METHODICAL APPROACH FOR DETERMINING PETROPHYSICAL PARAMETERS USING THE VINCI 3.28 HELIUM POROSIMETER

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ABSTRACT. The present study aims to review current methodological approaches for the laboratory determination of reservoir parameters of reservoir rocks using the helium porosimeter (HeP-E) of the French company Vinci Technologies. The variations in the technological solutions of the measurement methods are considered, as well as the qualitative and quantitative representation of the results. A methodology is offered for determining petrophysical parameters (porosity and permeability) using the Vinci 3.28 helium porosimeter which the Laboratory in the Physics of the Stratum at the University of Mining and Geology "St. Ivan Rilski" is equipped with. In the final part of the study, the advantages of the helium porosimeter are substantiated both in terms of the expediency and versatility of the research process and with respect to the presentation and reliability of the results obtained.

Keywords: porosity, permeability, laboratory assessment

МЕТОДИЧЕН ПОДХОД ЗА ОПРЕДЕЛЯНЕ НА ПЕТРОФИЗИЧНИ ПАРАМЕТРИ С ПОМОЩТА НА ХЕЛИЕВ ПОРОЗИМЕТЪР ТИП VINCI 3.28

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РЕЗЮМЕ. Настоящата разработка има за цел преглед на съвременните методични подходи за лабораторното определяне на резервоарните параметри на скали-колектори чрез използване на хелиев порозиметър (HeP-E) на френската фирма Vinci Technologies. Разгледани са вариацииите в технологичните решения на методите на измерване, както и качественото и количественото представяне на резултатите. Предложена е методика за определяне на петрофизични параметри (порестост и проницаемост) чрез използване на хелиев порозиметър тип Vinci 3.28, с който е оборудвана лабораторията по Физика на пласта към МГУ „Св. Иван Рилски". В заключителната част на разработката са обосновани предимствата на хелиевия порозиметър както по отношение експедитивността и универсалността на изследователския процес, така и по отношение на начина на представяне и достоверността на получените резултати.

Ключови думи: порестост, проницаемост, лабораторна оценка

Introduction

A number of important issues in the geology of oil and gas, in the prospecting, exploration, and development of hydrocarbon fields, in the assessment of the resources/deposits of hydrocarbons in various categories, as well as in determining the output technological indicators for their development, are related to the study of the petrophysical properties of reservoir rocks. The purpose of this study is to review the current methodological approaches for the laboratory determination of reservoir parameters of reservoir rocks using a helium porosimeter (HeP-E) of the French company Vinci Technologies, type Vinci 3.28 (Fig. 1), with which the Laboratory of the Physics of the Stratum at the University of Mining and Geology "St. Ivan Rilski" is equipped. The equipment was partially funded by a project from the Research Fund.

As a leading laboratory at the University of Mining and Geology "St. Ivan Rilski", it provides fluid and rock analysis services for the purposes of petroleum engineering. The methodological basis for the training of students in various courses of study has also been developed. Researchers ensure the functioning of the laboratory and strive for modernising the laboratory equipment and introducing contemporary analytical systems to determine important quantitative parameters of reservoir and fluid systems (Zaneva-Dobranova, 2017; Zaneva-Dobranova et. al., 2017; 2019).

Theoretical framework and equipment

Theoretical framework

The most important physical properties that characterise the ability of rocks to contain fluids and to release them under certain conditions are their capacity and permeability. Various groups of methods exist: geophysical, hydrodynamic, petrographic, etc. Laboratory methods are also important. In carrying out the experiment, the following ones were essential for obtaining the correct results: the technological solutions to the measurement methods; the qualitative and quantitative presentation of the results; the preliminary preparation of the sample studied; the genesis of the capacity and filter spaces; the laboratory equipment; the role of deformation effects; the skill of the laboratory assistant, etc.

Fig. 1. General view of the Vinci 3.28 helium porosimeter

The classical laboratory methods applied in practice were developed in the middle of the 20th century and are associated with the works of Kobranova and Leparskaya (1957), Kalinko (1963), Hanin (1969), Balinov and Troshanov (1968), Goroyan (1971), Balinov et al. (1972), Archer and Wall (1986), Dake (1994), etc. Recently, due to the need to apply specific methods and approaches, research activities have been focused on the study of rocks with unconventional reservoir properties (Zaneva-Dobranova, Georgiev, 2016). Along with that, traditional laboratory methods have been refined and laboratory equipment is being upgraded. A number of leading laboratories throughout the world are examples in this respect: the American Core Laboratories, Inc., the Russian GC Agrosi Ltd., CORETEST SERVICE Ltd. in Tyumen, etc., acting as service providers for the analysis of rock and fluid material for the needs of the petroleum industry.

