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ASSESSMENT OF THE CORRECTNESS OF TAKING LPG SAMPLES FROM A DISPENSER PURSUANT TO COMPANY STANDARD ZN/MG/CN-18:2007, BASED ON PROFICIENCY TESTING

OCENA POPRAWNOŚCI POBIERANIA PRÓBEK LPG Z ODMIERZACZA ZGODNIE Z NORMĄ ZAKŁADOWĄ ZN/MG/CN-18:2007 NA PODSTAWIE BADAŃ BIEGŁOŚCI

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Summary

The taking of samples is a very important stage in the process of preparing representative material for tests and obtaining reliable test results. The laboratories that strive for high quality of the services they offer should monitor their test results against the background of the results obtained by other reputable laboratories that provide similar services. In the pursuing of this objective, an excellent tool is the proficiency testing, which makes it possible to confirm the competence of

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laboratories to carry out fuel tests and/or to take fuel samples. The Automotive Industry Institute (PIMOT), as a leading body engaged in Poland in examining the quality of the propane-butane gas (LPG) used as a fuel, organized tests of the proficiency at taking LPG samples from a dispenser at a filling station. The tests were carried out for a number of laboratories that provided services within a similar scope. The laboratories participating in this project took fuel samples and sent them to the organizer for the samples to be tested and for the method of taking the LPG samples to be verified. In the article, the importance of taking the samples and of participating in the tests of proficiency at taking samples of liquefied propane-butane gas has been presented, the method of preparing representative material for tests and of verifying the homogeneity and stability of the batch under test has been described, and the approach to the examination of proficiency at taking LPG samples from a dispenser at a filling station has been discussed. The proficiency test results obtained from the participants have been presented, discussed, and analysed.

Keywords: propane-butane, LPG, taking of fuel samples, fuel dispenser, proficiency testing

Streszczenie

Pobieranie próbek jest bardzo istotnym etapem w procesie przygotowania reprezentatywnego materiału do badań i uzyskania miarodajnego wyniku. Laboratoria, które chcą zapewnić wysoką jakość oferowanych przez siebie usług, powinny monitorować uzyskiwane wyniki na tle innych renomowanych laboratoriów świadczących podobne usługi. W tym celu doskonałym narzędziem są badania biegłości umożliwiające potwierdzenie kompetencji laboratoriów do wykonywania badań i/lub pobierania próbek. Przemysłowy Instytut Motoryzacji, jako wiodąca jednostka badająca w Polsce jakość gazu propan – butan stosowanego jako paliwo, zorganizował badania biegłości pobierania LPG z odmierzacza stacji paliw. Uczestnikami były laboratoria świadczące usługi w podobnym zakresie. Uczestnicy pobierali próbki i przesyłali je do organizatora celem wykonania badań i sprawdzenia sposobu pobierania gazu LPG.W artykule opisano znaczenie pobierania próbek oraz uczestnictwa w badaniach biegłości z zakresu pobierania skroplonego gazu propan – butan, omówiono sposób przygotowania reprezentatywnego materiału badawczego, weryfikacji jednorodności i stabilności partii oraz omówiono podejście do badań biegłości z zakresu pobierania LPG z odmierzacza. W artykule przedstawiono wyniki badań biegłości uzyskane od uczestników i dokonano ich omówienia oraz analizy.

Słowa kluczowe: propan-butan, LPG, pobieranie, odmierzacz, badania biegłości

1. Introduction

The proficiency testing is one of the most effective tools that helps individual laboratories in showing their competence. It enables the laboratories to monitor the performance of tests through monitoring the trends having developed and to undertake any necessary corrective and/or preventive steps.

The Proficiency Testing (PT) is aimed at determining, by means of interlaboratory comparisons, laboratory's capability of carrying out tests or calibrations.

The Interlaboratory Comparisons (ILC) mean the organizing, carrying out, and assessment of tests or calibrations of the same or similar objects of testing, or calibrations by at least two laboratories, in compliance with predefined conditions.

For the proficiency testing to be done, an interlaboratory comparison must be first organized and, consequently, the conditions of carrying out the comparison must be predefined.

