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# CALCULATION OF THE VOLUME DETERMINATION ERROR OF THE UNDERGROUND GAS STORAGE CAVERN BY SONAR MEASUREMENTS

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*In work calculation of an error of scoping of a underground cavity by a method* sonar *measurement the shooting connected to a curvature of a sound beam depending on change of salinity and temperature of water will be carried out.*

## Introduction

For maintenance безаварийности technological processes of creation and operation of underground storehouses of hydrocarbons in hydrochloric adjournment by him it is necessary to give strictly certain form. A successful construction of underground capacities, optimum change of parameters выщелачивания, realization of operations on liquidation of insoluble partitions and accident-free operation of underground capacities is essentially complicated without periodic measurements of the form and volume of underground chambers.

Now the way of definition of the form and volume of underground capacities by a method sonar measurement shootings is used. This method consists in the following: the radiator of ultrasound located in chink a shell, generates pulses of elastic fluctuations which start to be distributed in an environment. The elastic wave through the certain time interval, reaches a wall of the underground chamber, is reflected from it and at a favorable corner of an inclination of a wall comes back to a radiator working at this moment in a mode of reception.

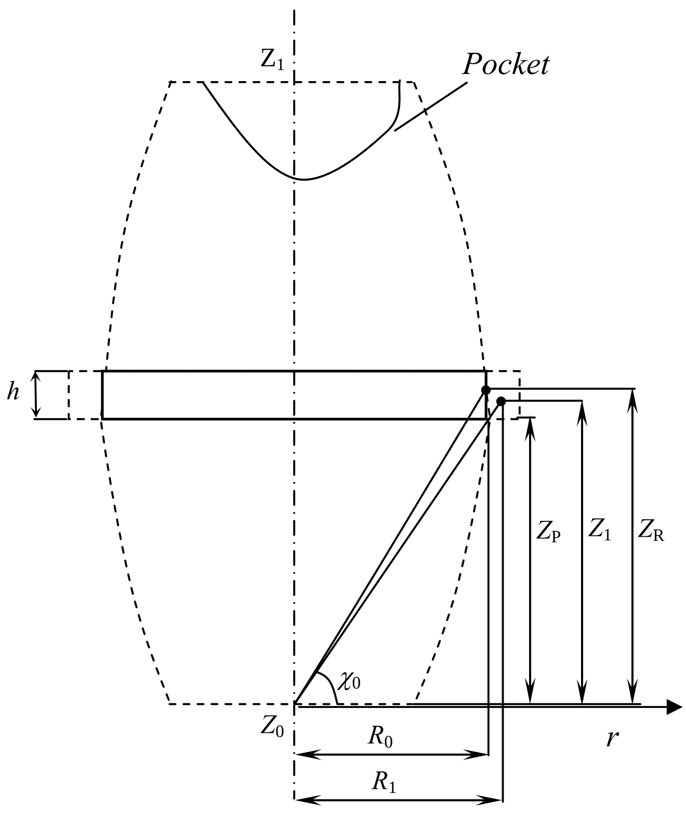



**Figure 1**

At washout of capacity so-called "pockets" can be formed (figure 1), measurement in which it is possible to carry out fig. only an inclined beam.

However in the non-uniform environment there is a curvature of a sound beam which is connected to change of salinity and temperatures of water with depth, than distinction of speed of distribution of elastic waves on volume of a cavity is caused. Such curvature of a course of a beam results in occurrence of an error of scoping of a underground cavity. The specified distinction of temperature and salinity on volume of a cavity is caused by that in process alkalizing in it swing fresh water from a surface, and she has smaller temperature, than on depth of several hundreds or thousand meters where there is a washout. When water delivery from a surface is made through a pipe in the top part of a cavity, and its removal - through other pipe located in the bottom part. The temperature and salinity of water in the top part of capacity appear below, than these parameters of water in the bottom part. At the same time calculation is conducted on the speed appropriate to a point of radiation. At realization of measurements it is necessary to take into account a curvature of a trajectory of a beam and non-uniformity of speed on this trajectory or to estimate an error which thus can arise.

