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# EVALUATION OF EFFECT OF CHANGES DURING LONG-TERM STORAGE ON FUEL CHARCTERISTICS

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***Abstract***

*This paper describes the effect of long-term petroleum fuels storage on their characteristics that are significant for fuel and engine fuelling with this fuel.*

*The paper shows the course of changes of selected fuels' parameters that, according to the author, have the biggest effect on fuel quality maintaining during long-term storage. These changes were related to potential usage problems that would be the effect of them. The presented results are the part of the project with the goal to develop the system of reserves control. It's pointed that there is necessary to continue work, especially aimed to create modern methodology to forecast the pace and nature of potential changes, not as so far - to evaluate the actual level of product under storage in actual or simulated-accelerated conditions.*

***Keywords:*** *liquid fuels, physical and chemical properties, use, storage*

## 1. Introduction

Storage of crude oil and petroleum products (mostly fuels) is one of the most crucial issues regarding ensuring the energy security of state. The reserves are maintained according to different formal rules and in different technical conditions. Despite this, the most important thing is that the product doesn't deteriorate in manner excluding its use as intended after the set period of time.

Storage course, and mostly, the course of possible quality changes during this process, are enforced by many conditions, both internal - connected directly with chemical composition and characteristics of products being stored as well as external ones - connected with storage conditions. The first group can cover the following:

- chemical composition - regarding the selection of components with defined susceptibility to ageing;
- extent of base product modification using additives.

The second group can cover the following:

- type, design and capacity of storage tank (e.g. horizontal/vertical, single-/double-walled, equipped with systems protecting from external contamination;
- way of foundation (underground, semi-underground, ground-based);

- condition of tank and distribution facility;
- frequency and mode of product handling, rotation;
- catalytic effect of construction materials.

The changes during long-term storage are inevitable. Modern technology regarding storage and distribution equipment only restricts this process and inhibits its dynamics. Provided the infrastructure development effects positively on long-term storage, the fuels' development doesn't do it so explicitly. Use of significant amount of additives means problems with stability (both chemical and one regarding physical and chemical characteristics). Moreover, the use of new components such as the bio-ones, causes some different behaviour - also during storage. Chemical composition mostly involves loss of part of original properties. The changes intensity and type are not equal for all parameters. The fuel characteristics can be classified into the following three areas:

- technological - covering the parameters important in fuels' manufacturing process;
- ecological - connected with restriction of harmful effect of fuel on environment both during vehicle (machinery) use and during fuel storage and distribution;
- operating - typical for fuel's behaviour in engine.

It's that not every change causes elimination of fuel from use. For the purpose of this paper, author limited himself to parameters affecting engine use. In most cases, the single use of out-of-spec fuel doesn't have to cause negative effect. However, it's a risk that long-term engine fuelling using fuel with parameters even close to acceptable ones also can affect the combustion process and other phenomena regarding the fuel use (corrosion of fuel system construction materials, sluggish fuel system contamination, formation of harmful carbon deposits on hot engine parts).

## 2. Test results

The research covered such fuels as: diesel fuel (ON), medium distillate marine fuel (PM), and aviation turbine fuel (TSL). The fuels were stored in steel barrels in different environment conditions. Testing was performed every 3 months. The extent of testing covered specification parameters and the ones that could show some chemical processes taking place in stored fuels. The following graphs show changes of selected parameters possibly connected with fuel behaviour during use.

The fig. 1 shows the course of existent gums content increase in aviation fuel. We can see the increasing tendency, more intense in case of fuels stored in confined space, at higher temperatures.

