

# Experimental determination of the lower explosion limit for two gasoline samples

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**Abstract.** The explosive atmosphere may be caused by flammable gases / vapours or combustible dust. If the amount of the substance, mixed with air, is sufficient, then a source of ignition is needed to cause an explosion. Liquids (for example petrol and other fuels) and solvents from industrial products emit flammable vapours which, when mixed with air, can ignite or explode. At normal temperatures, flammable liquids can emit enough vapours to form combustible mixtures with air, heat, and often thick, black, and toxic clouds of smoke. The behaviour of a fuel-oxidant mixture is characterized by certain explosions parameters, including explosion limits, which characterize the range of concentrations in which combustion propagates at very high speeds. For this work were performed experimental determination of the lower explosion limit for two commercial gasoline samples.

## 1 Introduction

Any chemical reaction accompanied by the sudden release of a large amount of heat is named explosion and systems that can support this process are called explosive or flammable systems.

Probability of appearance of an explosion involves the simultaneous existence of three factors:

- Combustible (flammable gaseous substance and / or dust);
- Oxidizing (oxygen from air);
- Sources of ignition [1, 2].

Explosions, followed or not by fire, are destructive phenomenon, with major social and economic implications, especially given current technologies. Therefore, risk assessment associated with explosion is the duty of every employer to ensure the safety and health by implementing risk management requirements prescribed by regulations.

Technology development resulted in solving numerous aspects of industrial risks, but nevertheless still appear new risks and a number of risk factors including risk of explosion which is impressive with serious consequences (human and material losses) which strongly influences social relations and indirect costs of the finished product [3]. Such situation justifies the high interest to the problem of formation of explosive mixtures with air which

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takes the form of fine dispersion of gas, vapor, mist or dust. This situation shows interest to justify high oil explosivity problem and not only illustrated by studies addressing such research and is justified by the need to give the answer to three problems: prediction, prevention and protection of the events (accidents) involving explosions of chemical compounds. Depending on the specific activities being used different types of substances with flammable properties. In industrial and civilian areas can appear various explosive atmospheres. In the mining industry, especially in the firedamp mines the flammable atmospheres can be methane gas, coal dust or a mixture thereof. Fires and explosions in coal mines are events particularly with serious consequences in the economic and social plan, as well as negative influences on the environment dynamic effects.

Flammable gases and vapours that may escape from an installation due to various causes (broken pipes, broken machinery, uncontrolled reactions, etc.) not ignited at the site of the leak may cause the occurrence of explosive mixtures. If flammable gases and vapours do not ignite at the source of escape, depending on the composition, physical characteristics, environmental conditions, they move in the form of a cloud, at various distances, until some source ignites it. In general, explosive atmospheres can be formed from gases that are lighter than air (e.g. hydrogen, methane, ammonia), but their explosion is less frequent, as they rise to the top of work spaces or disperse quickly. Liquefied or highly refrigerated gases, with a specific gravity close to that of air or higher, most frequently form explosive atmospheres. Explosive atmospheres generated by flammable liquids can consist of: vapours - air, vapours and / or fog - air, fine liquid dispersed (sprayed) in the air. The biggest danger is the fog, which also contains the vapours of the flammable substance from which it comes, because it has a high susceptibility to ignition and a high concentration of fuel.

The primary indicator for determining the explosion danger of air-gasoline mixtures is the explosion limit, which is a crucial parameter of flammable and explosive substances. It also serves as a foundation for defining pertinent standards and specifications. The explosive properties of combustible liquid vapors have been extensively discussed in the literature. In order to experimentally ascertain the basic explosive properties of methanol-air mixtures using a closed vessel, Saeed, K. implemented a new multizone model and evaluated the parameters of maximum explosion pressure and maximum pressure rise rate of methanol-air mixtures at various initial conditions of temperature, pressure, and equivalence ratio [4]. Zhenyi Liu studied the relationship between explosion limits and the critical oxygen content of petroleum vapor at various temperatures, and the results revealed that as temperature rose, the critical oxygen content decreased and the explosion limits became more varied [5]. Using an internal flammable liquid explosion-limit testing system, Ganbing Yao studied the explosion limits and inerting mechanisms of RP-5 and RP-3 oils [6].

The main parameters that characterize an explosion are the following [7]:

- Lower explosive limit (*LEL*) which is the concentration of flammable gas, vapour or mist in air below which an explosive gas atmosphere will not be formed;
- Upper explosive limit (*UEL*) which is defined as the concentration of flammable gas, vapour or mist in air, above which an explosive gas atmosphere will not be formed.

Explosion limits of combustible gas mixture are defining oxidant concentration range (at constant temperature and pressure) where an initial explosion can propagate independently in all of the explosive mixture [8].

- Maximum explosion pressure is the highest pressure that occurs during of an explosion of a flammable mixture in a closed vessel;
- Maximum rate of pressure rise ( $dp / dt$ )<sub>max</sub> - the maximum value of the pressure rise per unit of time during explosion of any explosive atmosphere type within the

explosiveness range of a flammable substance in a closed vessel, under specified test conditions.

