uniform temperature rise of 5.0 6.0 ℃ / min. Engage the stirrer at 90–120 rpm.
Ignition Testing:
Stop stirring when applying the test flame.
Lower the ignition flame into the cup vapor space for 1.5seconds and immediately return the shutter to the closed position.
For expected flash points <=110, apply the test flame starting 18℃ below the expected flash point and every 1℃ increment thereafter.
For expected flash points > 110℃, apply the test flame every 2 ℃ increment.
Observation:
- Flash Point: Recorded when a distinct flash/halo flame is observed inside the cup interior.
- Fire Point: Continued heating with shutter open/removed until the flame sustains burning for >=5 seconds.

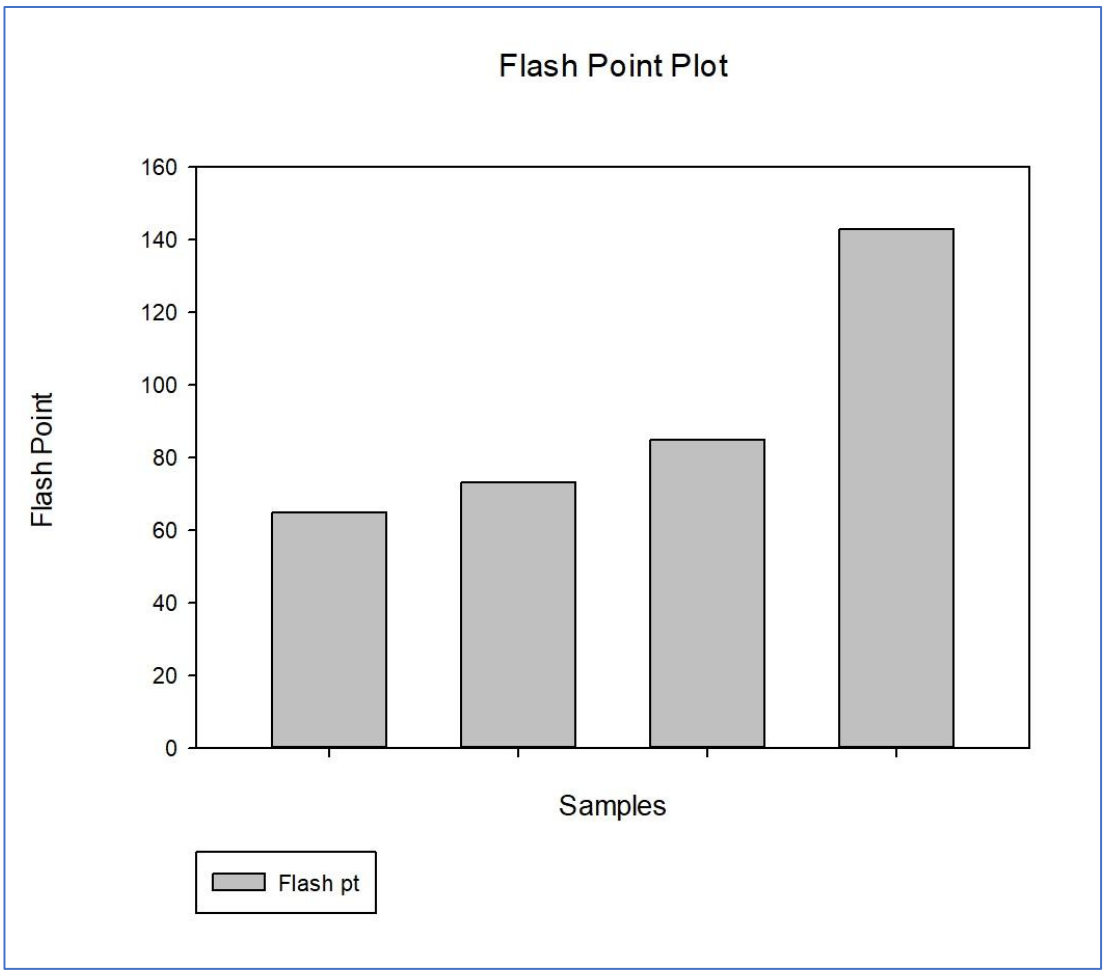

Fig 1. Flash Point Plot

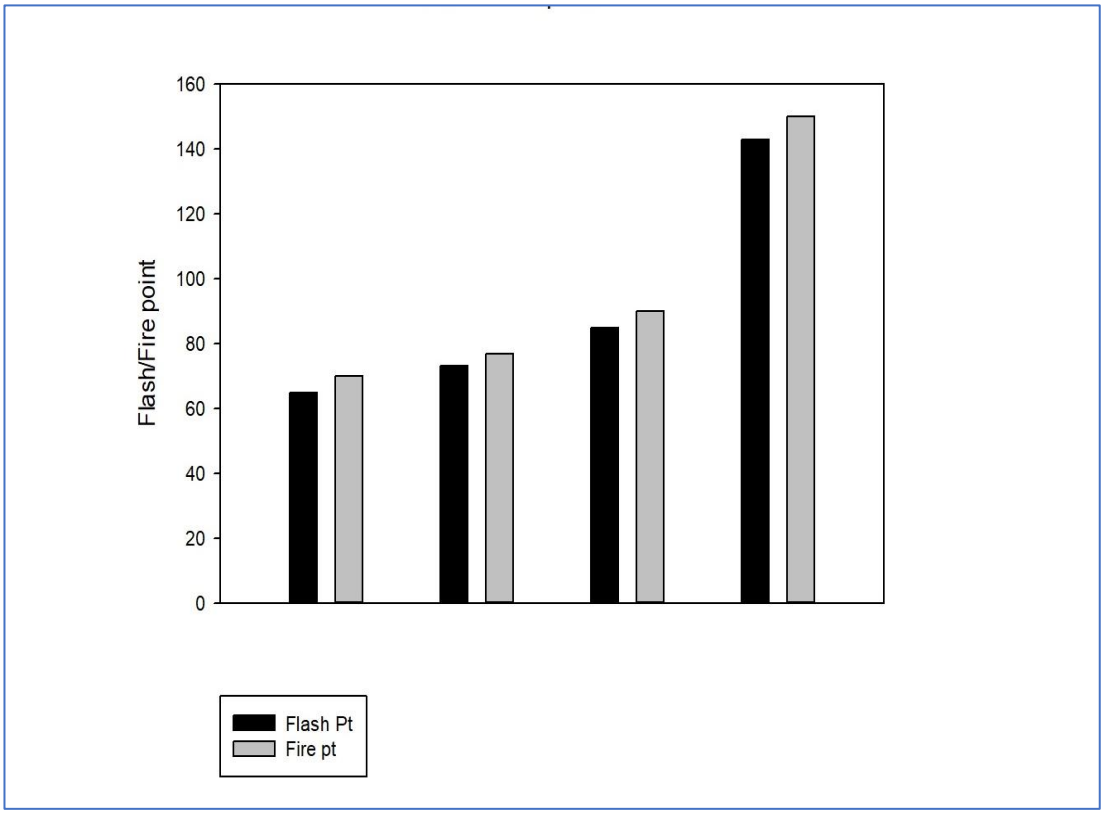

Fig 2 Flash/Fire Point Plot

Fig 3. Apparatus

4. DISCUSSION POINTS

Analysis of findings against existing literature:

1. Impact of Volatile Contaminants:

Minor traces of residual alcohols (e.g., methanol or ethanol left over from transesterification in biodiesel synthesis) dramatically drop the flash point below safety limits.

2. Safety and Storage Hazards:

Higher flash points correspond to lower vapor pressure at ambient temperatures, reducing fire hazards during transport and bulk storage (NFPA Class II vs. Class III liquids).

3. Precision & Repeatability:

Compare results with standard ASTM repeatability thresholds (2°C approx. for standard fuels). Experimental sources of error (e.g., incorrect stirrer RPM, draft air currents, overfilling the sample cup).

Neither fuel is universally better; whether a higher or lower flash point is preferred depends entirely on the application: fuels with a higher flash point are safer for storage and suited for compression-ignition (diesel) engines, whereas fuels with a lower flash point are necessary for rapid vaporisation and cold-starting in spark-ignition (petrol) engines.

Core Definitions

