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NEW CAPABILITIES OF STANDARD OF VOLUMETRIC WATER CONTENT OF OIL AND OIL PRODUCTS

НОВЫЕ ВОЗМОЖНОСТИ ЭТАЛОНА ОБЪЁМНОГО ВЛАГОСОДЕРЖАНИЯ НЕФТИ И НЕФТЕПРОДУКТОВ

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Abstract. The last decade has shown major changes in the field of oil production and processing: the necessity of commercial accounting of produced oil with high water content (water content over 90%); the development of on-stream moisture meters with new operating principles, moisture meters with measurement range of volumetric water content from 0 to 100% including meters of foreign manufacture; the measurement accuracy increase of on-stream moisture meters.

The work features an overview of the existing methods and instruments for the measurement of volumetric water content of oil and oil products. It is shown that working measuring instruments operate in the volumetric water content range of 0 ÷ 100%, while the State verification schedule and State special

standard GET 87-75 provide transfer of the unit up to 60% of the operating range only. Due to this, the necessity has arisen for the improvement of State primary special standard of unit of volumetric water content of oil and oil products.

As a result of the performed works, a new process system has been developed, consisting of a hydraulic circuit, measuring instruments for parameter determination of original components of oil-water mixtures, a facility for deep drying of oil, devices and auxiliary equipment providing refinement of the created mixture and maintenance of internal environment in the standard room. Reproduction of the unit of volumetric water content by the standard is based on the method of creating a water-oil mixture with set water content by means of precise proportioning of components and creation of an equal-part mixture on their basis. The proportioning is performed in mass fractions; the transition from mass to volume fractions is performed on the basis of predetermined parameters of original components of the mixture (density, original water content, salt content).

As a result of the conducted research, metrological characteristics of the new standard have significantly improved; the possible sources of additional error have been identified and minimized.

The new standard GET 87-2011 approved by Rosstandart order No. 252 features improved metrological characteristics and provides reproduction of the unit of volumetric water content within the range of (0,01 ÷ 99,9%).

Аннотация. В последнее десятилетие произошли масштабные изменения в области добычи и переработки нефти: появилась необходимость коммерческого учета добываемой нефти с высокой степенью обводненности (содержание воды порой превышает 90%), появились поточные влагомеры с новыми принципами работы, влагомеры с диапазоном измерений объёмного влагосодержания 0 – 100%, в том числе, иностранного производства, точность измерений поточных влагомеров повысилась.

В работе проведен обзор существующих методов и средств измерений объёмного влагосодержания нефти и нефтепродуктов. Показано, что рабочие средства измерения работают в диапазоне объёмного влагосодержания 0 ÷ 100%, в то время как Государственная поверочная схема и Государственный специальный эталон ГЭТ 87-75 обеспечивают передачу единицы только до 60% рабочего диапазона. В связи с этим назрела необходимость совершенствования Государственного первичного специального эталона единицы объёмного влагосодержания нефти и нефтепродуктов.

В результате проведенных работ создан новый технологический комплекс, состоящий из гидравлического контура, средств измерений для определения параметров исходных компонентов смесей нефть-вода, устройства для глубокой осушки нефти, устройств и вспомогательных средств, обеспечивающих термостатирование создаваемой смеси и поддержания микроклимата в помещении эталона. Воспроизведение эталоном единицы объёмного влагосодержания основано на методе создания водонефтяной смеси с заданным влагосодержанием путем точного дозирования компонентов и создания на их основе равномерной смеси. Дозирование осуществляется в массовых долях, переход от массовых долей воды к объёмным осуществляется на основании предварительно определенных параметров исходных компонентов смеси (плотности, начального влагосодержания, солесодержания).

При проведении исследований были существенно улучшены метрологические характеристики нового эталона, а также были выявления и минимизированы возможные источники дополнительной погрешности.

Новый эталон ГЭТ 87-2011, утвержденный приказом Росстандарта № 252, обладает улучшенными метрологическими характеристиками и позволяет воспроизводить единицу объёмного влагосодержания смеси нефть-вода в диапазоне (0,01 ÷ 99,9%).

Key words: oil, major, water content, measurement, standard, metrological characteristics.

Ключевые слова: нефть, учет, влагосодержание, измерение, эталон, метрологические характеристики.