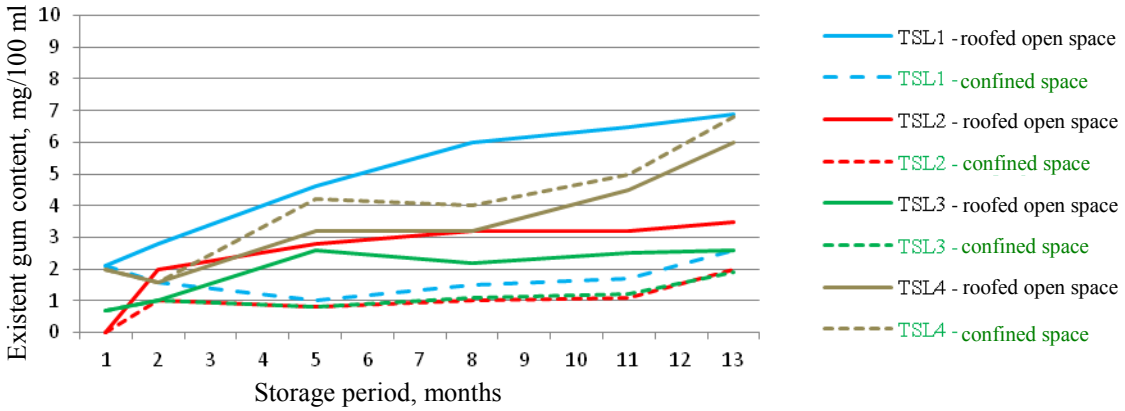


*Fig. 1. Existent gums content in aviation fuel increase during storage*

The second reason for deposits formation, connected with previous one, is lowering the thermal stability. The basis is different a little bit but the result is similar. The thermal stability describes hydrocarbons in respect of their resistance to chemical decomposition under severe thermal conditions. Due to high temperature (sometimes together with elevated pressure), the thermal degradation of hydrocarbons structure of minimum resistance takes place. As a result of the reactions the deposits and high-molecular compounds creation takes place. They don't burn in the engine, and like gum compounds, deposit on different engine parts. The fig. 2 shows the example of the course of aviation turbine fuel thermal stability change during storage.

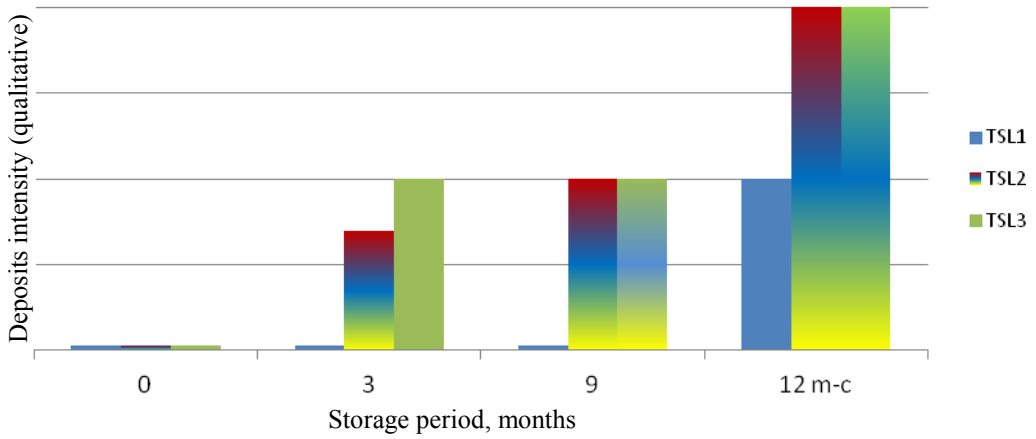


*Fig. 2. Tube rating change during JFTOT testing (multicoloured columns mean not natural "peacock" deposits, according to ASTM d 3241 [1]).*

Gums content in fuel and too low fuel thermal stability are harmful with regard to possible contamination of injection system and hot parts of the engine. The gums and thermal degradation products, as a high-molecular, don't undergo spraying, and, as a result, don't burn in engine. However, they enter combustion chamber together with the fuel. Due to high temperature, relatively big hydrocarbon molecules that didn't evaporate, deposit on injectors and hot parts of engine as carbon deposits. Such usually leads to disturbing the fuel-air mixture formation, and as a result, to incomplete combustion, and intensification of carbon depositing process, and irregular heat removal (thermal deformation of combustion chamber and cracks and melting can take place as a consequence). Deposits cause partial or, in extreme cases, full blocking of micro orifices for fuel injection into the combustion chamber. Such leads to unsprayed fuel jets (fig. 3).

