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USING IN OIL AND GAS INDUSTRY OF EXPERIMENTALLY DETERMINED FILTRATION PARAMETERS OF CAP-ROCKS

Cap-rocks (called also screen-rocks) together with reservoir rocks, underground traps and other geological factors determine the possibility of forming and conservation in the bowels of oil and gas pools. The data about screening properties of cap-rocks are needed for solution of a number of theoretical and applied tasks of oil and gas branch, specifically for character and scales of hydrocarbon fluids migration evaluation, determination of separate territories and objects of oil and gas content prospects, designing of underground gas storages and so on.

Experimental possibilities of cap-rocks over oil and gas pools were being studied and estimated by different indirect factors, such as lithologic – facial composition and structural-texture peculiarities of rocks, their chemical properties and other indications. In addition a priori it was supposed that such rocks are absolutely impermeable and filtration of water through them is practically impossible.

Direct methods of screen-rocks filtration properties experimental determination were begun only at the end of 60-th of the past century, when by the works of separate researchers it was proved, that these properties can be expressed quantitatively by corresponding filtration parameters. To such characteristic parameters available for direct measurement belong coefficient of absolute gas permeability K and gas inrush pressure drop Δp_{inr} through water saturated rock, after that it will be filtering continually.

The first news about experimental measurements of cap-rocks filtration parameters published in 1968 Thomas L.K., Katz D.L. and Tek M.R. [1] and Khanin A.A. [2] and later Marmorshtein L.M. [3]. In the named works were elucidated theoretical and methodical principles of research carrying out, their results and practical use. In Ukraine such studies began in the middle of 70-th of the past century in the Ukrainian State Geological Prospecting Institute (UkrSGPI) and are being carried out to this day, for what laboratory equipment is created that permits to imitate formation thermobaric conditions.

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Traditional experiments of permeability determination presuppose measurement of gas or liquid flow rate, that crossflow through samples of porous reservoir rocks of oil and gas. In the case of cap-rocks we have to do with extremely low values of permeability and fluids microflow rates measurement for which are suitable only the gases. Their viscosities in average is on 1,5–2 orders lesser than of low viscous liquids and favourable factor is also high elasticity of gases. According to experience the process of cap-rocks filtration properties determination is prolonged because of their low carrying capacity and considerable time of gas flow stabilization – from 1–3 up to 8–10 hours. Waiting for gas breakthrough trough water saturated rock which is reached by gradual increase of inlet pressure can last several days. As a way out from the situation it was created an equipment for serial measurements with three core holders that essentially accelerated the paces of experiments carrying out.

Absolute range of permeability coefficient K change of screen-rocks is sufficiently wide (from 10^{-4} up to 10^{-11} mkm^2 and less) and in it according to screening ability it is expedient to single out three categories of fluid-resistant rocks as is shown in Table 1. For characteristic of natural screens properties more comprehensible is using inverse value of permeability 1/K, naming it as screening coefficient [4]. At such interpretation with screening possibilities improvement that is to say ability to prevent filtration, the values 1/K scalarly increase (Tab. 1).

Table 1

The scale of cap-rocks screening ability evaluation

Category of cap-rocks	Coefficient of permeability as to gas (K), mkm^2	Coefficient of screening as to gas 1/K, mkm^{-2}	Inrush pressures drop through water saturated rock (Δp_{inr}), MPa	Screening ability
I	$< 10^{-8}$	$> 10^{8}$	> 40,0	High
II	10^{-6}–10^{-8}	10^{6}–10^{8}	15–40,0	Middle
III	$> 10^{-6}$	$< 10^{6}$	< 15	Low

Well-known factor is presence in rocks microfissures of different origin, through which under certain conditions is possible fluids filtration. Because of that authors carried out experiments with 1/K and Δp_{inr} values determination succesivement – at first on monolithic samples (through matrix of the rock), and afterwards on the same samples with artificial fissure. By the research was revealed that 1/K in this case diminishes at 1–2 orders and Δp_{inr} – up to 1 order, dependent from deformation properties of rocks and presence of swelling minerals that are conducive to “healing” of fissures.

For quantitative estimation of cap-rocks a notion is introduced about upper and lower limit of their screening properties. As an upper limit it should be considered values 1/K and Δp_{inr} for monolithic rock and as lower – these parameters for samples with microfissures. Such approach of cap-rocks screening ability estimation acquire particular meaning during creation and exploitation of underground gas storages.

For different oil and gas bearing rock masses on the territory of Ukraine numerous measurements of cap-rocks gas permeability are carried out (on more than 1500 samples) on the basis of which the graph was plotted of this parameter change depending on depth (Fig. 1). Essential deviations values of permeability or screening comparatively their averaged values are caused that rocks are different by genesis, lithologic composition, lithification degree and so on essentially differ by their filtration properties. For averaged permeability through matrix screen-rocks have chiefly average screening ability to the depth about 3.5 km and on bigger depths – high. At microfracturing presence such rocks to the depth 3.5 km have low screening ability and deeper – mainly average. Significantly, that with depths more than 3.5 – 5 km are connected hydrocarbon pools with abnormal high formation pressures (AHFP), because here in consequence of fractures deformation compression increase screening properties even fractured cap-rocks.

