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Meeting Paper

On Opportunity of the Radioactive Waste Self-Disposal in Rock Salt

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On opportunity of the radioactive waste self-disposal in rock-salt.

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Evolution of nuclear power branch and nuclear industry in the highly developed countries of the world resulted in an accumulation of radioactive wastes (RW) in large amounts. As result of radioactive radiation the RW has a serious danger during long time that depends on half-decay time of radionuclide contained (up to hundreds of thousands years). The safe and effective removal of RW out of biosphere is one of the most urgent problems today. The general decision of the problem is a disposal of RW in deep geological formation.

Some countries (Germany, USA, France, Russia) suggest rock-salt as a suitable media for the RW repository. The following reasons are taken in to account: high long-term geological stability, gas and water nonpermability, ability for self-remediation of structural defects, existence of powerful formations of salt (for example, domes), ease of treatment, chemical and radiation durability. By radioactive decay a heat is created into the RW matrix and quite high heat conduction of salt is important. The brine inclusions are always contained in salt media. Their moving to the heating source and accumulating of water in RW repository are usually mentioned as a disadvantage of salt disposal [1, 2].

An opportunity of the RW deep disposal into salt dome is of interest. Its idea is following. If RW is arranged in a container the last is heated, and the temperature of its surface depends on heat conduction of surrounding geological media and heat power that is proportional to activity of RW. The temperature may achieve the melting point of salt, and the cavity of melt is created around container to be on bottom of cavity if average density of container is larger then the melt density. Salt is melting on bottom of cavity and deposits in top part. As a result the container is moving into depth of dome.

The velocity of motion depends on the form of container. For sphere it is defined by the formula [3, 4]

$$u = \alpha\left[8g\chi^3 S^3 \Delta\rho / 3\eta R\right]^{1/4},$$

where: u - velocity of sphere,

$\alpha = \rho_l/\rho_s$; ρ_l, ρ_s - density of melt and solid salt,

g - acceleration of Earth's field of gravity,

$$S = \frac{c_{pl}(T_0 - T_m)}{L + c_{ps}(T_m - T_\infty)} \quad - \text{ Stephan's number,}$$

c_{pl}, c_{ps} - heat capacities of melt and solid for constant pressure,

$$\chi = \frac{\lambda}{c_{pl}\rho_l} \quad - \text{ thermal conduction,}$$

λ - heat conduction,
η - viscosity of melt,
L - specific heat of melt,
T_o - temperature of sphere surface,
T_m - melt-point,
T_∞ - temperature of enviroment,
R - radius of sphere.

Halite has the following properties [5]: $\rho_l \cong \rho_s = 2{,}18$ g/cm^3, $c_{pl} \cong c_{ps} = 2{,}56$ cal/(g ·C) (for T_m), $\lambda = 6{,}06 \cdot 10^{-3}$ cal/(cm·sek·C) (for T_m), $\chi = 1{,}08 \cdot 10^{-2}$ cm^2/sek, $T_m = 808^oC$, $L = 110$ cal/g, $\eta \cong 1{,}0 \cdot 10^{-3}$ kg/(m·sek). For R = 20 cm, S = 0,1 and $T_o = 930^oC$ velocity is $2{,}1 \cdot 10^{-2}$ cm/sek, that is ≅ 5,5 km/year. Thus the typical depth of salt dome about 5-8 km is attained for 1-1,5 year.

To achieve the necessary temperature the activity should be at least $4{,}4 \cdot 10^5$ Cu. It corresponds to specific activity about 20 Cu/cm^3. The value of activity is estimated for heat capacity of iostope of cobalt ^{60}Co (for that one watt of heat is equivalent 70 Cu).

The temperature inside of container depends on a heat conduction of container material; it is about 1050^{o}C for case of ceramic matrix.

The formula for velocity is applicable for uniform material, but the real salt contains some inclusions similar as brine, anhydride, gypsum etc. For some case the inclusions may effect the velocity of immersion. So, accumulation of heavy-melt impurities on botton of cavity results in the decreaseof motion (for example, melt-point of anhydride is 1193^{o}C and its density is 2,9 g/cm^3 [5]). The brine in form of inclusions may be mobile near melting cavity and its hot trace, but finally the vapour-brine inclusions [6] are likely to be scattered by cavity without capture. Thus the interaction with different inclusions may limit the depth of immersion of container. This question has to be investigated in future.

The immersion of hot source in solid halite was studied experimentally [7]. The modelling body of cylindrical shape is heated by electrical current; the temperature in lower part of body was about 900^{o}C. The velocity of immersion was $\approx 1{,}2 \cdot 10^{-3}$ cm/sek. Unfortunately the velocity was not measured under condition of temperature variation.

The main problem of RW status is the final elimination of long-living elements of RW (as TRU, isotopes of technetium etc). The solving of this problem is a purpose of development of the RW self-disposal method. Some words have to say about the contents of radionuclide in matrix. Heat power is supported by decay of shot-living isotopes (similar ^{90}Sr and ^{137}Cs), moreover their concentration are estimated about 1-2% (mol). These components are the main in the RW composition, as a result the RW is likely to be contained in solid matrix without any fractionation.

The method of self-immersion of RW one may use as an additional method to the deep geological disposal approach. The basic problem in the case when RW arranged inside the container releases heat as a result of radioactive decay is to find a container material that remains firm in a temperature of about 1300-1400°C in melted rock (for example basalt). This problem is considered in connection with the question of radioactive matrix choice and compatibility of materials [8].

For conclusion we may mention that many tasks are to be solve for realization of method (generally conceptual, scientific and tehnological tasks) but this method of the RW self-disposal in rock-salt gives the safe and reliable opportunity to close the RW problem.

References.

1. B.Cohen. - Uspehi phisicheskih nauk, 1978, v. 126, № 1, p.p. 101-123 (in Russ).
2. Nikiforov, A.S., Kastcheev, V.A., Poluektov, P.P. and Polyakov, A.S. - Atomnaya Energuya, 1988, v. 64, № 2, p.p. 453-454, (in Russ).
3. Emerman, S.H., Turkofte, D.L. - Int. J. Heat and Mass Transfer, 1983, v. 26, № 11, p.p. 1625-1630.
4. Kastcheev, V.A., Nikiforov, P.P., Polyakov, A.S. - Atomnaya Energuya, 1992, v. 73, № 3, p.p. 215-221 (in Russ).
5. The Tables of Physical Values. Ed. Kikoin, I.K. - Moscow, Atomizdat (1976), 1046 p., (in Russ).
6. Guegusin, Ja. E. The bubbles. - Moscow, Nauka (1985), p. 176, (in Russ).
7. Efankin, V.G., Kastcheev, V.A., Poluektov, P.P., Polyakov, A.S. - Atomnaya Energuya, 1994, v. 76, № 2, p.p. 161-163, (in Russ).
8/ Vertman A.A., Polyakov A.S., Poluektov P.P. - Advans Performans Matterials 4, 239-245 (1997), Kluwer Academic Publishers.