The benefits that accrue from the PT/ILC may only be gained if the tests are carried out as a normal routine. The advantages obtainable from the participation in the PT/ILC include:

- possibility of controlling the quality of testing, i.e. possibility of utilizing the participation as a feedback for analysing laboratory's own procedure followed during the tests;
- acquisition of information necessary to carry out corrective, preventive, and improving actions;
- validation of the test methods adopted and confirmation of correct performance of the standardized methods;
- collection of data needed to determine the uncertainty;
- the sample part that remained after tests may be used as a reference material, with the assigned value having been documented;
- verification of personnel's proficiency;
- comparison of laboratory's competence with that of other similar laboratories;
- confirmation of the quality of the test results reported to customers;
- reduction of the costs of validation or confirmation of the methods employed at the laboratory;
- the participation in specific PT/ILC programs in the field governed by official regulations may be a prerequisite for laboratory's participation in various research programs.

The proficiency at taking various samples, especially LPG samples, was tested to check the proficiency of individual laboratories at taking samples, to verify the procedure of taking samples of liquefied propane-butane, to evaluate the reproducibility of taking samples, to ensure that the material samples taken by the laboratories in their routine laboratory practice may be considered representative, and to ensure that the method of preparation of the samplers used and the type of the equipment used do not affect the quality of the test results obtained.

2. Taking of samples

The taking of samples is a very important part of the process of preparing representative material for an analysis. The correct procedure of taking an LPG sample has been described in detail in the relevant standards.

If the sample taking procedure is incorrectly carried out, the test result obtained will be disturbed, which will translate into erroneous conclusions and wrong assessment of the quality of the material batch as a whole. In consequence, the sample may be incorrectly assessed as meeting or failing to meet the quality requirements specified in the applicable regulation of the Minister of Economy.

The quality of taking a sample is even more important in the case of LPG, because of the specific medium involved, i.e. liquefied hydrocarbon gases. Such gases, popularly referred

to as LPG (Liquefied Petroleum Gas), are a mixture of hydrocarbons, chiefly propane and butanes, with admixtures of propene, butenes, ethane, pentanes, and pentenes, which may be stored and distributed at the normal ambient temperature in its liquid phase at a moderate pressure of 0.22-0.4 MPa. The LPG is obtained from the processes of degasolining of natural gas, crude oil stabilization on oil fields, crude oil distillation, catalytic cracking and hydrocracking, thermal processing of petroleum fractions, as well as reforming and isomerization of various petrol grades.

The LPG is pumped into cylinders at pressures of the order of 0.6 MPa. The cylinders in which the gas is stored and transported are usually filled to 80 % of their cubic capacity in order to avoid a cylinder burst due to thermal expansion of the liquid at a temperature change. At the decompression (evaporation), the LPG volume rises to a value of about 260 times as high as that of the liquid phase.

Therefore, for the sample to be considered representative, it must always be taken in its liquid phase, which requires that special conditions of taking the sample should be maintained and an appropriate sampler should be used. The containers used as samplers should be made of stainless steel, provided with metallic pipe connectors. The container size should be so selected that the sample size should be sufficient for the prescribed laboratory tests to be carried out. The container (sampler) should be provided with two valves and an overflow pipe (see Fig. 1 in Polish Standard PN-EN ISO 4257). The overflow pipe should make it possible to fill the sampler to 80 % of its cubic capacity. Before start of the sampling, a container for the sample and a conveying line to transport the LPG sample from the dispenser to the container should be appropriately prepared. With this objective in view, the container and the conveying line should be cleaned with low-boiling solvents (first acetone and then pentane). Afterwards, the conveying line and the container should be dried with inert gas (nitrogen); at the end of this process, the container should be filled with this gas. For an LPG sample to be taken correctly, this procedure should be completed within 30 min. from the last refuelling. The fuel agitation, which takes place during the refuelling process, may have an impact on the homogeneity of the material batch. Therefore, it is important that the sample representativeness should be prevented from any disturbance. When taking an LPG sample, at first the conveying line part between the source and the lower valve of the sampler should be connected and cleaned. The container should be filled with the sample by slow opening of the upper valve. After the upper valve is closed, the sampler should be turned and the sample should be released by opening the release valve. The cleaning process should be repeated trice. After this sampler flushing is completed, the sampler filling stage is started. When the sampler is filled to about 85 % of its capacity, excess liquid should be released until the gaseous phase appears at the upper valve (then the sampler is filled to about 80 % of its capacity) and the upper valve should be closed. The sample should be rejected if any leakage occurs or any of the two sampler valves gets open when the sampler is handled.