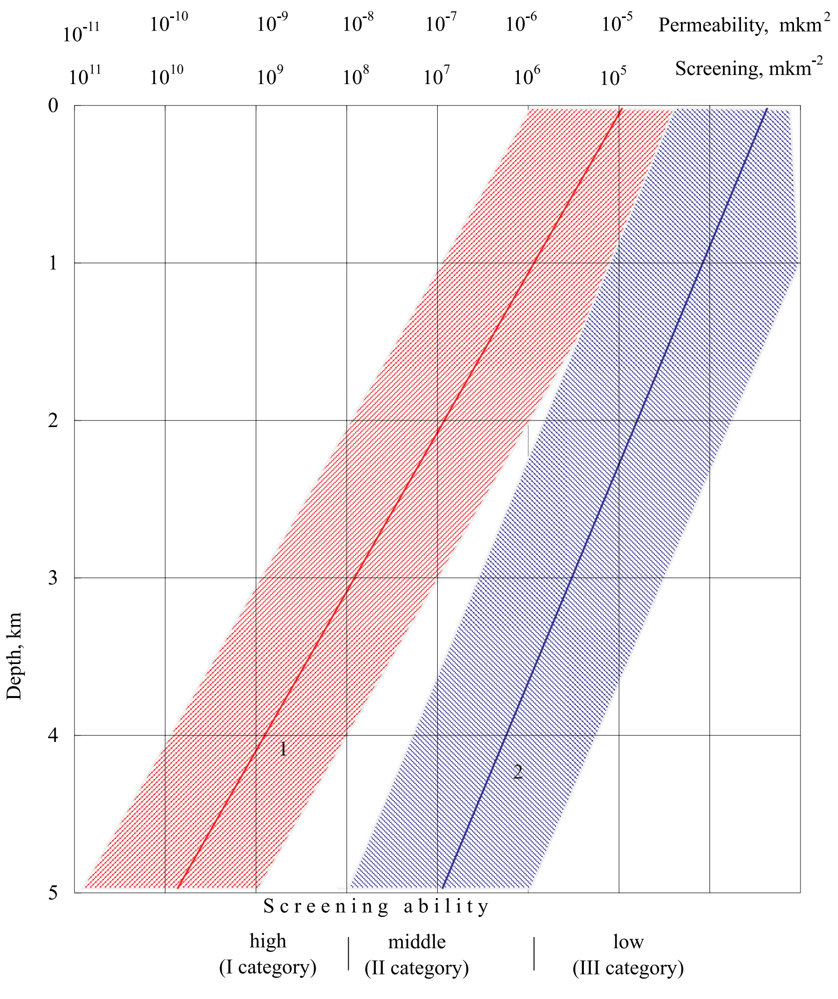

Fig. 1. Change with depth filtration properties of monolitic (1) and microfractured (2) samples of cap-rocks

For strong lithified, without swelling minerals, argillites of Carboniferous age of Dnipro-Donets oil and gas bearing region screening coefficient 1/K by matrix weakly increases with depth. If at the depth 3500 m it in average is $5 \cdot 10^8$ mkm^{-2}and at the depth 4500 m – $2 \cdot 10^9$ mkm^{-2}, then at mark 5500 m and lower it reaches 10^{10}– 10^{11} mkm^{-2}, moreover inrush pressure drops of gas through water saturated rocks change from 40.0 up to 70.0 MPa and more. Possible microfracturing reduces values 1/K on 1–2 orders and Δp_{inr} – up to 20 MPa and less. Fractured argillites with inrush pressure drops over 4.0 MPa often screen industrial hydrocarbon pools even with abnormal high formation pressures (AHFP). Such rocks – cap-rocks at the depths lower than 4000 m, where screening properties are formed mainly in consequence of fractures healing under the action of great geostatic pressure.

More lesser screening coefficients ($2 \cdot 10^6$ – $3 \cdot 10^7$ mkm^{-2}) at the depths 2500–3600 m have weakly lithified argillites of Permian age. The values Δp_{inr} change from 20 up to over 50 MPa. Sharply increased isolating ability are characterized Lower Permian anhydrites screening coefficients of which are on 3–4 orders higher. But microfracturing diminishes this ability on 3 orders and more. Therefore anhydrites can be reliable screen chiefly together with clay rocks.

The best isolation properties have Lower Permian saline deposits at the depths lower than 1500 m. Filtration properties were studied on the samples of plug salt in the middle of which visually were marked numerous microfractures. In conditions of gradual increase of geostatic pressure and temperature the salts sharply lost permeability and in the range of pressures 20–35 MPa and at temperatures near 30°C gas filtration practically stopped. Superhigh isolating abilities of salts can explain the fact that these rocks sometimes together with anhydrites screen great gas pools as in Dnipro-Donets oil and gas bearing region and in other regions of the world.

