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ACOUSTIC STIMULATION ON UNDERGROUND LEACHING

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Report presents the experience on acoustic intensification of underground leaching (UL) of less-common metals. In experiments the extended downhole antennas with a possibility of acoustic field focusing were utilized. It is experimentally shown, that the substantial process of UL can considerably be intensified by elastic vibrations, moreover, it is possible to receive rather continuous effect of intensification, using short-lived impact.

UL is perspective and enough ecological clean method of mineral resources mining, especially of less-common metals. Rock-products industry uses this method successfully since 60th years of past century, mainly for hydrogenous fields development. The forming of these fields is connected to metal deposition from oxygen groundwaters on an oxidation-reduction barrier originating at these waters motion on porous permeable seams. As a matter of fact, such type of field development by method of underground leaching is inverse natural process: earlier deposited metal transfer back in a mobile ionic form. For this purpose a lot of injecting and exhaust wells are located in bed surrounds. The leaching reagent is injected in productive bed, where dissolves in groundwater. Filtration of active solutions in productive seam leads to concentration of useful component in solution, which is extracted through exhaust wells. UL is the brightly expressed process of mass transfer in multiphase environments. The elastic vibrations influence on similar processes is well-known, though is learnt insufficiently [1, 2, 3].

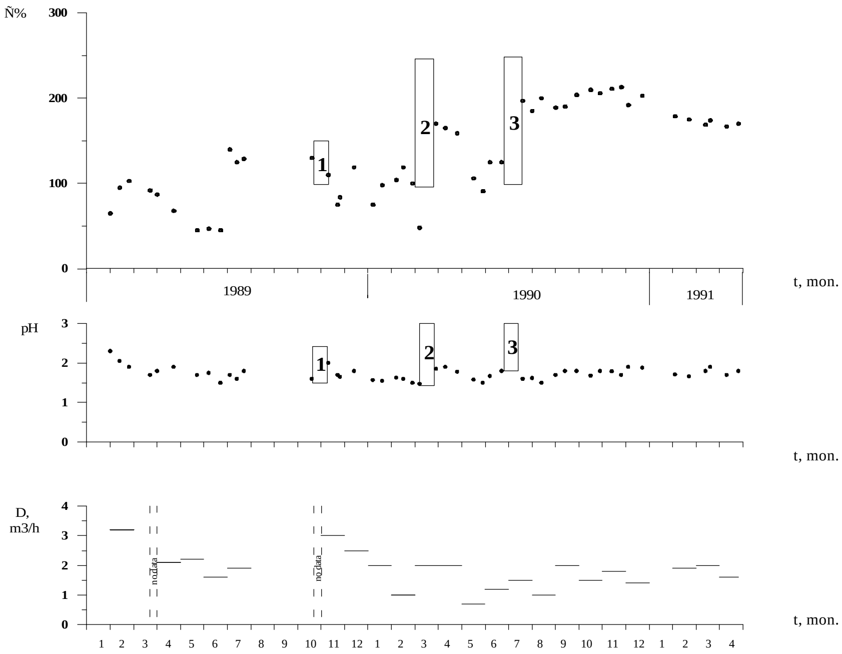

Fig. 1.

Report presents field experiments on acoustic intensification of UL. The object of action was near borehole area of exhaust well. Extended downhole antennas with a possibility of focusing were used as acoustic emitters. Focusing antennas was realized like zone lens [4]. Impact was carried on from hole filter of exhaust well, which one was in the productive reservoir of developed seam. The testing borehole was launched in exploitation in January 1989. Repair operations were not conducted on this borehole. Once 22.12.89 the hydrochloric acid treatment of hole filter zone was conducted. Hole size of well about 250 mm, the well is cased with a polyethylene tube outer and inner diameters 210 and 174 mm., respectively and is arranged with edge filter, which is situated between marks 148,8 and 158 meters. The water-level was, approximately, on 130 meters. Method of exploitation is pumping-out with flow rates 1-3 ì^3/h.

In a fig.1 all accessible history of this exhaust well is presented. The areas 1, 2, 3 correspond to time of acoustic impact and will be introduced below. The measuring of acoustic parameters of productive seam in region of testing well has given following results: longitudinal velocity $c_\ell \sim 1900 \pm 100$ m/s, velocity of transverse wave $c_t \sim 980 \pm 120$ m/s, the logarithmic decrement for longitudinal wave $d \sim 1{,}5 \div 3 \cdot 10^{-3}$. Errors of c_ℓ definition are connected to insufficiently precise directional survey, c_ℓ and d varied depending on positional relationship of testing well and wells, in which measuring were conducted. Four out of exploitation wells were located near testing well on spacing intervals 9, 10, 13, 15 meters. Measuring of time delays and amplitude of acoustic field radiated from testing well was conducted in these wells.

