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Gas measurement method and weighing method to measure the core porosity research and comparative analysis

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Abstract: In order to measure the core porosity quickly and accurately, the article from the principle to the experimental procedure describes two simple measurement methods: gas measurement method and weighing method. Gas measurement method to measure the core porosity is by checking the gas pressure changes before and after the gas into the core to determine the core porosity; weighing method to measure the core porosity is by measuring the core dry weight, wet weight, and buoyant weight to calculate the porosity. Comparative analysis of the advantages and disadvantages of the two methods, and obtained data is compared with the core porosity data as standard values PE-02 nuclear magnetic resonance core analyzer have measured, final conclusion: gas measurement method and weighing method to measure the core porosity, experimental operation convenient, measurement error is small, in the porosity measurement process integrate the two ways to obtain accurate porosity values.

Key Words: *porosity; gas measurement method; weighing method*

I. FOREWORD

With the rapid development of China's modernization, the issue highlights of the growing energy crisis. In which the oil and gas resources plays an important role in the field of energy, grasp the reservoir porosity and permeability is basis of recognizing the situation of oil storage, estimation of reserves, analysis of the situation of oilfield production; To laboratory experiments for improving oil recovery and reservoir development is of great significance, therefore, the porosity is the fundamental constants that oil exploration and development must master[1]. At present, in addition to gas measurement method and weighing method to measure the core porosity, there are also mercury intrusion method and nuclear magnetic resonance method etc. These measurement methods due to the experimental conditions, laboratory equipment expensive and other reasons, do not often use. Mercury intrusion method is the use of mercury in non-invasive to measure the total volume of the cores, and under the action of applied pressure obtain the pore volume so as to calculate the porosity, in principle, the mercury intrusion method can be applied to a variety of solid substances, however, in actual operation, for those structures can be compressed, even under high pressure the material is completely destroyed, there will have a significant impact on the experimental results; Further during the experiment, mercury need to use acid-washed, dry, distilled pure mercury[6], but this process may cause pollution to the environment, nor well to human health, and mercury price is also more expensive. NMR measurement of the core porosity, the principle mainly based on nuclear magnetic resonance relaxation time of the fluid is related with the pore size of the fluid environment. NMR method of measuring the core porosity is relatively advanced, but there are also influence factors, for example, if the rock presence of relatively large holes or cracks, fluid molecules collide with the rock surface is difficult to occur, the relaxation of the fluid itself can not be ignored, or viscosity of the fluid in rocks is very high, fluid diffusion movement is relatively weak, the relaxation of the fluid itself can not be ignored, but fluid itself relaxation have an impact on the measurement results; Furthermore, if the rock

porous media magnetic permeability distributing unevenly generates magnetic field gradient leads to the static magnetic field variation, diffusion of molecules also have an influence on the measurement results[4]. Compared with mercury intrusion and NMR methods, the experiment process of gas measurement method and weighing method is simple, easy operation, low cost, and experimental error is smaller. This article describes the two methods to measure the porosity, obtained data for comparison, analytical error reason, having certain guiding significance for the experimental core porosity measurements.

II. GAS MEASUREMENT METHOD TO MEASURE CORE POROSITY

2.1 Experiment principle

Boyle's law: the volume of ideal gas is inversely proportional to gas pressure under the conditions of quantitative and constant temperature. Formula:

$$V=\frac{C}{P} \tag{1}$$

V refers to the volume of gas, P refers to the pressure, and C is a constant.

Continue to derive this formula, the product of an ideal gas volume with the pressure is constant

$$PV=C \tag{2}$$

If at the same state of temperature, the relationship of the A and B gas of two states can be expressed as:

$$P_AV_A=P_BV_B \tag{3}$$

The ideal gas refers to molecular volume compared with the volume of gas can be negligible, there is no mutual attraction between molecules, the collision between molecules does not cause the loss of kinetic energy, the molecules collide with the wall also does not cause the loss of kinetic energy. Pure nitrogen used in this experiment can be seen as ideal gas in the condition of isothermal changing, which is consistent with Boyle's law. The schematic of core porosity measurement as shown in Figure 1:

