An automated system for measuring brine parameters in caverns under construction

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Underground caverns are constructed in rock salt deposits for liquid and gaseous hydrocarbon storage by geotechnological methods using drill wells with a special step control.
The development of automated monitoring systems for cavern creation during all steps of the reservoir construction while the parameters of the construction brine are changing because of the non-uniformity of the lithological structure of the salt massive is the actual problem.
During construction of an underground cavern it is constantly necessary to monitor the blanket-brine interface alterations, to measure the expenditure of supply water and the brine withdrawal, pressure and temperature parameters of working media, the obtained brine concentration, the quality of insolubles, and the supplies on surface. The concentration of the brine, formed under construction is changed from weakly mineralised to saturated.
The current geometrical volume of underground cavern on salt drawn out is calculated using measured brine parameters.
The blanket-brine interface can be defined by geophysical and electrocontact methods. The cavern form monitored during and after construction by sonar survey.
The concentration of the sodium chloride in the solution is determined by measuring the specific conductivity and temperature of the brine in-line.
An automated measurement system for brine parameters was developed by Podzemgazprom, Ltd jointly with <<Shirshov institute of Oceanology)) and <<Akvastandart>>, which can operate in the range of 5-317 kg salt/m^3 and under +2 - +36 ^{0}C and pressure till 25 bars. The device is based on the method of electromagnetic induction using a contactless transformed measuring transmitter for the brine conductivity.
The automated monitoring system consists of a measure transmitter for temperature, pressure and specific conductivity, a brine flowmeter, an analog-to-digital device and a computer program.
To ensure a high sensitivity, all conductivity measurement channels were subdivided into two regions corresponding to brine concentration of 5-317 and 240-317 kg salt/m3.
The calibration of the transmitter block was carried by adjusting the two operation using brine standard assays of various concentrations. The standard sodium chloride solutions prepared were in the range 5 to 315 kg salt/m^3. Seventeen brine assays with a concentration pitch of 20 kg salt /m^3 for the wide range and nine brine assays with concentration pitch 10 kg salt/m^3 for narrow range were prepared using sodium chloride (99.7% NaCl) as standard salt.
At the chemical laboratory a study was made of component composition determination using prepared standard solutions. For the study, the chemical and potentiometrical technique of chloride estimation were used. Chlorine, calcium, magnesium and sulphate ion concentrations in solutions were determined by the chemical technique. The concentration of sodium ions in solution was determined by the potentiometrical technique, selective to monoatomic cations.
The total error of the chloride ion measurement in the concentration ranging from 0.01 to 5.0 mol/l is +1% and the error in the calcium ion concentration in the range from 0.002 to 0.5 mol/l is $\pm$1,5%.
To calibrate the transmitter block a laboratory setup was carried out. It consisted of a measurement glass of 1000 ml, a magnetic mixer with heater elements, a transmitter measurement block, a manager block and a personal computer.
The calibration carried out in following order: the glass with standard assay of a known concentration was set up on electromagnetic mixer. The