The focused antenna, created like zone lens (7 Fresnel zones), consists of five antenna modulus of various length. Overall length of the antenna is about 5 meters, active antenna area S_A is about 7500 sm^2, electric capacity C_0 ~ 2,6 mf. The antenna modulus consist of piezoceramic (CTBS-3) cylinders (74×66×50; 32 mm.). Resonance frequency of the antenna in water is f_R =14,7 kHz, antiresonance frequency f_{AR} = 16,0 kHz, focus point F~7 m., pure resistance on resonance R_A = 3,8 Ohm, dielectric loss tangent of the antenna tg$d$ ~0,04, mechanical quality-factor in water Q_M~5, electro-acoustic efficiency factor h_{EA}~0,78. The own resonance frequency of the antenna in filter zone of testing well falls: f_R ~13,8 kHz and the resonance is characterized in following parameters: R_A~5,1 Ohm, h_{EA}~0,73. Focus point for longitudinal waves F~5,5 m. Besides the antenna starts to radiate efficiently on a resonance of water layer, which is situated between surface of the antenna and wall of well bore. In our case this resonance frequency is $f_R^W \sim 8{,}2$ kHz and the resonance is characterized R_A~4,4 Ohm, h_{EA}~0,65, focus point F~3,2 m. in this case.

Fig.2 shows the area 1 from fig.1. 29, 30.10.1989 combination of antenna modulus was tested with following parameters: length 3,5 m, $S_A \sim 4{,}5 \cdot 10^3$ sm^3, R_A~ 7 Ohm and h_{EA}~0,68, cylindrical divergent field was radiated with $f_R^W \sim 8{,}2$ kHz. 29.10.1989 the pulse-mode was tested with t_i ~ 3–6 ms, with on-off time ratio q=24 … 3. The impulse power flux density on the original aperture

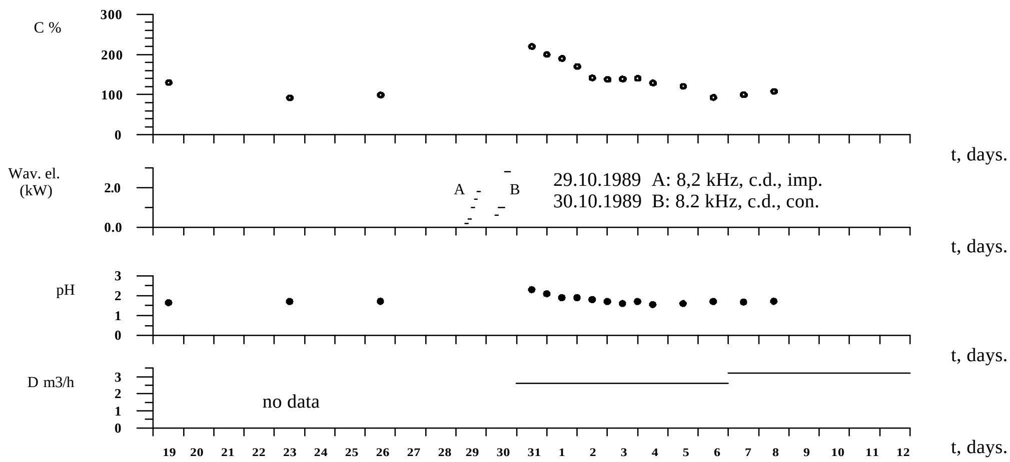

Fig. 2.

$\Pi_0^i \sim 0{,}7 \div 0{,}85\ \mathrm{W/sm^2}$, integrated power was operated by on-off time ratio. 30.10.1989 it was used continuous operation, the power was increased slowly, last four hours it was developed $\Pi_0^{con} \sim 0{,}5\ \mathrm{W/sm^2}$ on the original aperture.