Argillites and clay marls of Mesozoic age which are the screens for hydrocarbon pools of Near-Black Sea-Crimean and Carpathian oil and bearing regions are characterized by sufficiently high screening properties: 1/K by matrix change from $1.6 \cdot 10^7$ mkm^{-2} up to $1 \cdot 10^9$ mkm^{-2} and Δp_{inr} – from 14 up to 60 MPa. Even possible microfracturing at the depths lower than 4000 m weakly diminishes their filtration properties and they are capable to screen hydrocarbon pools with AHFP.

Clay rocks – cap-rocks with thickness from 3–5 up to 100 m are reach Neogene molasses of above mentioned oil and gas bearing regions. Weakly lithified clays and argillites with content in upper parts of section (up to 2500 m) of great number of minerals that swell are characterized by screening coefficients $1.2 \cdot 10^6$ – $1.7 \cdot 10^8$ mkm^{-2} and Δp_{inr} – 6–20 MPa. The presence of montmorillonite and hydromica minerals is conducive to fractures „healing" of different origin in consequence of which diminishing of isolating properties of these rocks is minimum. That's why already at the depths 1500 m and lower in Precarpathian and Near-Black Sea-Crimean oil and gas bearing regions under above mentioned clay beds with thickness even 3–5 m occur gas pools with AHFP.

On the basis of cap-rocks filtration parameters experimental determination interesting is tentative evaluation of possible migration volumes through them of oil and gas (Tab. 2). The calculations show that through the matrix of conditioned screen with area only 1 km^2, thickness 50 m and permeability 10^{-8} mkm^2 that is typical for depth 2.5 km during 1 mln. years with pressures drops 1 MPa can be filtered approximately 76 billion m^3 of gas or 8 mln. m^3 of oil. The presence in such screen separate longitudinal microfracture with length 1 km and opening only 0.1 mm will increase volumes of oil and gas migration approximately on 4 orders and through fracture-rupture with opening 1 mm – on 7 orders. Such dislocations that fade in sedimentary cover or crop out to the day play decisive role in reforming or destruction of pools. Diffusion massflow in similar conditions would be incommensurable, on many orders lesser, consequently it should be regarded as a process of dispersion and equalizing of hydrocarbons concentrations in formation waters and rocks in geological scales of time (hundreds of million years).

Table 2

Estimation of possible oil and gas migration through cap-rocks

Migration conditions	Time, years	Volumes of oil migration in mln. m^3		Volumes of gas migration in bilion. m^3	
		At pressure drop, MPa			
		0.1	1	0.1	1
Through matrix filtering $K = 10^{-8}$ mkm^2	100 thousand	0,0788	0,788	0,759	7,59
	1 mln	0,788	7,88	7,59	75,9
Through fracture with opening 0.1 mm, length 1 km $K = 0.83 \cdot 10^{-4}$ mkm^2	100 thousand	656	$656 \cdot 10$	$632 \cdot 10$	$632 \cdot 10^2$
	1 mln	$656 \cdot 10$	$656 \cdot 10^3$	$632 \cdot 10^2$	$632 \cdot 10^4$
Through fracture with opening 1 mm, length 1 km $K = 0.83 \cdot 10^{-2}$ mkm^2	100 thousand	$656 \cdot 10^3$	$656 \cdot 10^4$	$632 \cdot 10^4$	$632 \cdot 10^5$
	1 mln	$656 \cdot 10^4$	$656 \cdot 10^5$	$632 \cdot 10^5$	$632 \cdot 10^6$
Through matrix diffusion	100 thousand	–	–	$622 \cdot 10^{-6}$	$622 \cdot 10^{-5}$
	1 mln	–	–	$622 \cdot 10^{-5}$	$622 \cdot 10^{-4}$

Note: The conditioned cap-rock with area 1 km^2, thickness 50 m that occurs at depth 2.5 km

The data of cap-rocks filtration parameters experimental determination one can successfully use in the practice of underground gas storages (UGS) creation and exploitation [5]. For increase of storage volumes it is expedient to raise maximum formation pressure in the storage but not exceeding the lower limit of cap-rock screening properties so as do not cause gas cross-flow. In depleted gas pools if technogenic unsealing is absent the pressure of storage one can safely bring only to the level of natural formation that existed at the beginning of development. At the same time at presence of reliable experimental provision the formation pressures and consequently the active volumes of gas storage can be essentially increased.

For example on separate UGS of Precarpathians that were created in used gas pools in depths interval 500–850 m, gas inrush pressure drops through water saturated Sarmatian cap-rocks even at microfracturing presence are equal to 1.8–3 MPa. Inasmuch as formation pressures in gas pools before beginning of their development corresponded with hydrostatic (5–8.5 MPa) then in these storages one can safely increase gas injection pressures increasing the volumes of its storage on 20–35%. Particularly responsible is study of cap-rocks filtration properties for UGS creation in water-bearing beds. In them did not exist natural gas pool and presence of information about filtration properties of these rocks can prevent negative consequences – the storage turn out to be nonhermetic.

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