Ignition temperature of liquid fuels using the Marcussons' open-cup method

Introduction

Within the scope of the technical analysis of liquid fuels in addition the determination of density, viscosity, surface tension also includes determination of the flash point, fire point and autoignition temperature.

The flash point or ***ignition temperature***, t_z, of a volatile liquid is the lowest temperature at which it can vaporize to form an ignitable mixture in air. Measurement of liquid fuels flash point requires providing an ignition source. At the flash point, the vapor may cease to burn when the source of ignition is removed. This temperature does not significantly affect organization of the combustion process (boilers, furnaces, internal combustion engines), however is of great importance from the viewpoint of safety and fire hazards. This applies mainly to treatment processes, storage and transport of liquid fuels. The flash point is often used in petroleum refining industry as an indicator of quality (purity) of petroleum fractions [1,2]. Ignition temperature of the liquid fuel is strongly dependent on the boiling temperature of the fuel its viscosity, density and chemical composition [3].

The fire point, t_p, a higher temperature, is defined as the temperature at which the vapor continues to burn for at least 3 seconds after being ignited by an external source. Neither the flash point nor the fire point are related to the autoignition temperature of fuel or the temperature of the ignition source, which are much higher. Similar factors affect the fire point as those given above affecting the flash point.

There are two types of methods used to determine the flash point (ignition temperature) and the fire point:

1) Abla-Pensky or Pensky-Martens closed-cup method [4,5],
2) Marcusson or Brenken open-cup method [6,7].

In order to eliminate the influence of heating rate and the geometrical dimensions of the experimental setup, these methods have been standardized. It should be stressed, that when comparing or verifying the results of measurements done with various standardized methods, both the flash point and the fire point are usually 30 K higher for the open-cup method than for the closed-cup method. The choice of the method depends on the type of fuels ignition temperature. It is often assumed that for fuels with a flash point higher than 50 °C (323 K) and not containing volatile constituents, the Marcusson method may be used (open-cup). In order to ensure repeatability of the results it is also important to prepare the fuel sample properly. The recipes for fuel samples preparation are given in Table 1.

Table 1. Methods of preparation of samples for determining the flash point [3]

Fuel type	Procedure
Petroleum products (asphalts)	Heat to the pour point
Asphalts with water	Heat to about 80÷100 °C above the melting point, but about 30°C lower for t_z<250°C and about 50°C lower for t_z>250°C
Products conatining water below 0.1%	Dehydrate
Asphalt products of t_z about below 80°C	Cool to the 50°C temperature below predicted ignition temperature t_z

The aim of the exercise

The aim of this exercise is to learn the properties of liquid fuels, which affect the safety issues associated with their use. The determined properties of the fuels are the flashpoint (ignition temperature) and the fire point using the Marcussons' open-cup method.

Description of the test rig

In Fig. 1 the scheme of the test rig for the Marcusson method is presented. The sample section is built out of two metal containers placed one in another. The inner container is of cylindrical shape (40 mm in diameter and 40 mm high) and comprises the open cup. It is surrounded with a 400 W heating coil placed in sand used to equilibrate the heating supplied to the cup walls. The heating rate of the sample can be smoothly adjusted by means of the autotransformer.

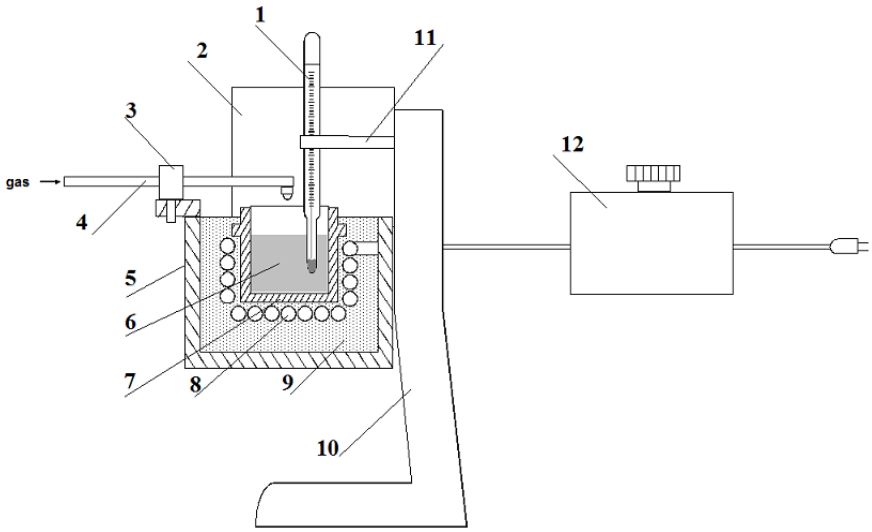

Fig. 1. Scheme of the test rig using Marcusson open cup method 1, thermometer, 2, flame shield; 3, screw to the regulate level of the burner above the cup, 4, gas ring with valve ; 5, outer container; 6, liquid fuel sample; 7, open cup; 8, heating coil; 9, sand; 10, stand; 11, thermometer holder; 12, autotransformer

Measurement procedure

Before proceeding with the measurement check the quality of the electrical and gas connectors. If they are correct follow the steps below:

1) clean the open cup using an organic solvent and dry it
2) prepare sample of fuel according to the information given in Tab. 1
3) fill the cup to the lower line using pipette or syringe for the products of which temperature t_z is above 250°C and to the upper line for other fuels
4) place the cup in the container with sand, so that the heating coil surrounds the volume of the cup. **Attention** - the temperature of the apparatus before putting the cup in it should be about 60 K smaller than the ignition temperature. Put the sand around the crucible. Place the thermometer in the sample 5mm from the wall and 2mm from the bottom of the cup
5) turn on the heating system. The heating rate should be 6 K/min in the initial phase (to about 30 K below the expected flash point)
6) when fuel temperature will be 30K under the expected ignition temperature reduce heating rate to 3 K/min
7) ignite and adjust the flame to obtain 10 mm flame length
8) move the flame over the open cup to check the fuel ignition, the time of the passing over flame should be about 1s
9) check if the fuel ignites every with a frequency corresponding to 1K rise of fuel temperature
10) register the lowest temperature when the volatiles start burning but immediately extinguish after the ignition source is removed. This temperature is the flash point (ignition temperature)
11) continue heating the fuel and igniting it until the vapor continues to burn after the ignition source is removed. This temperature is the fire temperature
12) remove the thermometer and put an asbestos tile on the top of the cup to extinguish the fire
13) turn off the heaters power supply,
14) take out the cup using pliers,
15) open a window and get some fresh air,
16) note down the atmospheric pressure,
17) when the temperature of the sand in the crucible will fall to about 60 K below the ignition temperature of the measured fuel, repeat steps 2-18 using next fuel sample
18) turn off the main gas valve after the measurements are finished

Analysis of the results

Results of the measurements of flash point and fire point of liquid fuels must be presented in form of a report by filling Table 2.

Results of the measurements should be corrected using formula (1) if the atmospheric pressure is 2 kPa different than the standard state pressure (101.325 kPa):

$$\Delta T = 0.25\ (101.325 - p_a) \qquad (1)$$

where:

ΔT - temperature correction, K

p_a - ambient pressure, kPa

The final result is understood as an arithmetic mean of at least two results not differing by more than 6 K. If the obtained difference is higher than 10 K it is necessary to carry out another measurement take the mean of three results.

Table 2. Results

	Fuel	Ignition temperature (flash point) t_z, °C	Fire point t_p, °C	Pressure p_a, kPa
1				
2				

Literature

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