- Explosion index:

$$K_{\max} = K_{st} = K_G = (dp / dt)_{\max} \cdot V^{1/3} \quad (1)$$

$K_{st}$  – dust explosion index

$K_G$  – gas explosion index

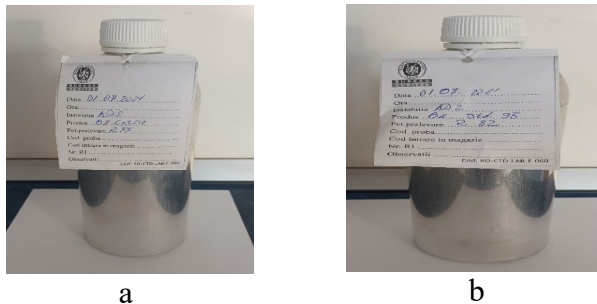
$(dp / dt)_{\max}$  - maximum rate of pressure rise

$V$  – explosion vessel volume

For this work have been performed investigation tests with Apparatus for determining the explosion limits FRTA-I for two commercial gasoline samples.

## 2 Materials and methods

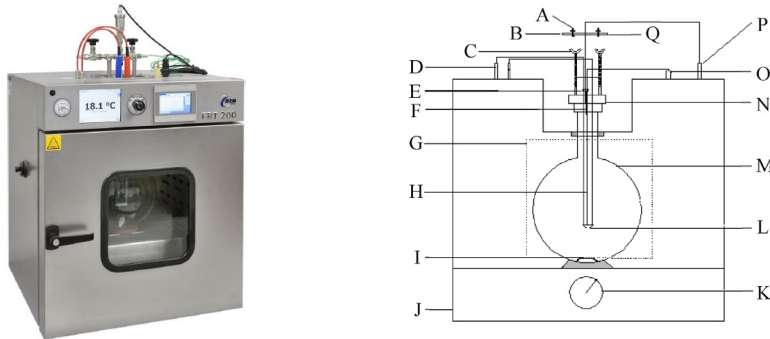
There were performed explosivity tests for two commercial gasoline samples shown in Figure 1 and 2 to determine the lower explosion limit. Commercial gasoline is a mixture of a large number of different hydrocarbons. Gasoline is produced to meet a host of engine performance specifications and many different compositions are possible.



**Fig. 1.** a. Sample 1 – Extra gasoline: b. Sample 2 – Standard gasoline 95

The analysis was performed in accordance with SR EN 1839:2017 Determination of the explosion limits and the limiting oxygen concentration (LOC) for flammable gases and vapours [9]. The equipment used for this determination is an FRTA-I explosion limits instrument presented in figure 3. The instrument consisted of a 5 L glass pressure test vessel placed inside a stainless-steel oven main unit equipped by temperature sensor and pressure transducer for monitoring gas temperature and pressure within the test vessel. Two needle valves served for fine regulation of vacuum or air inflow into the glass vessel. Gasoline samples were injected into the vessel through a serum bottle septum with a microsyringe. A pair of tungsten electrodes with spark plugs are inserted into the test vessel and connected to the ignition device (high voltage power supply, 15 kV and 30 mA). The oven is equipped with barometric pressure transducers, magnetic stirrer, safe viewing glass door made from safety glass and ventilation hole in the rear panel. There were two touch panels on front side of the main unit: one for control and display of the oven temperature and the second for displaying temperature and pressure inside the vessel, barometric pressure and control and configuration of the ignition device. The maximum operating temperature of the instrument was about 50 °C The instrument is based on electric ignition

and visual observations of flame propagation and designed for testing with air used as oxidizer [10, 11].



A-Needle valve, B-vacuum pump interface, C-threaded rod holder, D-high voltage feedthrough, E-serum bottle septum, F-pressure transducer, G-external vent bezel, H-thermocouple, I-stirring bar, J-main unit, K-magnetic stirring, L-ignition electrodes, M-glass vessel, N-PTFE head, O-thermocouple socket, P-pressure transducer socket, Q-intake [6]

**Fig. 3.** Apparatus for determining the explosion limits FRTA-I

At the beginning of an experiment, the air inside the chamber was first removed with a vacuum pump. After air pressure was stabilized, a certain amount of gasoline samples was injected by syringe and the magnetic stirrer turned on to accelerate samples vaporization until the chamber pressure stabilized again, which was recorded. Then, air was introduced into the chamber up to ambient pressure and stirred for an additional 5 min to ensure the mixture was evenly mixed. Next, the stirrer was turned off and, 10 s later, ignition applied. This delay time allowed turbulence to subside, without losing the homogenous nature of the mixture. After ignition, whether or not explosion occurred, the gas in the chamber was evacuated and air introduced up to ambient pressure. Finally, the air was removed and added again three times for effective flushing of the contents.