Results of incomplete combustion, deposits formation, and adverse thermal phenomena formation as a consequence, are shown in fig. 4 and 5 [2].

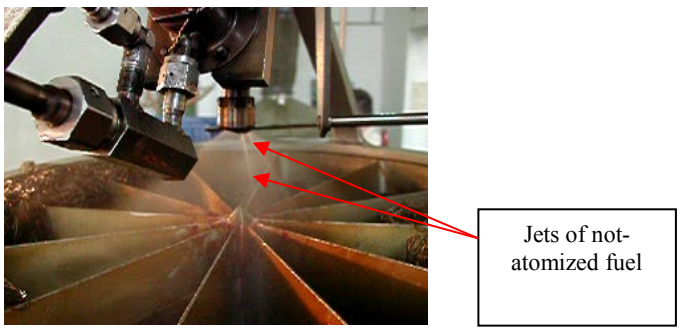


*Fig. 3. Jets of not-atomized fuel during testing the carbon deposited injector*

*Fig. 4. Carbon deposits on injector*

*Fig. 5. Thermal damage of flame tube*

The water content in fuel increases together with storage period extending (fig. 6).

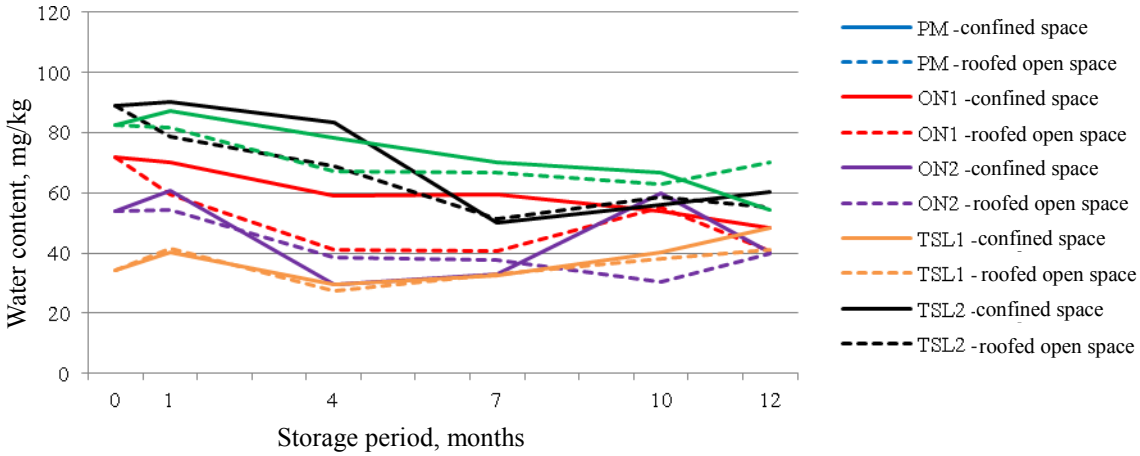


*Fig. 6. Water content in fuels (TSL, PM and ON) vs. storage period*

It's noticed that bigger water content occurs in fuels stored at elevated temperatures (confined spaces). Such is because the water solubility in fuel is proportional to fuel temperature. In case of fuel stored under roofed open space, where the ambient humidity is higher, the water content was lower. One should take into consideration that this is dissolved water, and the water excess condensed as separated (free) water on the tank bottom. Total water content was higher in case of fuels from roofed open-space storage. Water presence (content) effects on fuel use at low temperatures. It can cause ice locks that stop fuel flow to engine. In case of aircrafts without fuel warming systems it's necessary to use the fuel special additives - fuel system icing inhibitors. The other adverse result of water presence is its effect on corrosion of fuel and exhaust systems. The steam, together with exhaust gases, can generate acids that, in turn, can be aggressive to metallic construction materials. But there is also positive aspect of water presence in combustion process. It significantly lowers the combustion temperature and leads to lower the $NO_x$ emission.