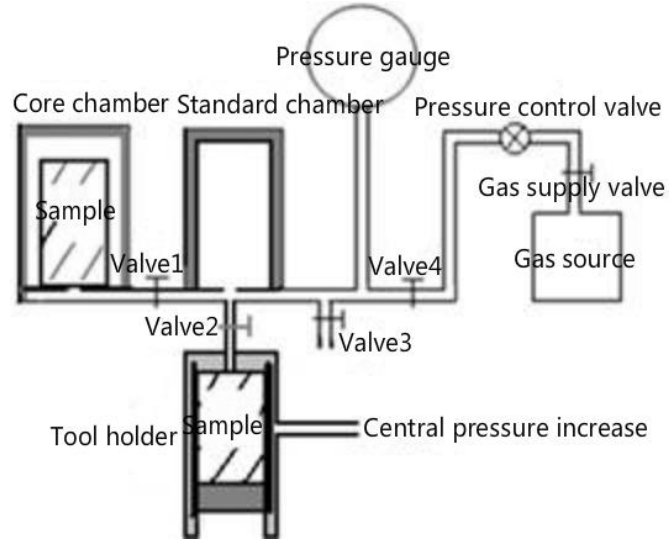

Figure 1 experimental schematic

The volume of standard chamber with its subsidiary pipeline is V_1, filled with nitrogen makes the pressure reaches P_1. The volume of core chamber with its subsidiary pipeline is V_2, place a core into core chamber, the pressure stable to P_2 over a period of time after opening the valve1, from Boyle's law, and we know that:

$$(P_1+P)V_1+PV=(P_2+P)(V_1+V) \tag{4}$$

P—indoor atmospheric pressure

V—the core pore volume plus the remaining volume of core chamber with its subsidiary pipeline

By (4) obtained:

$$V=\frac{P_1 - P_2}{P_2}V_1 \tag{5}$$

Thus getting the particle volume of the core, Vg:

$$V_g=V_2-V \tag{6}$$

Similarly, the standard chamber is filled with nitrogen then the pressure reaches P_1, place the core into the tool holder, the role of tool holder is wrapped up the core closely by adding central pressure, to make the core no space around, the volume of tool holder subsidiary pipeline is V_3, the pressure stable to P_3 over a period of time after opening the valve2, by Boyle's law:

$$(P_1+P)V_1+P(V_3+V_p)=(P_3+P)(V_1+V_3+V_p) \tag{7}$$

P—indoor atmospheric pressure

V_p—pore volume of the core

By (7) obtaining the core pore volume, V_p:

$$V_p=\frac{P_1}{P_3}V_1 - V_1 - V_3 \tag{8}$$

Finally by (6), (8) computing the core porosity Φ:

$$\Phi=\frac{V_p}{V_p + V_g}\times 100\%=\frac{P_1P_2V_1 - P_2P_3(V_1 + V_3)}{P_1P_2V_1 - P_2P_3V_3 + P_2P_3V_2 - P_1P_3V_1}\times 100\% \tag{9}$$

2.2 Experimental device

Nitrogen bottle, Pressure gauge, Standard chamber, Core chamber, Tool holder, Pressure control valve (Shown in Figure 1)

2.3 Experimental content

1) Put the treated of washing oil, washing salt, drying core into the core chamber, keep all the valves in the closed state, nitrogen into the standard chamber and make the standard chamber reach a certain pressure value P_1 by valve 4 and pressure control valve.

2) Opening the valve 1, make the nitrogen enter into the core chamber from standard room, record the pressure value P_2 when the pressure become stable.

3) Exhaust the gas of standard chamber and core chamber, mount the core into the tool holder, close all the valves, and then add the central pressure.

4) Make the nitrogen get into the standard chamber, and then make the standard chamber reach pressure value P_1 by valve 4 and pressure control valve, opening the valve 2 makes the nitrogen enter into the tool holder from standard room, record the pressure value P_3 when the pressure becomes stable.

5) Calculate the core porosity[2].

III. WEIGHING METHOD TO MEASURE THE CORE POROSITY

3.1 Experiment principle

After washing oil, washing salt and drying processing the rock samples, using electronic scales weigh out the mass of the samples at room temperature for M_0. The rock samples are saturated with water, then be removed and immediately weighed, the mass of the samples (wet weight) for M_1. So, the pore volume of rock samples can be calculated as:

$$V_p = \frac{M_1 - M_0}{\rho_W} \tag{10}$$

ρ_W —the density of water, the unit g/cm^3

According to the Archimedes principle, an object immersed in a still fluid is subjected to a vertical upward buoyancy, the buoyancy is equal to the weight of the object displaces the fluid[3]. The saturated sample mass in water by using electronic balance weighing (buoyant weight) is M_2, so the total volume of rock sample is:

$$V_T = \frac{M_1 - M_2}{\rho_W} \tag{11}$$

By (10), (11) computing the core porosity Φ:

$$\Phi = \frac{V_p}{V_T} \times 100\% = \frac{M_1 - M_0}{M_1 - M_2} \times 100\% \tag{12}$$

3.2 Experimental equipment

Electronic balance, Beaker, Sample bottles, Tweezers, Suspension loop, Saturated device.

3.3 Experimental Content

1) Dry weight measurement of the rock samples

Turn the balance to zero, use tweezers to put the washing oil, washing salt, drying processing and cooling to room temperature rock samples into the balance, weigh the dry weight of the rock samples.