### 3 Results and discussion

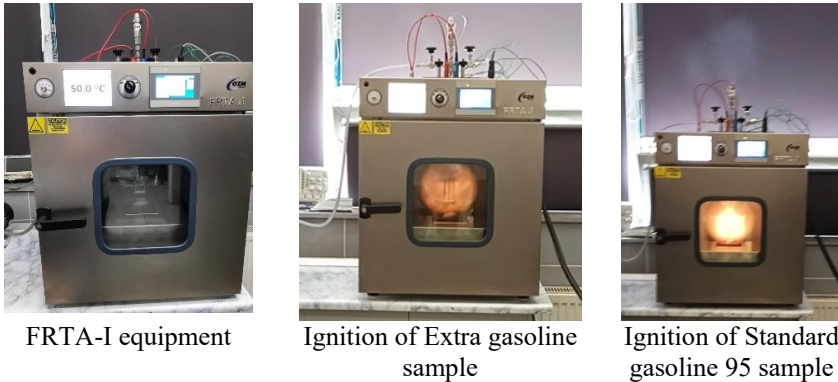
The two samples of gasoline were sampled by an economic agent that ordered a study regarding the determinations of gasoline explosion limits, that were needed for the calibration of an explosive detection system, all sampling conditions being respected.

The lower explosion limit of the gasoline samples was tested using the FRTA-I explosion instrument. The mixture concentration was calculated based on the ratio between the partial pressure of the fuel (gasoline) and the initial pressure, respectively the atmospheric pressure. The sample concentration increased gradually from a lower sample concentration until the flame was observed to spread. In this test, the initial volume of the samples introduced was 250  $\mu\text{l}$  and increased to 450  $\mu\text{l}$ . The test temperature was 50°C. Then, whether an explosion had occurred after ignition by means of a high voltage discharge was judged according to explosion criteria. If an explosion occurred after ignition, the gasoline vapor concentration was reduced and the test repeated. If an explosion did not occur after ignition, the gasoline vapor concentration was increased and the test repeated. The gasoline vapour concentration was modified until there was an acceptable sample concentration difference between ignition and non-ignition events. The test for non-ignition was repeated at least 3 times.

After performing the tests were obtained the following results, shown in table 1 and figure 4:

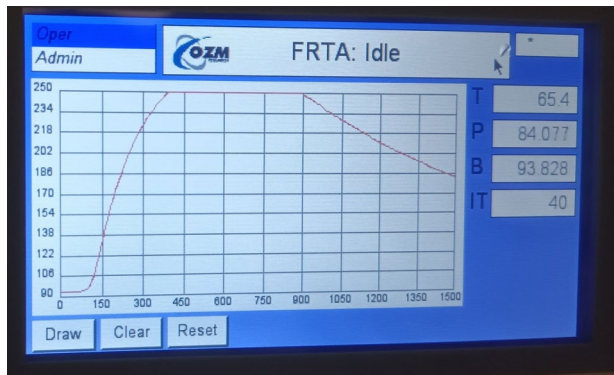
**Table 1. Results**

No.	Sample identification	LEL [%]
1.	Sample 1 – Extra gasoline	1.2
2.	Sample 2 – Standard gasoline 95	1.19



**Fig. 4.** Determination results

At the concentrations of 2.4% and 1.3% respectively of the air-gasoline vapor mixtures, explosion pressures higher than 2.5 bar were obtained, as can be seen in figure 5:



**Fig. 5.** Explosion pressure graph

The Lower Explosion Limit for the analysed samples is the lowest concentration of fuel at which the explosion can occur and can propagate autonomously throughout the gas-oxidant mixture, even after the efficient source of initiation has ceased. Below this concentration the mixture is too poor to support combustion, as there are not enough fuel gas molecules. As the temperature rises, the lower flammability limit changes moderately, the flammability decreases.

By comparing the experimental results with data from the literature for similar fuel samples, it was observed that lower explosion limit is close to 1.2% [12, 13].

## 4 Conclusions

To assess the risk of explosion and explosion expertise type events, it is necessary to know the parameters of explosion characteristics of air - flammable substances mixtures.

Explosion limits, also called flammability limits, are an important parameter in characterizing flammability / explosiveness for flammable liquids and gases / vapours, characterizing the range of concentrations in which combustion propagates at subsonic velocities. Flammable and combustible liquids are present in almost all workplaces in several industries, which is why it is necessary for all those who use / handle these liquids to be aware of the dangers they can generate and to work safely with them.

In this paper the experimental results obtained are well fitted within literature data for similar commercial gasoline samples. The aim of the study was to determine the explosion limits for two commercial gasoline samples using an FRTA explosion limit instrument. The findings are highly significant for assessing safety, preventing fires and explosions, and completing the air-gasoline technical indicators. Moreover, calibrating the method for the explosion limit determinations opens the path for researching various gasoline – air mixtures when methanol is present. The results obtained in this paper are well fitted within literature data for similar commercial gasoline samples.

The development of methods for the determination of explosion parameters for flammable air - vapor mixtures lead to increased expertise in the field of explosions, the expansion of knowledge concerning explosion type phenomenon and improved work health and safety. Determination the security characteristics has an important role in the first phase of the explosion risk assessment, and in assessment phase of the equipment and protective systems intended for use in potentially explosive environments.

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