- **Flash Point:** The lowest temperature at which fuel yields enough vapor to form an ignitable mixture with air near its surface, producing a momentary flash when exposed to a flame (without sustained burning).
- **Fire Point:** The lowest temperature at which the fuel vapours continue to burn continuously for at least 5 seconds after being ignited. The fire point is typically 5°C to 15°C higher than the flash point.

Significance of Higher Flash and Fire Points

- **Maximum Handling and Storage Safety:** Higher values reduce the risk of accidental fire, vapor explosion, or ignition from static electricity during transport, handling, and bulk storage (e.g., Diesel has a flash point of around 52°C–96°C).
- **Thermal Stability in Heavy Machinery:** Ideal for compression-ignition engines, industrial boilers, and aircraft where high operational temperatures are involved and spontaneous pre-ignition must be avoided.
- **Relaxed Regulatory Compliance:** Fuels with flash points above 55°C or 60°C are generally classified as less hazardous cargo, simplifying shipping and storage regulations.

Significance of Lower Flash and Fire Points

- **Quick Cold Starting:** Fuels with low flash points vaporise easily at low ambient temperatures, making quick starting possible in spark-ignition engines (e.g., Petrol/Gasoline has a flash point of around -43°C).
- **Rapid Combustion Efficiency:** High volatility facilitates quick air-fuel mixing in carburettors and port injection systems.
- **Elevated Fire Hazard:** Represents high flammability. Even tiny leaks, open sparks, or static charges at ambient conditions can ignite fuel vapours instantly, requiring explosion-proof storage and handling systems.

Key Comparison

Feature	Low Flash & Fire Point (e.g., Petrol)	High Flash & Fire Point (e.g., Diesel, Kerosene)
Primary Advantage	Easy ignition and cold-starting	Transport and storage safety
Ignition System	Spark-ignition engines	Compression-ignition engines / Burners
Volatility	High	Low
Fire Hazard Risk	High at ambient temperatures	Low at ambient temperatures

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