**Calculation of a methodical error of scoping of a underground cavity by a method sonar measurement shootings**

Let's assume, that the dot radiator is located in a point with coordinates (0, Z0) (figure 1). The horizontal distance, passable a beam from a radiator up to a point located at some other level z, will be equal

$$r = \pm \int_{z_0}^{z} \frac{dz}{tg\chi(z)}$$ ; (1)

The corner of sliding *χ (z)* a beam at an any level z is connected to a corner *χ0* an output(exit) of a beam from a radiator a parity

$$C(z)\cos\chi_0 = C_0 \cos\chi(z)$$ ; (2)

Where *C (z)* and $C_0$ - speeds of distribution of waves in the beginning of coordinates and at height *z*. To find from a parity (2) $tg\chi(z)$ receive the equations of a beam as

$$r(z) = \cos(\chi_0)\cdot \int_{z_0}^{z} \frac{1}{\sqrt{n(z)^2 - \cos(\chi_0)^2}}\, dz$$ ; (3)

Where

$$n(z) = \frac{C(T_0, S_0)}{C(S(z), T(z))}$$ ; (4)

Factor of refraction, *S* - salinity, %; *T* - temperature, °C.

Let's accept values z0 = 0 m, z1 = 50 m, *S0* = 32 %, *S1* =0 and $\chi_0 = \frac{\pi}{3}$ It is glad.
After substitution of values in the equation (3) diagram of a deviation of a trajectory of a beam depending on coordinate z (figure 2). From the diagram it is visible, that with increase of depth the beam changes a trajectory of movement. It is connected to increase of salinity and temperatures of water with increase of depth (figure 3).

Thus for calculation of speed of a sound in salty water the empirical formula received Del Grosso [1] is used

$$C(S,T) = 1448{,}6 + 4{,}618T - 0{,}0523T^2 + 0{,}00023T^3 + 1{,}25(S-35) - 0{,}011(S-35)\cdot T + $$
$$+ 0{,}0027\cdot 10^{-5}\cdot (S-35)\cdot T^4 - 2\cdot 10^{-7}\cdot (S-35)^4\cdot (1 + 0{,}577\cdot T - 0{,}0072\cdot T^2)$$ ; (5)

Where *S* - salinity, %
*T* - temperature, °C

$$S(z) = S_0 + \frac{S_1 - S_0}{z_1 - z_0}\cdot z; T(z) = T_0 + \frac{T_1 - T_0}{z_1 - z_0}\cdot z$$ ; (6)

Dependences of speed *with* from salinity *S* and look like temperature *T*, represented on figure 4.

Under diagrams it is possible to see, that value of speed of elastic waves grows with increase of salinity and temperatures of water.

Calculation of a transit time of a sound pulse on a beam from a radiator up to a wall of the chamber is made under the formula (7).