2) Saturate the rock samples by vacuuming

Put the rock samples into a beaker container filled with distilled water, water level in the beaker should be higher than the rock samples, and then place the beaker in a vacuumed saturated device. After checking the hermetic of all parts of the vacuumed saturated device, start vacuum pump, draw out of gas in the rock samples until the rock samples do not have air bubbles emerged.

3) Wet weight measurement of the rock samples

Put an empty sample bottle into the balance, turn the balance to zero, then take out the saturated rock sample from the beaker with tweezers, absorb water attached to the surface of the rock sample with appropriate humidity filter paper and then put the sample into the sample bottle, weigh the wet weight of the rock sample.

4) Buoyancy weight measurement of the rock samples

Mount a bracket on the top of the balance weighing pan, place a beaker with suitable diameter on the bracket, the beaker has an appropriate amount of distilled water. Hang the suspension loop on the balance hook, turn the balance to zero. Immerse the rock sample which have weighed wet weight in the distilled water with the suspension loop, hang the other end of the suspension loop on the hook, and weigh the buoyancy weight of the rock sample.

5) Calculate the core porosity.

IV. THE EXPERIMENTAL RESULTS AND ERROR ANALYSIS

4.1 The experimental results

A block porosity data obtained by the gas measurement method and weighing method is compared with the core porosity data as standard values PE-02 nuclear magnetic resonance core analyze have measured, as shown in Table 1:

Core number	Lithology	Core occurrence	Standard values (%)	Gas measurement porosity (%)	Relative error (%)	Weighing porosity (%)	Relative error (%)
1	Sandstone	Regular shape	12.168	12.179	0.09	12.17	0.016
2	Sandstone	Regular shape	16.569	16.58	0.066	16.572	0.018
3	Sandstone	Regular shape	12.932	12.949	0.131	12.935	0.023
4	Argillaceous sandstone	Regular shape	19.143	19.165	0.115	18.917	1.18
5	Argillaceous sandstone	Regular shape	19.221	19.24	0.099	18.928	1.524
6	Sandstone	Regular shape	18.719	18.729	0.053	18.725	0.032
7	Sandstone	Regular shape	15.25	15.264	0.092	15.255	0.033
8	Sandstone	Regular shape	13.164	13.185	0.16	13.165	0.008
9	Sandstone	Regular shape	19.816	19.843	0.136	19.828	0.061
10	Sandstone	Regular shape	16.77	16.789	0.113	16.773	0.018
11	Sandstone	Regular shape	20.741	20.78	0.188	20.756	0.072
12	Sandstone	Regular shape	19.831	19.851	0.101	19.837	0.03
13	Sandstone	breakage	12.97	13.09	0.925	12.979	0.069
14	Sandstone	Regular shape	20.537	20.547	0.049	20.54	0.015
15	Sandstone	breakage	18.743	18.943	1.067	18.76	0.091

Table 1 core porosity data

And to compare the results of the porosity relative error of graphically represented as shown below:

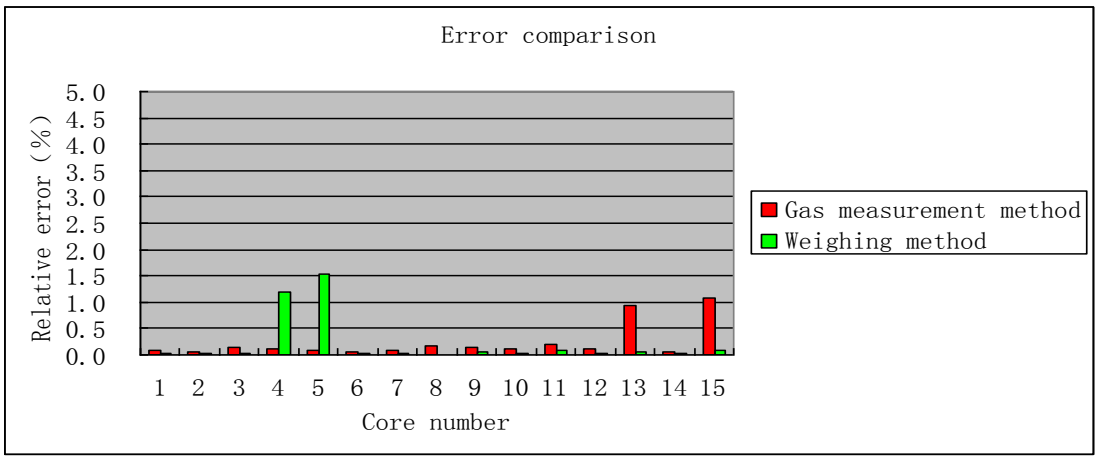

Figure 2 core porosity error comparison

As can be seen from Figure 2, No.4 and No.5 core measured by weighing method the porosity relative error is relatively larger; No.13 and No.15 core measured by gas measurement method the porosity relative error is relatively larger. From the data in Table 1 will find that the former core lithology is argillaceous sandstone, the latter core occurrence breakage.