After all the operations related to the sampler filling procedure are completed, the leak tightness of the sampler should be checked with the use of an appropriate leak tester.

The successive stages of taking an LPG sample from a dispenser have been described in detail in Company Standard ZN/MG/CN-18, which has been based on authors' experience

and Polish Standard PN-EN ISO 4257, applicable to the taking of LPG samples from stationary tanks.

The Company Standard ZN/MG/CN-18 has been quoted in the Regulation of the Minister of Economy of 31 January 2007 on the method of taking liquefied petroleum gas (LPG) samples (Dz. U. No 44 of 2007, item 279) as a document that defines the method of taking LPG samples from a dispenser. Therefore, through having been quoted in the legal instrument mentioned above, it has become a standard for obligatory use.

3. Synchronization of the braking of vehicle combinations without EBS

The representativeness of a fuel sample taken for tests depends to a considerable degree on the homogeneity of the whole mixture contained in the tank. Therefore, it has been stated on the grounds of experiments and many years of experience that for the sample to be taken correctly, it should be taken no later than within half an hour after the last refuelling. This makes it possible to avoid the taking of the gaseous phase, which may be formed in large quantities in the connections and instrumentation at the filling station. Below is shown a table with example analysis results obtained "with recirculation" and "without recirculation" of the LPG mixture.

Table 1. Hydrocarbon composition of LPG samples taken before and after recirculation from the same material batch contained in a tank truck

Item	Compound	Analysis results			
		"Without recirculation"		"With recirculation"	
		[mass %]	[mole %]	[mass %]	[mole %]
1.	Methane	< 0.1	< 0.1	< 0.1	< 0.1
2.	Ethane	1.9	3.1	1.7	2.8
3.	Propane	48.5	54.3	47.4	53.3
4.	Propene	1.7	2.0	1.6	1.9
5.	n-Butane	38.8	32.9	40.0	34.2
6.	trans-2-Butene	0.2	0.2	0.2	0.2
7.	cis-2-Butene	0.1	0.1	0.2	0.1
8.	Isobutane	7.6	6.4	7.7	6.6
9.	1-butene	0.3	0.3	0.3	0.3
10.	Isobutene	0.2	0.1	0.2	0.1
11.	1,3-butadiene	< 0.1	< 0.1	< 0.1	< 0.1
12.	n-Pentane	0.1	0.1	0.1	0.1
13.	Isopentane	0.5	0.4	0.6	0.4

4. Preparations for the statistical analysis of the results of taking fuel samples for proficiency testing

The proficiency testing by interlaboratory comparisons (PT/ILC) was organized within the PETROL GAZ Section of the POLLAB Club (KPLB = Polish Club of Measurement, Testing and Analytical Laboratories), pursuant to the assumptions of the KPLB Procedure No 1, issue 6, of 6 Dec. 2013 and based on the guidelines laid down in standards PN-EN ISO/IEC 17043:2011 and ISO 13528:2005. The proficiency tests were carried out within external inspection of the quality of taking LPG samples from a dispenser pursuant to Company Standard ZN/MG/CN-18:2007.

The material for tests was liquefied petroleum gas (LPG) with its hydrocarbon composition specially selected to make the taking of a representative sample particularly difficult. The gas contained hydrocarbons with the lowest density and the highest vapour pressure, i.e. methane and ethane, which might have an impact on the taking of representative samples. The samples for proficiency testing were taken from a dispenser at a selected filling station, by 10 different participants in the tests.

All the participants took single samples by themselves; then, all the samples were submitted to the Analytical Laboratory at PIMOT. For the competence of individual laboratories to take LPG samples from a dispenser to be confirmed, the hydrocarbon composition was determined in compliance with PN-ISO 7941:1993 and PN-ISO 7941:1993/Ap. 1:2002 and the total sulphur content was determined according to ASTM D 6667-14, for the samples taken by all the participants in the tests.

Based on these parameters, the results of taking LPG samples from a dispenser were assessed in accordance with Company Standard ZN/MG/CN-18:2007.

