INFLUENCE OF A LOW-FREQUENCY ACOUSTIC FIELD ON THE 
CAPILLARY IMPREGNATION OF GAS-SATURATED POROUS SYSTEMS

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Experimental results on the influence of a low-frequency acoustic field on the capillary impregnation of gas-saturated 
artificially cemented and noncemented porous rock samples are given. It is found that the impregnation rate can be 
increased and gas can be displaced completely from the porous collector on account of the field action.

At present the ultrasound capillary effect, a substantial increase of the rate and efficiency of porous material impregna-
tion by the action of an ultrasonic acoustic field, is widely used in industrial processes [1, 2]. The ultrasound effect on the 
capillary impregnation of porous materials has been adequately studied both for impregnation of gas-saturated porous media [3, 
4] and for capillary displacement of liquid hydrocarbon from them [5]. The influence of a low-frequency acoustic field on the 
capillary impregnation has not been studied at all.

Moreover, it is the low-frequency field that is highly promising for the development of advanced methods of action on 
mineral deposits, particularly on natural hydrocarbons. Low-frequency action appears advantageous in these methods because it 
is associated with a much lower damping in the rocks compared to high-frequency action. Therefore, we studied capillary 
impregnation of gas-saturated porous materials in a low-frequency acoustic field.

The influence of low-frequency acoustic action on the parallel-flow impregnation of porous media was studied experi-
mentally in artificially cemented and noncemented rock samples. The noncemented porous specimens were manufactured from 
quartz sand of various fractions, which allowed materials with different permeabilities from units to tens of square micrometers 
to be studied in the experiments. As cemented media we used cement—sand mixes with various sand and cement proportions. 
Media with different porosities (from 20 to 28%) and permeabilities (from 0.03 to 0.8 \( \mu \)m\(^2\)) were simulated by varying the sand 
and cement proportions and by using different sand fractions. The specimens were impregnated with distilled water at atmos-
pheric conditions. In the experiments the action was applied at 0.4-6 W/m\(^2\) and a frequency of 20-200 Hz.

The height and velocity of water rise in the specimen (the impregnation rate) and the average water saturation of the 
specimen in its moist part (water saturation of the specimen) were considered as parameters controlling the impregnation 
process. The capillary rise was measured directly from the water—gas interface position in the specimen. The impregnation rate 
was taken as the water rise increment per unit time. Water saturation of the specimen was estimated from the ratio of the water 
volume in the impregnated part of the specimen to the void volume in its watered part.

The influence of the acoustic action on the capillary impregnation process was studied in its different stages. In the first 
experimental series, the impregnation parameters found in two variants (with and without acoustic action throughout the 
impregnation process, from the beginning to the end) were compared. In the second experimental series, we studied the acoustic 
field effect on the impregnation process in the damping stage, that is, on additional impregnation. In the third experimental 
series, the impregnation parameters under acoustic action on the impregnation process with a variable oscillation frequency were 
followed.

The experiments revealed that under certain conditions a low-frequency acoustic action can influence the impregnation 
parameters. An acoustic field influences impregnation of both high-permeable and low-permeable porous materials. Impregna-
tion of the high- and low-permeable specimens has practically no qualitative differences, but there are quantitative differences 
between these processes. We will therefore give, as an example, the experimental data in individual series, or for low-perme-
Fig. 1. Time variation of the water rise in sample 1P (a) and water saturation of the sample (b) without the action (1), with the action at 1 W/m² and frequency of 50 Hz (2). H, cm; t, min.

Fig. 2. Time variation of the water rise (H) in specimen 1P, impregnation rate (v), and water saturations of the specimen under acoustic action at 0.5 W/m² (a, b) and frequency 25 Hz (a) and 200 Hz (b). IA, initial action; v, cm/min.

able or high-permeable media. In most of the experiments the impregnation rate was found to increase at the initial moment under acoustic action. The rate increment on account of the acoustic field effect was 1.1-1.4 times on the average, both for low- and high-permeable media. The acoustic action increased water saturation and, correspondingly, decreased the entrapped gas volume in the sample. The water saturation in the acoustic experiments was 7-12% and 8-15% higher than that in the experiments without acoustic action for high- and low-permeable media, respectively.

It was found that the impregnation rate and water saturation of the specimens tended to increase as the oscillation frequency and intensity rose.

As an example, Fig. 1 shows the data for impregnation of specimen 1P under the action of an acoustic field throughout the impregnation process and without the action. The sample was made of noncemented sand with 100-μm grain diameter, 38-μm² permeability, and 39% porosity. One can see from the figure that 1 W/m² low-frequency sonication of the specimen at a frequency of 50 Hz resulted in a 1.1-1.3 times higher initial impregnation rate than the impregnation without sonication.