The helium porosimeter allows to determine the size of the grains and pores in the test specimen due to the isothermal expansion of helium, and then the density and effective capacity are determined. The results of the tests, using a helium porosimeter, are characterised by correctness of measurement, high accuracy (precision), and negligible random error of the results obtained in repeating conditions (Ahmed, Mehan, 2016; Twardowski et al., 2004).

In its essence, the methodology of this type of porosimeter does not differ significantly from the classical ones that study the reservoir properties of rocks. It is based on fundamental achievements and the laws of the physics of the oil stratum, the hydro- and thermodynamics, etc. At the heart of the principle of operation of the Vinci 3.28 helium porosimeter is the Boyle-Mariotte law. It can be used to calculate the volume of the grains and pores based on two consecutive pressure measurements and on the helium mass data. The analytical expression includes the initial and the measured (final) pressure, volume and temperature.

$$\frac{P_{ref} * V_{ref}}{T_{ref}} = \frac{P_{exp} * V_{exp}}{T_{exp}}$$

where:
P_{ref} is the reference (initial) pressure;
V_{ref} is the reference (initial) volume;
T_{ref} is the reference (initial) temperature;
P_{exp} is the measured (final) pressure;
V_{exp} is the measured (final) volume;
T_{exp} is the measured (final) temperature.

During the series of tests, it is assumed that the temperature is kept constant, therefore:

$$T_{exp} = T_{ref}$$
$$P_{ref} * V_{ref} = P_{exp} * V_{exp}$$

The Vinci 3.28 helium porosimeter equipment and the test sequence

What is different in the design, in comparison with the mercury porosimeter, is the ability to comprehensively study various characteristics, to automate the process, and to shorten the duration of the experimental work. The helium porosimeter used is significantly safer and the results obtained are commensurate with those of the mercury porosimeter. The storage conditions of the reagent used (helium) do not require special equipment of the laboratory and thus the risk of performing measurements is reduced.

The porosimeter has the following structure which is schematically shown in Figure 2.

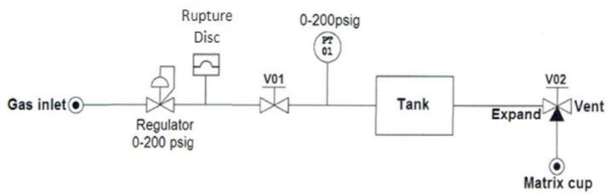

Fig. 2. Structure of the Vinci 3.28 helium porosimeter

Description (*from left to right*):

- Gas inlet – saturating agent – helium gas (a bottle with a pressure regulator and a shut-off mechanism);
- Discharge line;
- Regulator – primary pressure regulator (200 bar);
- Rupture disk – gas temperature control and regulation system;
- V01 – functional valve;
- PT01 – main electronic block with a computer output and a digital pressure gauge on the front panel;
- Tank – helium tank;
- V02 – distributing cock with positions for sample saturation and specimen ventilation;
- Discharge line;
- Matrix cup – saturation group - a system of an encapsulated core holder and a core holder attachment mechanism.

The developed methodology of the research process includes several important elements (Fig. 3).

The primary material is received in the laboratory and some procedures are performed that are related to its photographing and the attachment of a unique identifier. The primary material produces test specimens which are cleaned, dried to a constant weight and the corresponding sequential research identifier is attached. The next step in the process is to carry out quality control of the specimen, monitoring its integrity as required. The specimen prepared is photographed.

The following are important elements of the research process:

- the size of the samples tested;
- the calibration of the instrument.