5. Homogeneity and stability of the material used for the tests

The responsibilities of the coordinator of proficiency testing include the providing of homogeneous material for tests, durable for the period of storage and stable from the time of preparation of the samples for tests until the completion of the proficiency testing. To testify that the above properties of the material are maintained, the organizer of the tests should confirm the homogeneity and stability of the material to be used for the proficiency tests. This is of great importance because thanks to this, the material provided for the participants will actually be comparable and the results obtained by the laboratories will reflect the actual competence of the laboratories to carry out tests or to take samples, without being disturbed by inadequate homogeneity or durability of the material. Thus, honest assessment of the proficiency of participants at the carrying out of individual tests or at the taking of samples will be made possible.

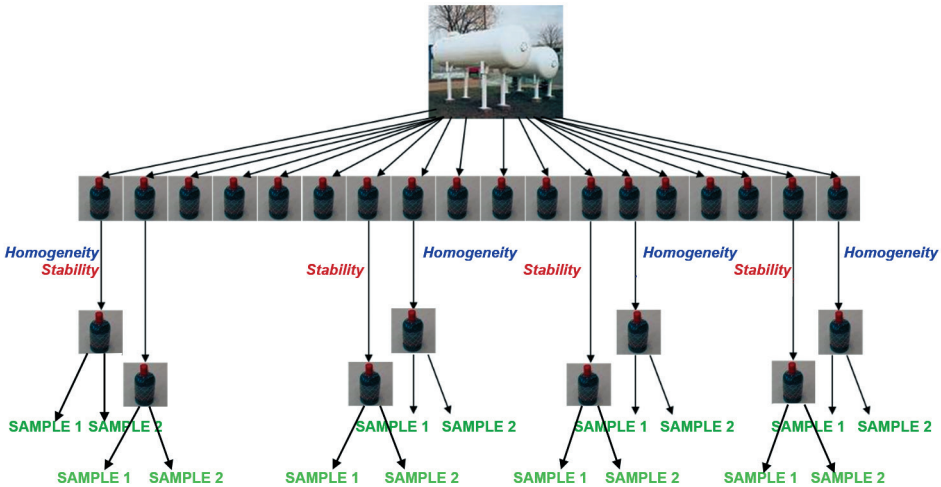

Fig. 1. Schematic diagram of the procedure of verifying the homogeneity and stability of the material for tests

The homogeneity of the material for tests was verified on four samples selected from the material batch prepared for proficiency testing. Each of these samples was subjected twice to determining the hydrocarbon composition according to PN-ISO 7941:1993 and PN-ISO 7941:1993/Ap. 1:2002 and the total sulphur content according to ASTM D 6667:2014.

The stability of the material for tests was verified after 10 weeks from the sample taking date. On each of the test samples, two analyses were carried out in parallel to determine the selected parameters, in the following order: hydrocarbon composition according to PN-ISO 7941:1993 and PN-ISO 7941:1993/Ap. 1:2002 and total sulphur content according to ASTM D 6667:2014.

The hydrocarbon composition and sulphur contents are the basic and most individual quantitative LPG characteristics that reflect the quality of this fuel. Due to LPG propensity for stratification, the hydrocarbon composition and sulphur contents may undergo changes both throughout the volume of the material batch and during the storage time. Therefore, it is fully reasonable to use these parameters as tools for the assessment of homogeneity and stability of the material for tests. Moreover, such LPG characteristics as calorific value, density, and vapour pressure are calculated parameters, which are directly determined by, and closely connected with, the gas composition. Hence, they did not have to be used for the assessment of homogeneity and stability of the gas.

The samples were considered satisfactorily homogenous if the following criterion was met:

$$Ss \leq 0.3\hat{\sigma} \tag{1}$$

where: Ss – inter-sample standard deviation;
$\hat{\sigma}$ – standard deviation used for proficiency testing.

The samples were considered satisfactorily stable if the following criterion was met:

$$|\bar{X} - \bar{Y}| \leq 0{,}3\hat{\sigma} \tag{2}$$

where: $\bar{X}$ – overall mean value obtained at homogeneity verification;

$\bar{Y}$ – overall mean value obtained at stability verification;

$\hat{\sigma}$ – standard deviation used for proficiency testing.

6. Homogeneity and stability assessment

Table 2 shows the results confirming that the LPG material used for proficiency testing meets the requirement $Ss \leq 0.3\hat{\sigma}$, which means that the material is satisfactorily homogenous.