Properties regarding safe use of the fuel are also the subject of changes. It's clear especially in case of conductivity decrease with time, which is the most intense at the beginning, and then stabilise (fig. 7). Conductivity decrease during use means worse circumstances for discharging from the volume of fuel being stored. Such could lead the single-signed charges to cumulate, resulting in significant differential potentials in products being stored (even up to over ten thousand volts). It can be dangerous because of possible explosion.

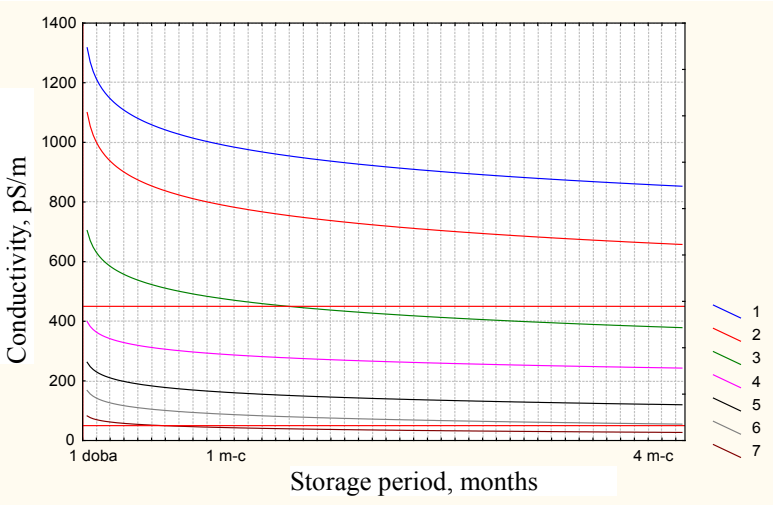


*Fig. 7. Conducivity change in different samples of aviation turbine fuels (TSL) during storage* [3]

The changes mostly are not individual, isolated from other phenomena. They are the most often connected with each other in cause-result way, and are the most frequent reason of process intensification. Such situation take place in case of microbial contamination of fuels. Fuel under storage often has contact with water. Such circumstances promote microbial growth, i.e. fungi, mould, and bacteria (fig. 8). The microorganisms presence has two meanings. First - they cause acceleration of some ageing phenomena (e.g. it's observed that thermal and chemical stability decrease together with contamination growth). Contamination decomposition products have mostly acidic reaction, causing additionally so called biological corrosion. Second - dead microorganisms can cause filter clogging and problems with fuel flow.

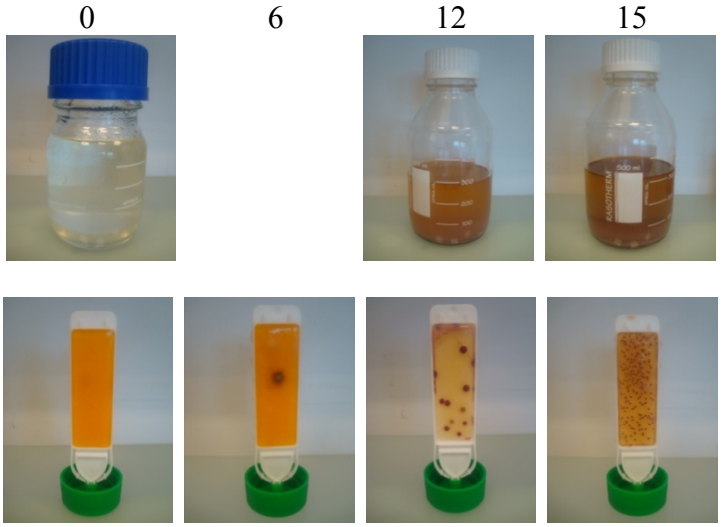


*Fig.8 Aviation turbine fuel (TSL) microbial contamination during storage*

There are visual indications of adverse effects caused by long-term storage. The fig. 9 shows the colour change vs. reference colour scale. Darker fuel - more chemically changed - the lower number. We can see that fuels change the colour - get darker, as a result of majority of ageing processes, i.e. high-molecular compounds creation, oxidation, and microbial contamination.