Fig.3 shows the area 2 from fig.1. It is a period of time, when acoustic stimulation of UL was begun with the help of focused field. The operations were conducted without pumping-out. The schema was following: the antenna was bottomed into filter zone so that the focus point (center of the antenna) was on mark 150 m, after approximately 20 minutes of operation the antenna was lowered on 1 meter up to level 157 m on center. Then antenna was uplifted slowly as lowered. 12.03.1990 it was radiated $f_R \sim 13{,}8$ kHz within 16 hours. The radio pulse-mode was used t_i~6 ms. The impulsive electric power W_i^E was maintained by constant at a level approximately 12 kW, the average electric power W_{av}^E was operated by on-off time ratio, thus, $\Pi_0^i \sim 1{,}15\ \mathrm{W/sm^2}$, theoretical gain factor of used

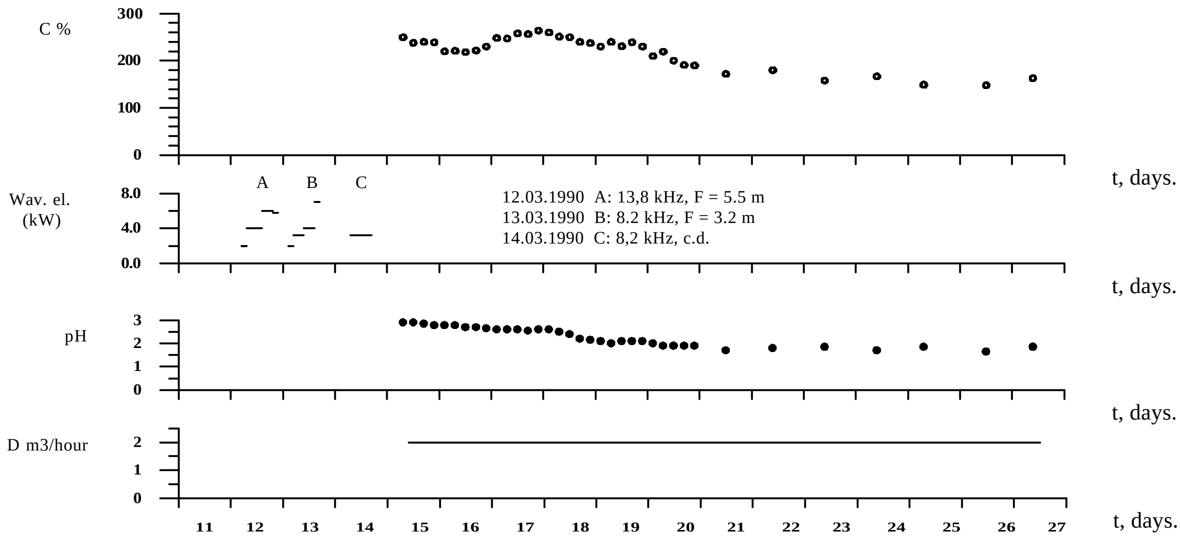

Fig. 3.

zone lens K_g ~0,31; keeping in mind damping, we receive following estimations for impulse flux density of acoustic power in focus point Π^{i}_{F} : $\Pi^{i}_{F}\left(F=5{,}5\,m\right)\sim 0{,}1\,W/sm^{2}$. 13.03.1990 the same schema was obtained, but frequency was $f^{W}_{R}\sim 8{,}2$ kHz., thus F~3,2 m., W^{E}_{i} ~13,5 kW, $\Pi^{i}_{0}\sim 1{,}1\,W/sm^{2}$, W^{E}_{av} was operated by on-off time ratio. Theoretical gain factor in this case K_g ~0,5, keeping in mind damping, we receive following estimations: $\Pi^{i}_{F}\sim 0{,}25\,W/sm^{2}$ for F=3,2 m. 14.03.1990 combination antenna of modulus applied 30.10.1989 was obtained without focusing. Regime was realized: continuous condition with $\Pi^{con}_{0}\sim 0{,}5\,W/sm^{2}$, during 8 hours. Center of the used antenna coincides with the center of the filter.