Table 2. Hydrocarbon composition and total sulphur content of the LPG used to verify the homogeneity of the material for tests

Parameter	Method	Unit	$\bar{X}$	Ss	$0.3\hat{\sigma}$	Criterion $Ss \leq 0.3\hat{\sigma}$
Hydrocarbon composition of the LPG	PN-ISO 7941:1993 PN-ISO 7941:1993/ Ap. 1:2002	mass %				
Methane			0.28	0.02	0.05	OK
Ethane			0.36	0.03	0.05	OK
Propane			67.54	0.10	0.11	OK
Isobutane			11.41	0.04	0.11	OK
n-Butane			19.92	0.09	0.11	OK
Isobutene*			–	–	–	–
Isopentane*			–	–	–	–
Total sulphur content (with the odorant admixture)	ASTM D 6667:2014	mg/kg	28.2	0.12	0.13	OK

* The content of the specific compound was identical in each sample and it was not taken into account in the statistical interpretation.

Table 3 shows the results confirming that the LPG material used for proficiency testing meets the requirement $|\bar{X} - \bar{Y}| \leq 0{,}3\hat{\sigma}$, which means that the material is satisfactorily stable in time.

Table 3. Hydrocarbon composition and total sulphur content of the LPG used to verify the stability of the material for tests

Parameter	Method	Unit	$\bar{X}$	$\bar{Y}$	$\lvert\bar{X}-\bar{Y}\rvert$	$0.3\hat{\sigma}$	Criterion $\lvert\bar{X}-\bar{Y}\rvert \leq 0.3\hat{\sigma}$
Hydrocarbon composition of the LPG	PN-ISO 7941:1993 PN-ISO 7941:1993/ Ap. 1:2002	mass %					
Methane			0.28	0.29	0.01	0.05	OK
Ethane			0.36	0.41	0.05	0.05	OK
Propane			67.54	67.59	0.05	0.11	OK
Isobutane			11.41	11.37	0.04	0.11	OK
n-Butane			19.92	19.87	0.05	0.11	OK
Isobutene*			–	–	–	–	–
Isopentane*			–	–	–	–	–
Total sulphur content (with the odorant admixture)	ASTM D 6667:2014	mg/kg	28.2	28.1	0.10	0.13	OK

* The content of the specific compound was identical in each sample and it was not taken into account in the statistical interpretation.

7. Statistical assessment of the obtained results of taking LPG samples

The assigned value, uncertainty of the assigned value and standard deviation were determined, and the test results obtained by the participants were assessed, in accordance with the requirements laid down in standards PN-EN ISO/IEC 17043:2011 and ISO 13528:2005. The assigned value X^* was determined as the mean value of results obtained by the participants, with taking into account the technique minimizing the influence of outliers by using the robust statistical method of Algorithm A according to ISO 13528:2005. The uncertainty of the assigned value u_x was calculated according to ISO 13528:2005, so that this parameter could be taken into account, if necessary, in the assessment of results obtained by the participants.

The test results were assessed with using the standard deviation S^* of results submitted by participants or standard deviation SR of reproducibility, which characterizes the precision of the standardized methods.

The test results obtained by the laboratories were subjected to assessment with the use of criteria based on the z-score or z'-score indicators.

- z-score:

$$z = \frac{x - X^*}{\hat{\sigma}} \tag{3}$$

- or z′-score:

$$z' = \frac{x - X^*}{\sqrt{\hat{\sigma}^2 + u_x^2}} \tag{4}$$

where: x – result obtained by an individual participant;
X^* – assigned value;
$\hat{\sigma}$ – standard deviation used for proficiency testing;
u_x – standard uncertainty of the assigned value.

The estimated uncertainty u_x of the assigned value X^* was compared with the standard deviation $\hat{\sigma}$ used for proficiency testing. If the criterion $u_x \leq 0.3\hat{\sigma}$ was not met, the participants' performance was evaluated with taking into account the uncertainty of determining the assigned value and the z′-score indicator was calculated instead of the z-score. The evaluation criteria were adopted as follows:

- $|z| \leq 2$ – acceptable;
- $2 < |z| < 3$ – warning;
- $|z| \geq 3$ – unacceptable.

Estimation of the assigned value and standard deviation

To determine the assigned value X^* and the standard deviation S^* of the results obtained by the laboratories participating in the proficiency testing scheme, Algorithm A according to ISO 13528:2005 was used.

Algorithm A

1) The results obtained by the participants were arranged in the ascending order of values $x_i \ldots x_p$.