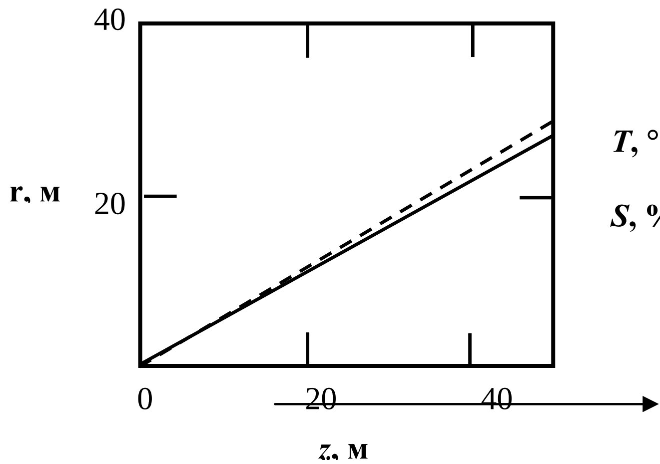



Figure 2

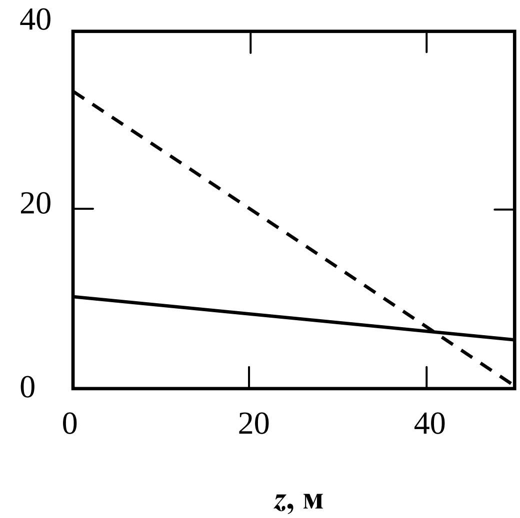



Figure 3

$$t(z) = \frac{r(z)}{C(S(z),T(z))} \cdot \cos(\chi_0) + \frac{1}{C(S(z),T(z))} \cdot \int_{z_0}^{z} \sqrt{n(z)^2 - \cos(\chi_0)^2}\, dz \quad ; (7)$$

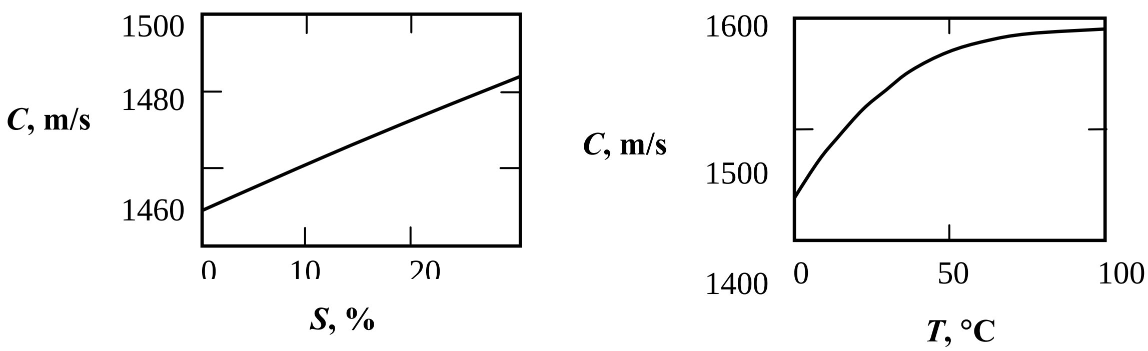



Figure 4

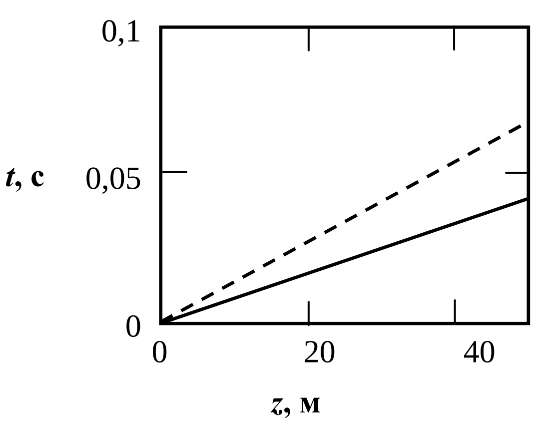



Figure 5

$$t_0(z) = \frac{z}{\cos(\chi_0)} \cdot \frac{1}{C(S(z_0),T(z_0))} \quad ; (8)$$

As a result of calculations the diagram (figure 5) a transit time of a sound pulse from a radiator up to the certain height $z$ was constructed. However interest represents not a transit time up to identical height, and a transit time up to a wall of cylindrical development in radius $R_0$. As the beam is bent upwards, measured time will be more, than real. At the same time calculation of radius will be carried out by multiplication of speed for the period of distribution that will give the overestimated result, in comparison with real distance along a rectilinear direction of a beam up to a wall of development(manufacture). Thus the designed radius will be more real.