State control over natural resources is currently increasing primarily in relation to the production of crude hydrocarbons [1].There is a legal framework and Federal Laws of the Russian Federation «Concerning Subsurface Resources», «Concerning Energy Conservation», «Concerning the Ensuring of the Uniformity of Measurements» imposing obligations on legal bodies to perform accounting of produced energy resources for taxation purposes as well as for the preparation of the national register of hydrocarbon reserves.

Until recently, accurate accounting of hydrocarbons in our country had been ensured only on lease automatic custody transfer meters of commercial and, as a rule, processed oil during its transfer to Transneft major pipeline transport system and the consumers. However, in the majority of world countries the accounting of producible hydrocarbons is performed mostly at oil wells. In 2006 a document came into force determining the measurement of the quantity of crude oil and oil gas at separate wells and licence areas at the territory of the Russian Federation - GOST R 8.615 – 2005 «State system for ensuring the uniformity of measurements. The measuring of quantity of taken from bowels oil and oil gas. General metrological and technical requirements». Accuracy requirements for the quantity measurement of crude oil and associated gas recovered from wells were stated in this document for the first time in domestic practice [2].

The majority of Russian oil and gas fields are equipped with measuring devices – automated group metering stations type «Sputnik» developed over 30 years ago. The measuring and metering system in such stations far from perfect and has large errors [3]. Besides, there are a number of discrepancies between

the subsurface users and the State along the entire technological chain "oil well - main pipeline". The most important discrepancies are:

- discrepancy concerning the application of measurement methods, methods of determination of the quantity of produced crude hydrocarbons and methods of its accounting;
- non-availability of criteria for the selection of measuring devices, measurement methods and measurement information at production facilities and stages of crude hydrocarbons production flow;
- imperfection of the system for determination and accounting of actual losses at production facilities.

In view of the above the problems of hydrocarbons accounting are urgent not only for oil and gas companies, but also for the State accounting policy in general.

The requirements of GOSTR8.615 stimulate oil companies to use certified measurement units as early as at oil wells. Oil well production is a multicomponent mixture composed of oil, gas and water with water cut level capable of reaching 90% of the volume, especially at aging fields. Therefore, for the accounting of crude hydrocarbons water content shall be determined at all stages of the technological cycle of oil production and processing.

Measurements of volumetric water content in oil and oil products can be graded in accordance with the following principle:

- periodic (laboratory) measurements;
- continuous measurements during the performance of operating procedures at production facilities.

Periodic (laboratory) measurements include:

- measurements in accordance with GOST 2477-65 “Oil and petroleum products. Method for determining water content”;
- measurements using a titrator in accordance with the Karl Fischer method;
- measurements using a laboratory moisture meter.

General characteristics of laboratory methods are specified in Table 1.

Table1. General characteristics of laboratory methods

Method	Error characteristics
Measurements in accordance with GOST 2477-65	reproducibility up to 5% of measurement result
Measurements in accordance with the Karl Fischer method	Measurement range from 0 to 5% of water volumetric fraction, relative error 3%
Measurements performed using a laboratory moisture meter	Measurement range from 0.03 to 2%, absolute error ±0.03 of volumetric fraction of water

Continuous measurement is important for operating procedures in oil production and gathering; therefore, such measurements are often performed using in-flow moisture meters. Currently, there are moisture meters with volumetric water content measurement range 0 ÷ 100% based on the new operating principles [4 - 6]. The list and characteristics of the most common in-flow moisture meters in the Russian Federation are given in Table 2.

Table 2. Metrological characteristics of in-flow moisture meters

Moisture meter model	Measurement range, % of volume fraction of water	Absolute error, % of volumetric fraction of water
VSN-2-XX (ВСН-2-XX)	0÷60	In subrange (0÷20) ± 0,2
		In subrange(20÷60) ± 1
	0÷100	In subrange(0÷70) ± 1
		In subrange(70÷100) ± 1,5
UDVN-1pm (УДВН-1пм)	0.01÷2	± 0,05
	0.01÷6	± 0,08
	0.01÷10	± 0,1
	0.1÷20	± (0,10+0,01*W)
	0,1÷30	± (0,10+0,015*W)
PVN-615 (ПВН-615)	0,01÷50,0	± 0,7
	50,0÷70,0	± 0,9
	70,0÷99,9	± 1,4
Phase Dynamics, model L	0÷2	± 0,05
	2÷4	± 0,1
	4÷10	± 0,15
	10÷20	± 0,2
Phase Dynamics, model F	0÷10	± 0,15
	10÷20	± 0,2
	20÷70	± 1,0
	70÷100	± 1,5

As we can see, modern in-flow moisture meters have an extended range and improved metrological characteristics. For application at oil production facilities in-flow moisture meters shall undergo mandatory testing [7].