2) Initial values of X^* (robust mean value) and S^* (robust standard deviation) were calculated:
$X^* = \mathrm{I}$ median $x_i \mathrm{I}$ (i = 1, 2, ..., p)
$S^* = 1.483 \times$ median $\mathrm{I}x_i - X^* \mathrm{I}$ (i = 1, 2, ..., p)

3) Now, coefficient φ was calculated:

$\varphi = 1.5 \times S^*$

4) For every value of x_i (i = 1, 2, ..., p), the X_i^* value was calculated as follows:

$$X_i^* = \begin{cases} X^* - \varphi, \text{ if } x_i < X^* - \varphi \\ X^* + \varphi, \text{ if } x_i < X^* + \varphi \\ x_j \text{ in all the other cases} \end{cases}$$

5) New X^* and S^* values were calculated.

6) The calculations as described above were repeated iteratively until convergence of results was achieved.

Estimation of the uncertainty of the assigned value

The standard uncertainty u_x of the assigned value X^* was calculated with using the robust statistical method pursuant to ISO 13528:2005, Algorithm A, according to formula:

$$u_x = \frac{1.25 \times S^*}{\sqrt{p}} \tag{5}$$

where: S^* – robust standard deviation of results, calculated according to Algorithm A;
p – number of participants.

8. Results of proficiency testing

Results of the proficiency testing (individual hydrocarbon contents and total sulphur content) have been given in the table below; the z-score or z'-score values obtained have been presented in relevant graphs.

Table 4. Hydrocarbon composition and total sulphur content of the samples taken by individual participants in the proficiency testing, determined at the PIMOT laboratory

Laboratory code	Hydrocarbon composition of LPG samples (mass %) according to PN-ISO 7941:1993 and PN-ISO 7941:1993/Ap. 1:2002					Total sulphur content (with the odorant admixture) [mg/kg] according to ASTM D 6667:2014
	Methane	*Ethane*	*Propane*	*i-Butane*	*n-Butane*	
1	0.20	0.38	67.26	11.51	20.18	27.8
2	0.30	0.41	67.68	11.34	19.80	28.1
3	0.29	0.40	67.64	11.35	19.86	29.5
4	0.25	0.39	67.45	11.43	20.02	28.5
5	0.19	0.37	67.16	11.54	20.26	28.8
6	0.30	0.41	67.71	11.34	19.78	28.4
7	0.30	0.41	67.70	11.33	19.80	29.3
8	0.27	0.43	67.31	11.48	20.06	28.3
9	0.28	0.40	67.53	11.38	19.94	27.5
10	0.26	0.40	67.59	11.60	19.68	28.5
Assigned value X*	0.27	0.40	67.52	11.40	19.93	28.4
Standard deviation S*	0.04	0.02	0.20	0.11	0.19	0.57

Apart from the above, the isobutene and isopentane contents in the LPG samples taken were also determined. In consideration of low values of these contents, however, these LPG components were not taken into account in the statistical interpretation.

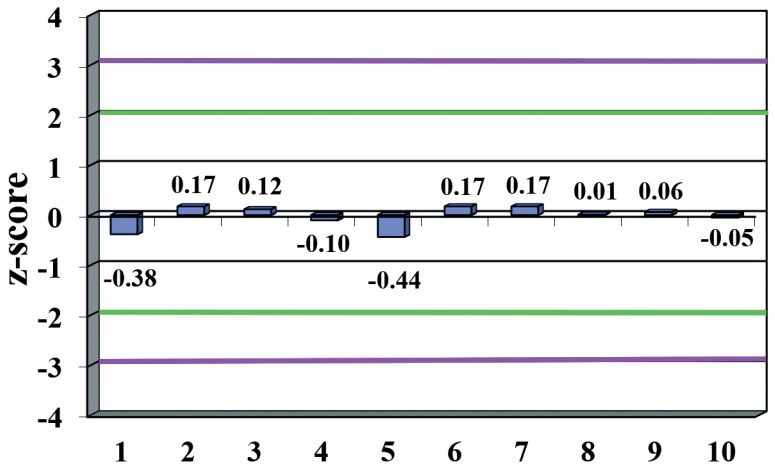

Fig. 2. Values of the z-score indicator for the methane contents in the LPG samples taken by individual participants