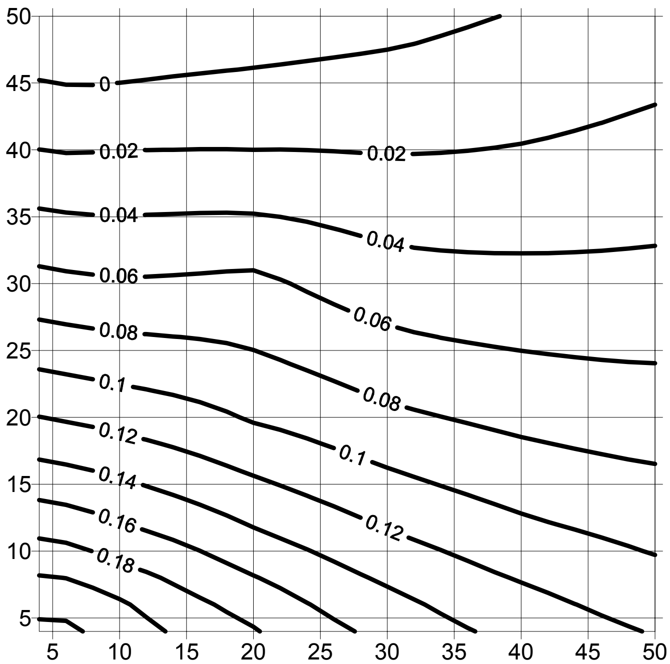
If designate $V_p$ as apparent volume of a layer,

$$V_p = \pi \cdot R_p^2 h \quad (9),$$

We can calculate relative error. Here is *h* - height of a layer of the cylindrical form (figure 1).

The error of scoping of underground capacity sonar measurement shootings is made by a method under the formula (10).

$$\frac{\Delta V}{V_0} = \frac{V_\kappa - V_p}{V_p}; (10)$$




- Real volume of a layer. Here *h* - height of a layer of the cylindrical form (figure 1).

Calculation of apparent value of radius of development is made under the formula (13)

$$Z = R_p \cdot tg(\chi_0); (11)$$

$$l_\kappa = t(Z) \cdot C(S(Z_0), T(Z_0)); (12)$$

$$R_\kappa = l_\kappa \cdot \cos(\chi_0); (13)$$

Where the radius of layer $R_p$ was accepted equal 15 m.

Results of calculation of an error of measurement of volume at values of bottom and top temperatures $T_0$ and $T_1$ accordingly and below and 0 % above on 50 m of height of capacity are given a gradient of salinity of 32 % on fig. 6.

From these izoline equal errors follows, that the size of an error depends both on a difference of temperatures, and from temperature $T_0$ in the bottom part of capacity. So, for example, at temperatures $T_0$ = 50ºC and $T_1$ = 25ºC the error of scoping does not exceed 6 %. At the same time at $T_0$ = 30º C and $T_1$ = 5ºC (an identical difference of temperatures 25º C) she is increased up to 15 %, that in some cases can appear unacceptable for practice.

## Conclusions

As a result of the carried out(spent) calculations it was received, that non-uniformity of a temperature field and salinity on volume of a cavity at sonar measurement to shooting can bring in an essential error to measurement of the volume, exceeding 10 %. It puts a question on necessity of development of techniques of updating of this error or realization of measurements in the established fields.

## REFERENCE

1. Lysanov J.P. " Theoretical bases of hydroacoustics ", Moscow, The higher School, 1965. – 235page.