Until recently, measuring instruments had been certified and actively operated in organizations, while the State verification schedule and State special standard GET 87-75 (fig. 1) had provided transfer of the unit only up to 60% of their operating range.

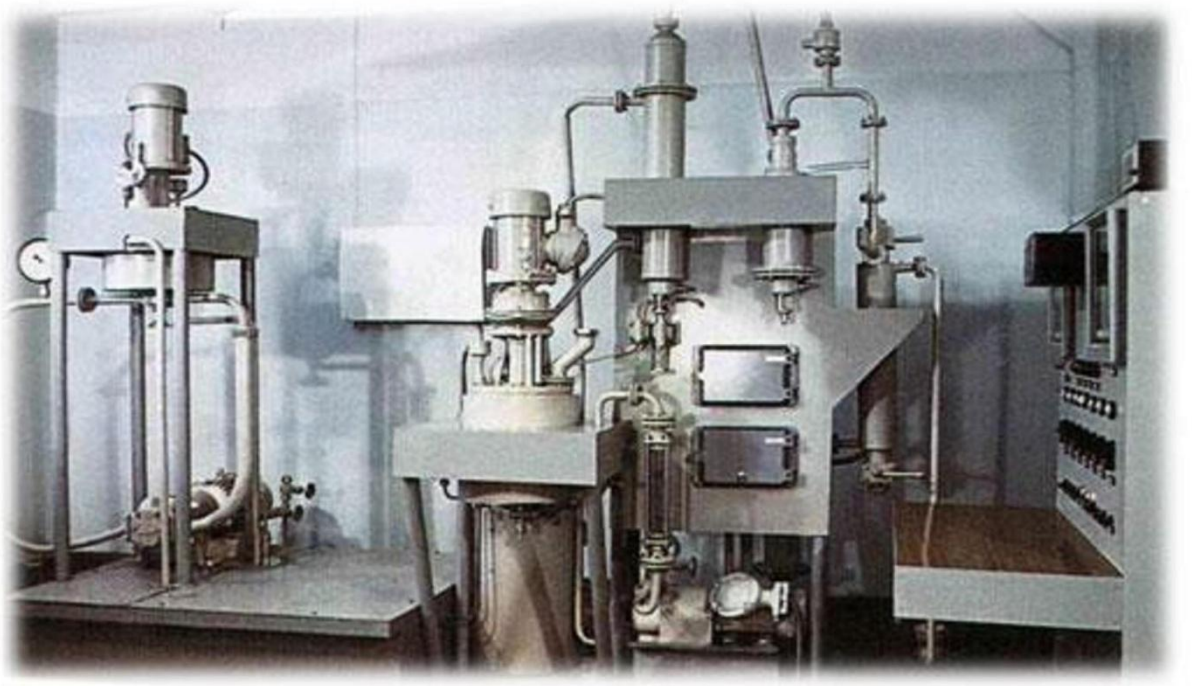


Figure 1. State special standard of volumetric water content unit of oil and oil products GET 87-75

Failure to ensure the uniformity of measurements was a major premise for the development of a new special standard of volumetric water content of oil and oil products.