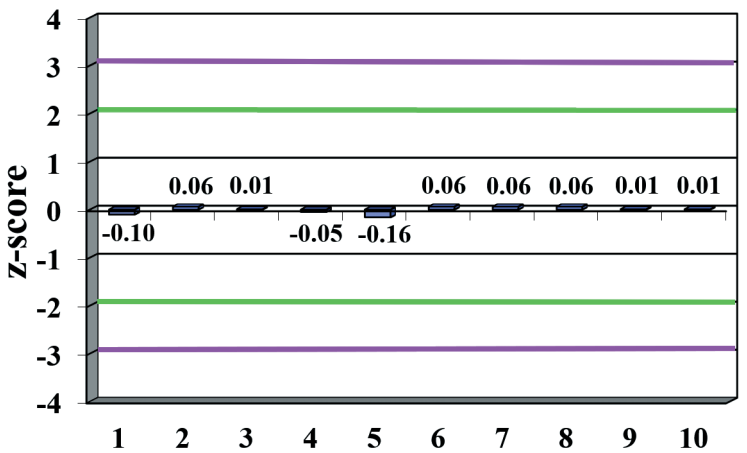

Fig. 3. Values of the z-score indicator for the ethane contents in the LPG samples taken by individual participants

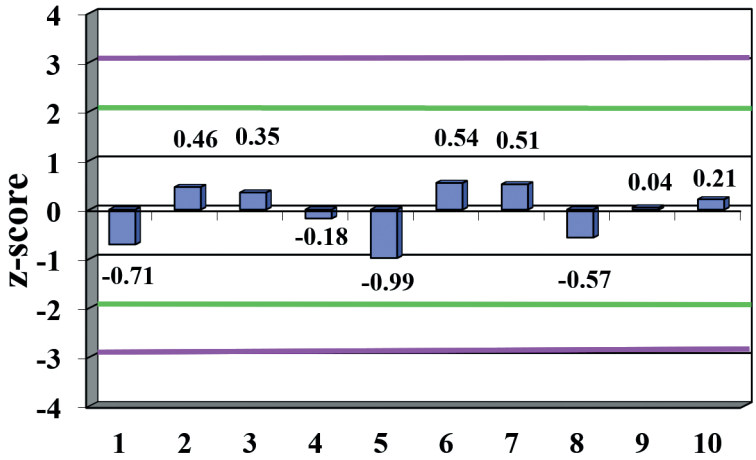

Fig. 4. Values of the z-score indicator for the propane contents in the LPG samples taken by individual participants

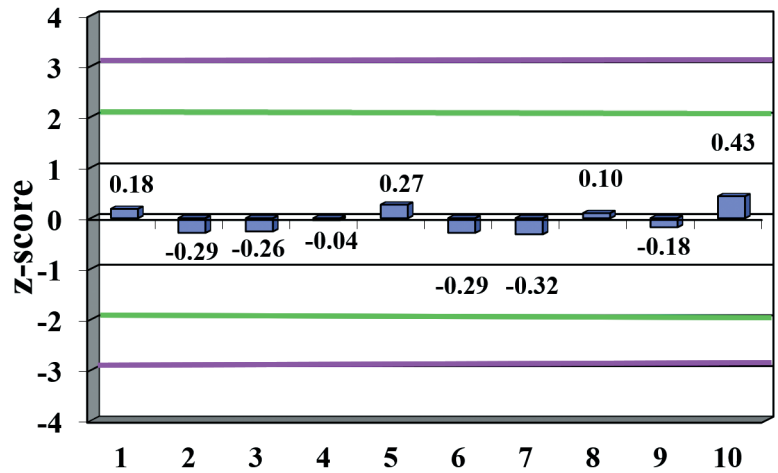

Fig. 5. Values of the z-score indicator for the isobutane contents in the LPG samples taken by individual participants