Fig. 4 shows the area 3 from fig. 1. This period of time the acoustic stimulation was kept already inside mining operation, i.e. combined with pumping-out of productive solution. The focused antenna was displaced along the filter with the help of electric hoist with the speed 1 m / min. Center of the antenna was located on depth 150 m, further within 7 minutes the antenna was continuously lowered, then 7 minutes was continuously uplifted. The acoustic stimulation was conducted in a continuous condition 22.06 (time of impact T=9 hours) and 25.06 (T=10 hours) with operational frequency $f^{W}_{R}\sim 8{,}2$ kHz , F=3,2 m, $\Pi^{con}_{0}\sim 0{,}7\,W/sm^{2}$ in this connection $\Pi^{con}_{F}\left(F=3{,}2\,m\right)\sim 0{,}15\,W/sm^{2}$. Unfortunately, it was not possible to increase Π^{con}_{F} because of cavitation. 23.06 (T =10 hours) and 24.06 (T=14 hours) the stimulation was conducted on frequency $f_{R}\sim 13{,}8$ kHz, F = 5,5 m, $\Pi^{con}_{0}\sim 0{,}7\,W/sm^{2}$ $\Pi^{con}_{F}\left(F=5{,}5\,m\right)\sim 0{,}06\,W/sm^{2}$. Analyzing of figs.1-4 gives following basic deductions. Under acoustic field stimulation concentration of a useful component in pumped off solution increases sharply. It is possible legibly to pick out concentration growth, which relates with immediate speeding up of heterogeneous reacting at the moment of acoustic field operating because of concentration gradient increase on phase interface (see, for example, [1]). The local maximums of concentration in fig. 4 indicate it, when follow immediately acoustic field actuation. Figs.3 and 4 show maximums of concentration, which are registered in exhaust well in some day after stimulation stopping. Most likely, it is result of acoustic field acting in focus regions of used downhole antenna. Position of the maximum, which has appeared 17.03 (fig.3), was strongly influenced by own hydrogeology of productive seam, since the pumping-out was activated only 15.03. Maximum fixed 28.06 (fig. 4) has appeared at regular exploitation of well and, possibly, its timer position could show such characteristic as filtration rate K_F for the given condition of pumping-out. In experiment introduced in fig. 4 reflexes from distances 5,5 m. and 3,2 m. were overlapped, most probably. If it is so, K_F ~1,3 m / day, that corresponds to common conceptions of process. Certainly, it is necessary to allow for diffusion processes, such as leveling of concentration in seepage moving in a permeable medium, etc. Nevertheless, there is assurance, based on focused field technology, possibility exists to construct not only instrument for UL stimulating, but also peculiar instrument to study these geo-technological processes.

The strong residual effect of concentration increase is less clear. This effect we could trace till April 1991 (further data miss). Here it is necessary to note, the reservoir was already exploited in

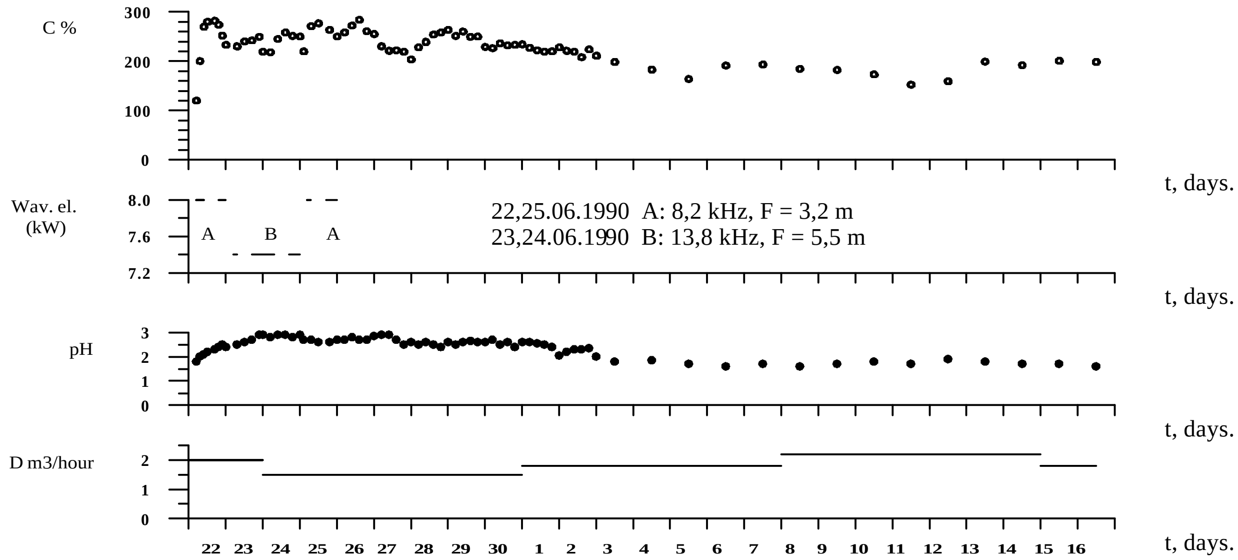

Fig. 4.

steady-state conditions on time of stimulating experiment, moreover productive seam is hardly heterogeneous at permeability and concentration. In all probability, elastic oscillations enhance diffusion in capillary - porous heterogeneities situated inside productive seam in a radius of elastic field action. The result is irreversible increasing of effective space of interphase. Variation of effective diffusion coefficient is improbable. This work was supported the Russian Foundation for Basic Research (project No. 00-02-16156).

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