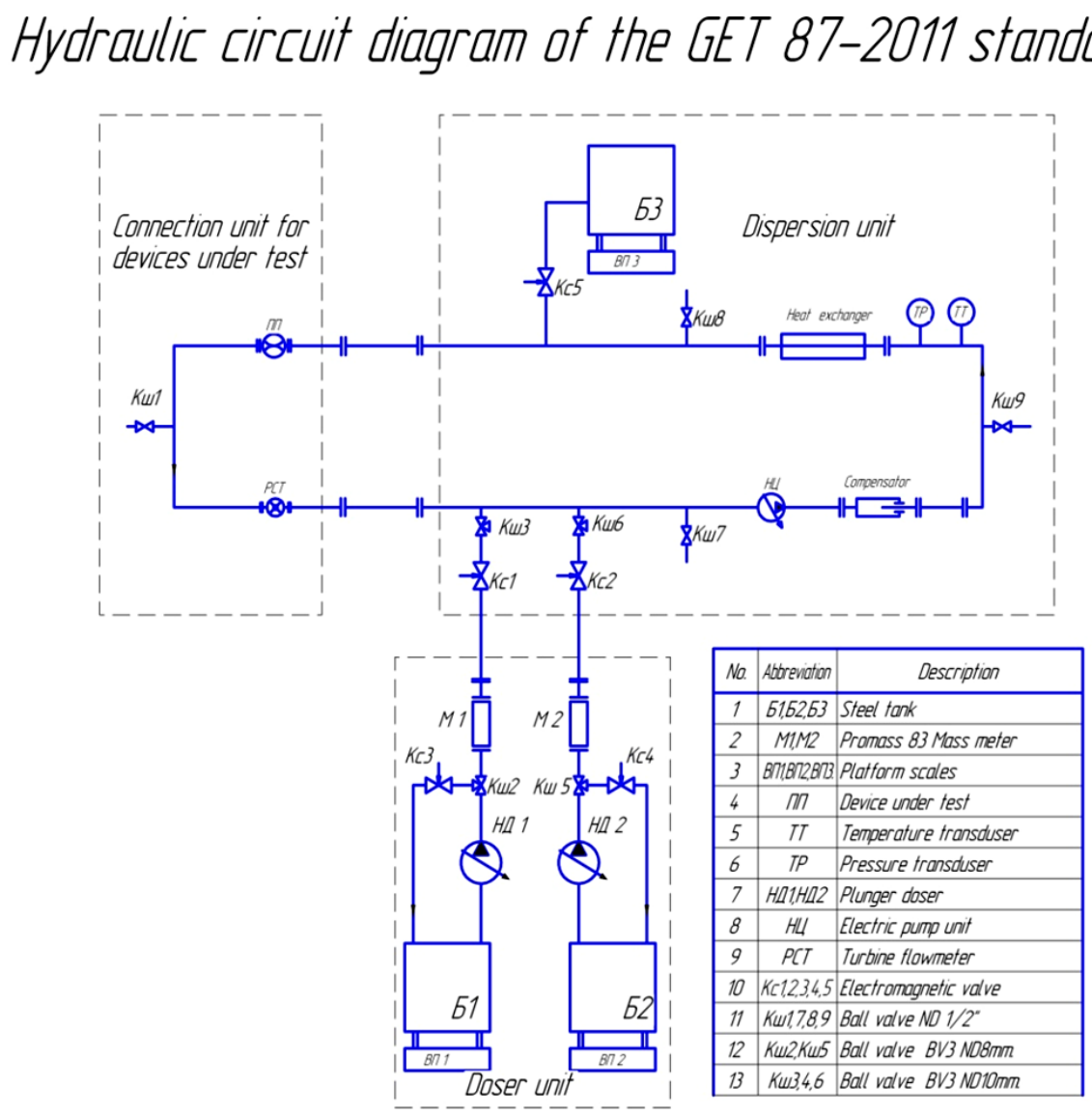
The new standard was developed by the FGUP VNIIR specialists by means of modernization of the existing special standard GET 87-75.The major goals were as follows:

- increase of the reproduction range of volumetric water content unit up to 99.9% of volume fraction of water;
- reduction of the unit reproduction error.

The performed works resulted in the development of a new technological complex (figure 2). Structurally it consists of a hydraulic circuit, measuring instruments for the determination of parameters of original components of oil and water mixtures, a device for the deep drying of oil, devices and accessories providing thermostatting of the new mixture and internal environment control in the room where the standard is located.

Figure 2. General view of the new standard

Hydraulic circuit diagram of the standard is given in figure 3.