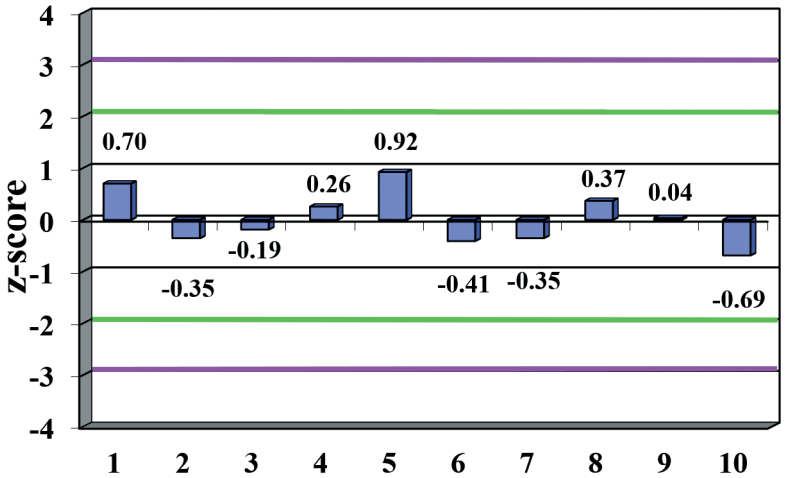

Fig. 6. Values of the z-score indicator for the n-butane contents in the LPG samples taken by individual participants

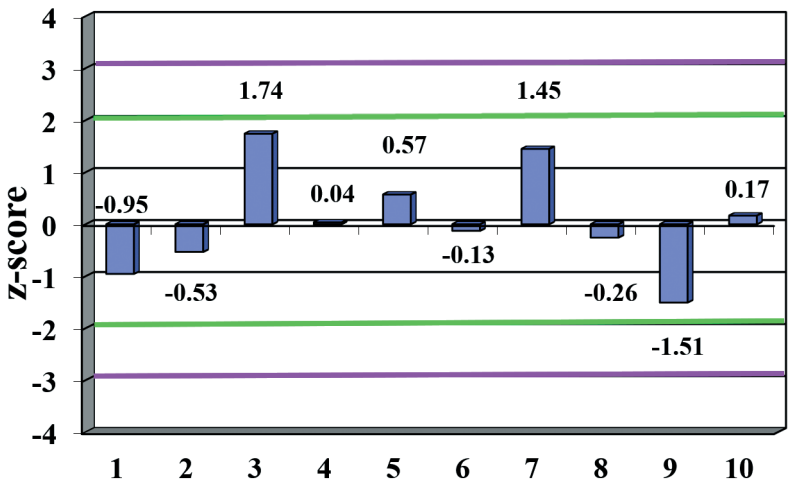

Fig. 7. Values of the z′-score indicator for the sulphur contents in the LPG samples taken by individual participants

Based on the z-score and z′-score values calculated for determining the hydrocarbon composition of LPG samples according to PN-ISO 7941:1993 and PN-ISO 7941:1993/Ap. 1:2002 and the total sulphur content according to ASTM D 6667:2014, all the participants in the tests of the proficiency at taking LPG samples from a dispenser at a filling station pursuant to Company Standard ZN/MG/CN-18:2007 obtained satisfactory results. None of the laboratories participating in the proficiency testing obtained z-score or z′-score the absolute values of which would exceed the level of 2.

9. Recapitulation and conclusions

The analysis of taking LPG samples from a dispenser at a filling station by individual participants in the proficiency testing provided grounds for a statement that the quality of taking LPG samples from a dispenser was satisfactory and that the method of taking the samples by individual participants was unobjectionable. The importance of the sample taking operation, including the equipment used, the equipment preparation method, as well as the sample taking and transportation procedure should be borne in mind so that the sample is kept representative for the whole material batch. Based on the test results, the provisions of the standard were assessed as properly formulated, as the participants in the tests interpreted them correctly and identically. Moreover, the method of taking LPG samples as specified in the standard was found to be suitable for quality testing of this fuel, as coherent test results were obtained in spite of the LPG samples having been taken by different laboratories. Thanks to the proficiency testing organized by PIMOT, the participants could acquire valuable knowledge of their competence and they had an opportunity to take corrective and preventive measures or implement improving procedures, if necessary. This confirms the necessity of organizing further comparative tests in the field of taking samples of petroleum products.

The proficiency tests described herein will be used to develop Company Standard ZN/MG/CN-18:2007 into a Polish National Standard. The outcomes of these tests have confirmed the procedure of taking LPG samples to be correct and to result in the obtaining of representative samples and comparable test results. This will be a basis for the preparation of standard specifications having the status of a Polish National Standard.

The full text of the article is available in Polish online on the website http://archiwummotoryzacji.pl.

Tekst artykułu w polskiej wersji językowej dostępny jest na stronie http://archiwummotoryzacji.pl.

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