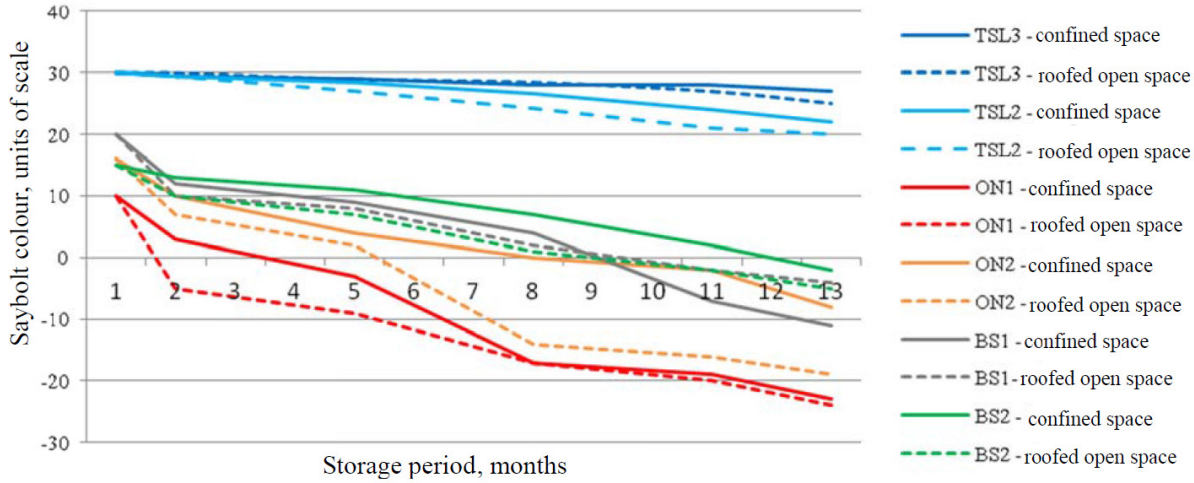


*Fig. 9. Fuels' colour change during storage.*
*TSL - aviation turbine fuel, ON - diesel fuel, BS - gasoline*

In general, the colour of the fuel has no effect on its operation properties, but it is the indication of some problems with fuel. Moreover, it has an effect of our imagination - the user pays an attention on fuel appearance.

## 3. Summary

Above mentioned selected changes of fuels' properties are based on test results. Taking them into consideration we can say that changes in fuel took place. Such changes are often so significant that use of engine or fuel becomes impossible or hard. Often it's impossible to prevent the losses. It's possible, indeed, to follow trends, but it relates to fuel already being stored. More important are parameters that enable prediction of potential storage period just yet at the preliminary stage of the process. Such parameters are not included in specifications at the moment, but it's obvious that its very significant issue. Changes predicting during storage would enable managing the reserves efficiently. Such attitude would eliminate cases of excessive quality deterioration. It would restrict the possible use the fuels with parameters being close to acceptable ones. Thanks this the operation safety would be better.

Storage process is important in relation to quality, and its course depends on many factors. The intensity of changes is different depending on both storage conditions - external circumstances as well as composition and original properties of product itself. Having the knowledge about the effect of such conditions, and ageing process mechanisms it's possible to take technical and technological remedial measures.

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## References

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[2] Dzięgielewski W., Gawron B., Problem stabilności termicznej współczesnych paliw do turbinowych silników lotniczych – badania wstępne, Journal of KONBIN, nr 1(21), str. 121-130, Warszawa 2012.
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