No.	Abbreviation	Description
1	Б1,Б2,Б3	Steel tank
2	М1,М2	Promass 83 Mass meter
3	ВП1,ВП2,ВП3	Platform scales
4	ПП	Device under test
5	ТТ	Temperature transduser
6	ТР	Pressure transduser
7	НД1,НД2	Plunger doser
8	НЦ	Electric pump unit
9	РСТ	Turbine flowmeter
10	Кс1,2,3,4,5	Electromagnetic valve
11	Кш1,7,8,9	Ball valve ND 1/2"
12	Кш2,Кш5	Ball valve BV3 ND8mm
13	Кш3,4,6	Ball valve BV3 ND10mm

Figure 3. Hydraulic circuit diagram of the GET 87-2011 standard

In comparison with the GET87-75 standard, the improved standard provides reproduction of the volumetric water content unit in the full range (0.01 – 99.9% of volume fraction of water) in conditions most closely resembling the operating conditions of working measuring instruments (temperature range 10 ÷ 70°C, manometric pressure up to 1 MPa).

The operating medium is water-in-oil emulsions prepared on the basis of oil and water preliminarily dried to the condition specified in the requirements of GOST R 51858. Prior to mixing the density of original components (oil and water and residual water content in oil are determined using the measuring instruments included in the standard).

During the performance of research metrological characteristics of the new standard were substantially improved by using high accuracy measuring instruments, and the probable causes of additional error were isolated and minimized.

The comparison of metrological characteristics of the original and improved standards is given in Table 3.

Table 3. Metrological characteristics of the standards

Standard	**Metrological characteristics**						
	Range of reproduction, % of volume fraction of water	Mean square deviation, S, % of volume fraction of water	Residual systematic error, Θ, % of volume fraction of water	Standard uncertainty estimated by type A, U_A, % of volume fraction of water	Standard uncertainty estimated by typeB, U_B, % of volume fraction of water	Combined standard uncertainty, U_C, % of volume fraction of water	Expanded uncertainty atK=2, U_P, % of volume fraction of water
GET87 – 75	0.05 – 60	$23 \cdot 10^{-4}$	$65 \cdot 10^{-3}$	-	-	-	-
ImprovedGET 87	0.01-0.1	$1 \cdot 10^{-3}$	$3 \cdot 10^{-3}$	$1 \cdot 10^{-3}$	$1.4 \cdot 10^{-3}$	$1.7 \cdot 10^{-3}$	$3.5 \cdot 10^{-3}$
	0.1-10	$1.8 \cdot 10^{-3}$	$1.14 \cdot 10^{-2}$	$1.8 \cdot 10^{-3}$	$5.5 \cdot 10^{-3}$	$5.7 \cdot 10^{-3}$	$1.2 \cdot 10^{-2}$
	10-60	$2.2 \cdot 10^{-3}$	$2.86 \cdot 10^{-2}$	$2.2 \cdot 10^{-3}$	$1.38 \cdot 10^{-2}$	$1.39 \cdot 10^{-2}$	$2.8 \cdot 10^{-2}$
	60-99.9	$4.3 \cdot 10^{-3}$	$5.73 \cdot 10^{-2}$	$4.3 \cdot 10^{-3}$	$2.76 \cdot 10^{-2}$	$2.79 \cdot 10^{-2}$	$5.6 \cdot 10^{-2}$

Table data shows that uncertainty has substantially decreased in the entire reproduction range of the volumetric water content unit: in the range of 0.01÷10% of volume fraction of water - 5-fold, in the range of 10÷60 % of volume fraction of water - 2-fold, in the range of 70÷99.9 % of volume fraction of water -up to 14-fold.

Characteristics of the improved standard were successfully confirmed during the acceptance tests. On April 20, 2012 State primary special standard of oil and oil products volumetric water content unit GET 87-2011 was certified in accordance with Rosstandart order No.252.

Volumetric water fraction unit shall be transferred from the State primary special standard to State standards (standards of organizations) as well as directly to working measuring instruments. Interstate standard «State system for ensuring the uniformity of measurements has been developed for this purpose. State verification schedule for oil and oil products volumetric water content measuring instruments».

Conclusions

Thus, as a result of performed works a State primary special standard of oil and oil products volumetric water content has been developed at the premises of FGUP VNIIR, which corresponds to the modern research and technical requirements and provides reproduction of the oil and water mixture volumetric water content unit in the range (0.01 ÷ 99.9%) with improved metrological characteristics.

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