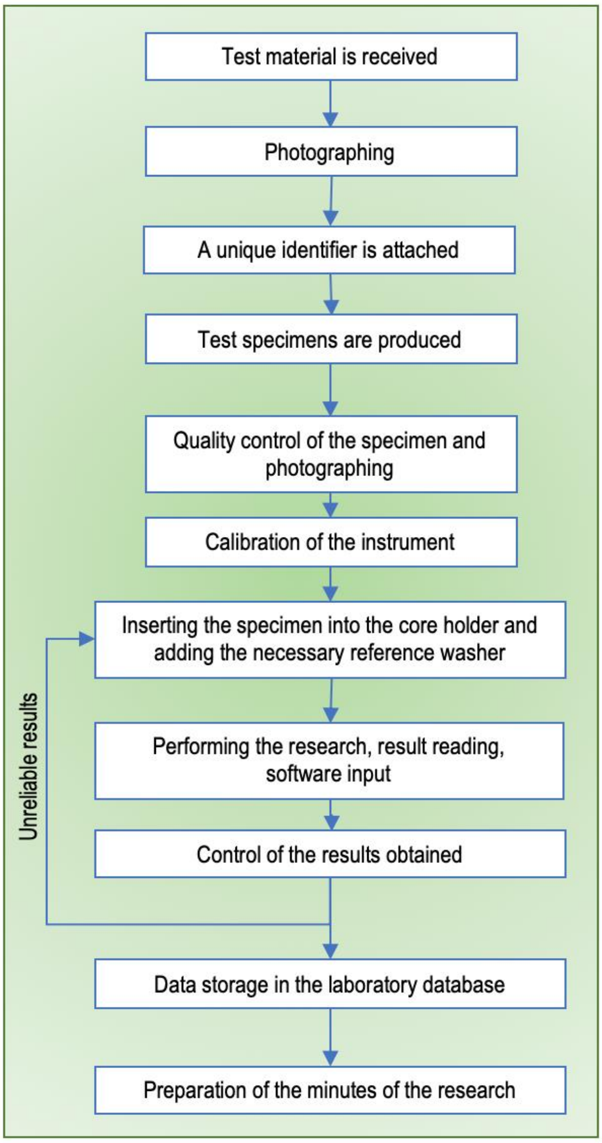

Fig. 3. Schematic presentation of the research sequence

To ensure greater reliability of the test, the sample size rule (the ratio of specimen height to specimen diameter) should be observed. The above should be 2:1. The core holder has a fixed diameter of 38.5 mm (1.5 inches); therefore, the optimum specimen height should be 76.2 mm (3 inches). If specimens of this height cannot be prepared from the test material, the height may be reduced to 38.5 mm (1.5 inches), i.e. to the ratio of 1:1, without significantly affecting the measurement results. The height of the specimen in the core holder (up to 76.2 mm) is supplemented by a set of 6 washers supplied with the apparatus. These are reference metal washers (Fig. 4), calibrated by the manufacturer, with a definite thickness and volume, depending on the need to adjust the height of the test specimen. When inserting any of the washers into the core holder, its factory number is input in the software product with the helium porosimeter. This is done in order to automatically read and correct the imperfection of the test core and, accordingly, the measurement result.

Fig. 4. Reference washers for the Vinci 3.28 helium porosimeter

The calibration of the instrument is based on the Boyle-Mariotte law on the volume constancy in an isothermal process (Fig. 5).

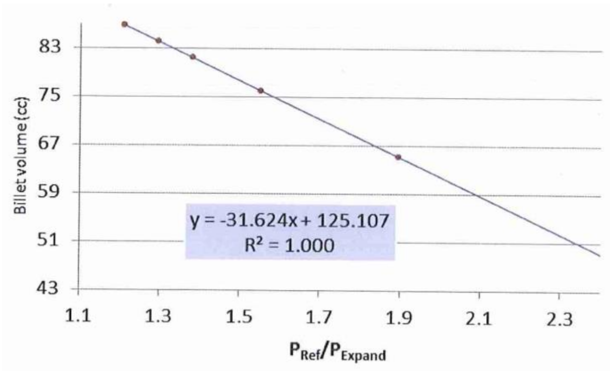

Fig. 5. Calibration curve of the helium porosimeter

It is a *sine qua non* that before each series of measurements, the apparatus must be properly calibrated. Technologically, this procedure in the helium porosimeter has been considerably simplified to avoid technological errors on the part of the operator. The six available washers are sequentially inserted into the core holder and volume and pressure measurements are carried out.

Once the volume has been established, an indication is made in the apparatus software of the particular washer being used at the time of measurement, and the computer automatically determines the Pref/Pexp ratio. The variation range should be between 1.3 and 5 depending on the installed calibration washer.

Another essential part of the preliminary preparation is checking for leaks from the apparatus. In case the pressure constantly changes, the system automatically signals for helium leakage. This requires a thorough check of the connections in the system and the elimination of the problem before resuming the measurements.

Through these two preliminary procedures, the manufacturer guarantees the relevance and reliability of the results obtained during the measurement. The instrument calibration procedure is carried out on a daily basis, prior to commencing laboratory work and measurements, and lasts for about 30–40 minutes.

Following the instrument calibration procedure, the steps outlined in the schematic diagram of the research sequence are performed: inserting the sample, adding the necessary reference washer, and starting the test. The gas initially fills the reference tank and then saturates the sample. Usually, the time to stabilise the saturation pressure is in the range of 3–10 min. This stage is controlled by the operator. Depending on the lithological composition of the rock studied, with denser rocks, the stabilisation interval can be lengthened up to 20 min. If stabilisation is not achieved, the study should be repeated by adjusting the gas temperature or checking for helium leaks.

After the saturation is completed, the measurement results are input into the instrument software. The results obtained are controlled. In case they deviate significantly and/or the pressure ratios are not observed, the measurement procedure is repeated. If the results are satisfactory, they are stored in a database. An individual measurement report is prepared in accordance with a report form of the laboratory.

The main results include: porosity, permeability, volume and mineral density of the rock.

Conclusion

The methodical approach considered is versatile and offers expeditiousness of the research process and reliability of the obtained results. Thus, it can be applied both in research work and in the training of students and Ph.D. students in the petroleum field. The methodology and equipment have been implemented in the laboratory of "Physics of the Oil and Gas Stratum" at the University of Mining and Geology "St. Ivan Rilski".

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