4.2 Error analysis

1) Gas measurement method and weighing method to measure the core porosity even under proper operating conditions will also produce errors, such as gas measurement method: temperature changes will affect the gas pressure, if the indoor temperature changes during the measurement, it will affect the measured porosity. If using impure nitrogen will also produce errors, and the instrument must be hermetic well. The main source of errors in weighing method, first, the core saturation time is not enough, distilled water into the pores without adequate; another using a filter paper to absorb water attached to the rock sample surface, too much or too little, it will affects the results.

2) As regular shape sandstone cores, gas measurement method and weighing method to measure the core porosity, the relative errors are all relatively small, but according to the data: gas measurement method to measure the core porosity values, which the porosity values are larger than the standard values and the porosity of weighing method measurement, this is because the gas molecules are more easily enter into the pores, into the small pores which the liquid is difficult to get into. The standard values measured by NMR are minimum, because attenuation fast fluid signal (such as clay fluid signal) in rock samples may not be detected by instrument [5].

3) From No.4 and No. 5 core, when the core lithology is argillaceous sandstone, the relative errors of porosity values measured by weighing method are relatively large. During the experiment we found the distilled water used to saturate core became slightly turbid, this is because in the process of saturation a small amount of clay in argillaceous sandstone was dissolved in water, then according to the formula (12):

$$\Phi=\frac{V_p}{V_T}\times 100\%=\frac{M_1-M_0}{M_1-M_2}\times 100\%$$

M_1-M_2 is the mass of the core supplanting water, the part of argillaceous dissolved becomes pore of the core, so the total volume of the core is unchanged, M_1-M_2 does not change; but argillaceous is dissolved that led wet weight M1 become small, so core porosity measurement becomes small, at this time the core porosity measured by gas measurement method is more accurate.

4) For the core occurrence damaged sandstone, such as No. 13, 15, the relative error of porosity value measured by gas measurement method is relatively large, look from the formula (4):

$$(P_1+P)V_1+PV=(P_2+P)(V_1+V)$$

The damaged core does not impact on calculating the particle volume. In process of calculating the pore volume, due to the core is damaged, the tool holder can't wrap the core closely, so the core damaged place volume is equivalent to the pore volume, the core pore volume increases, so the calculated porosity is not accurate, the result is relatively large, or look from the equation (8):

$$V_p=\frac{P_1}{P_3}V_1-V_1-V_3$$

The core is damaged, P_3 will decline much more than normal, so that the entire equation becomes larger, the porosity of final calculation will be larger. But using weighing method, the core occurrence has no effect on weighing dry weight, wet weight and buoyant weight. At this time the porosity measured by weighing method is more accurate.

Therefore, using the gas measurement method to measure the porosity should ensure the hermetic of instrument and use pure nitrogen to measure under isothermal condition; measuring the porosity by weighing method, the saturated time must be long, adsorbing excess water of core surface must be skilled and accurate; when the cores have been damaged, using weighing method as much as possible; the cores contain clay, using gas measurement method as much as possible. Thus the measured porosity values would be more accurate, the error is small.

V. CONCLUSIONS

Through the above theoretical analysis and experimental tests, we can draw the following conclusions: measuring core porosity by gas measurement method and weighing method, convenient experimental operation, simple instrument structure, measurement error is small, and each has its advantages and disadvantages, can complement each other. Therefore, in the course of measuring the core porosity should synthesize the two methods to get accurate porosity values.

REFERENCES

[1] Zhenggang Pu. Measurement of Core Porosity and Error Analysis [J]. Chemical Engineering of Oil and Gas, 1996, 03:153-155+181.

[2] Shijun Zhao, Rongting Ren, Shaoguo Ma. Study on Measurement of Core Porosity Based on Linear Fitting [J]. PETROLEUM INSTRUMENTS, 1997, 04:10-11+62.

[3] Zhenbao Ling, Debao Zou, Kun Zhang, Min Xu, Jun Wang. Investigation on Measuring Methodology of Rock and Ore Sample Porosity [J]. Journal of Jilin University (Earth Science Edition), 2011, 03:921-924.

[4] Xiaowen Wang, Lizhi Xiao, Ranhong xie, Yuanzhong Zhang. Chinese terrestrial formation NMR porosity study [J]. Science in China (Series G: Physics, Mechanics & Astronomy), 2006, 04:366-374.

[5] Zhongdong Wang, Hao Wang, Nenggen Li, Longhai Qiao. Analysis of Core NMR Data from Laboratory Measurements [J]. Well Logging Technology, 2001, 03:170-174.

[6] Dongwu Chang. Mercury intrusion method to measure porosity reduces the error methods and analysis [J]. Experimental Technology and Management, 2003, 05:76-80.