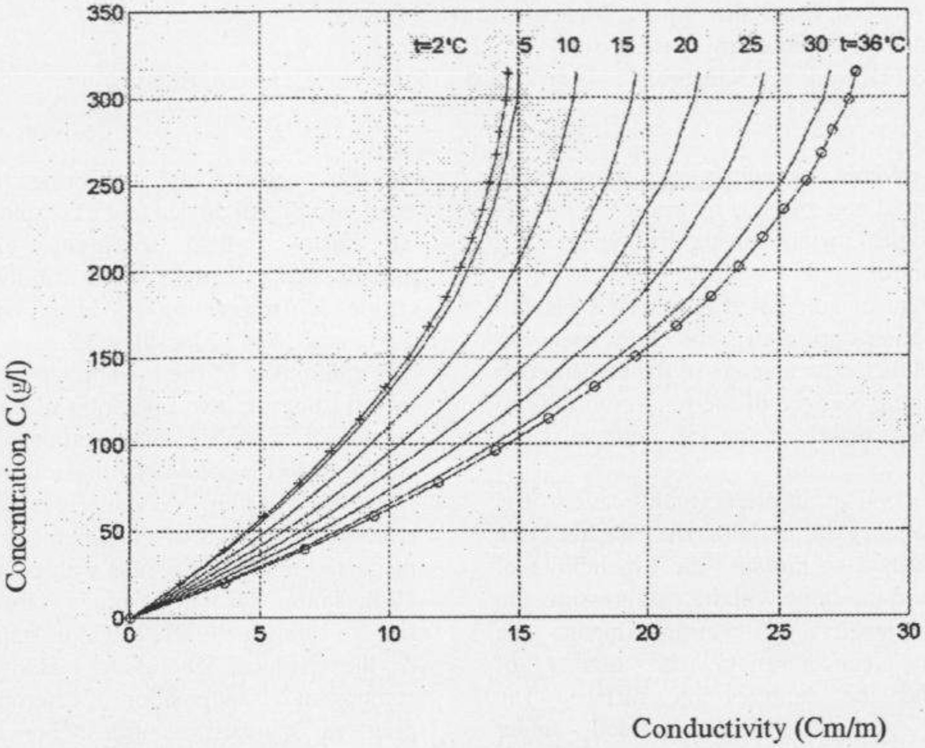


Figure 1. Calibration variety in the concentration range from 5 to 315 kg/m^3

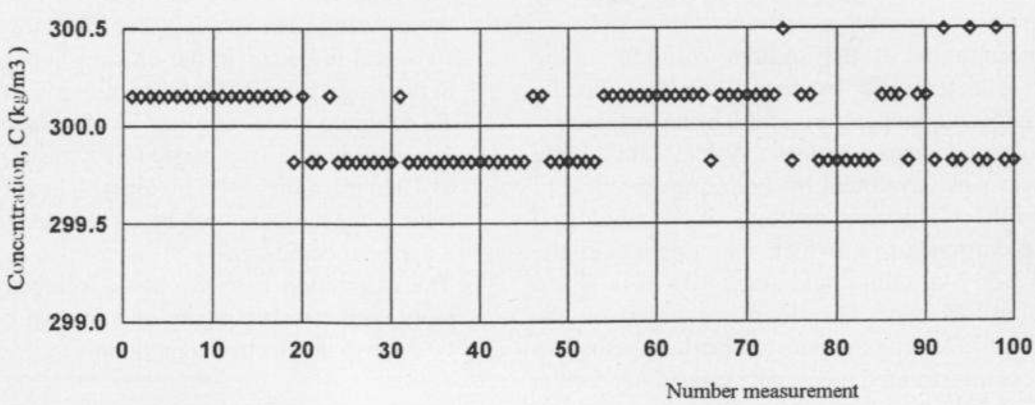


Figure 2. The measurement error of brine concentration

transmitter block was put into it. Continuous brine mixing was achieved by switching on the electromagnetic mixer. The brine temperature was smoothly changed in the range from 2 to 35 ^{0}C. The calibration is specialin the sense that the brine is continuously heated or cooled, instead of the usual thermostating. This method is acceptable because of the high technical performance parameters of measurement complex, the transmitters discreteness allows them to perform up to 5 measurements per second with a temperature measurement accuracy of 0.05^{0}C.

A program was developed for calibration in the MATLAB system (The MathWorks, Inc.USA). It is interactive system to elaborate engineering and research estimation of data arrays.

The arrays of experimental data on all assays are processed and ordered as a data matrix, reflecting the change in conductivity in dependence of the temperature and the brine concentration.

The data are used to calculate the polynomial coefficients, by evaluating the change in absolute conductivity R depending on the change in concentration C.

The developed program allows to calculate coefficients P(I) - P(n+l) polynomials P(x)n, which approximates by a least square method the function C = f(R), being a gauge curve, using experimental data. The program calculates values of polynomial by the following formula.

$C(R) = P_1 R^n + P_2 R^{n-1} + \dots + PnR + P(n+l)$ in a point Ri,

Where R_i is the brine conductivity.

On fig. 1 the totality of gauge variety of brine concentrations for the alteration of the absolute conductivity R for various values of the brine temperature in the range from 5 to 13 gram/litre are given.

Using these results the specific conductivity of a standard brine assay (C = 300 kg/m3, t = 20T) is measured for both measuring ranges D_1 and D_2 of the transmitter block.

The processing results of obtained data for range D_1 are represented on fig.2. As graph shows, the scatter of calculated values of brine concentration is between C = 300.49 kg/m^3 and C = 299.48 kg/m^3 Maximum divergence of standard brine assay with obtained data is C = 0.49-0.52 kg/m^3. The measurement error of specific conductivity was for the D_1 range equal to +/- 0.17% and for D_2 range +/- 0.06%.

In 1998 at Novomoskovsk brine field of chemical plant 'Nitrogen" the experimental and industrial trials of automated system brine parameters measurement, obtained in process of washing were carried out.

The trial purposes were: the control of the system operation in industrial conditions, improvement of the measurement of brine parameters, real-time data processing, improvement of processing technique of obtained data, selection and chemical analysis of brine assays, the comparison of brine concentration indications, measured by different means.

The trials were carried as follows. A transmitter block containing equipment for measurement of temperature, pressure and specific conductivity was places as a modular item on a vertical site of brine pipeline.

Above the transmitter block a flow-meter of a brand RTR-100 (error ±1.5%) was placed. It was used for determining brine expenditure.

The data from transmitters block of specific conductivity measurements, temperature and brine were continuously transmitted pressure by a communication circuit and received by the information and control block, then transmitted to the computer for processing.

In fig.3 the experimental data on the alteration of the brine concentration during the process of underground cavity creation within 7 hours of continuous measurements by the automated complex are shown. The arrays of calculated values of the obtained brine concentration, data of daily average expenditure and temporal parameters (data of operation start, common duration of the creation process etc.) are the input parameters for the monitoring program of the underground reservoir creation

For gathering and processing of measurement data, definition of geometrical volume created underground cavity on salt mass taken out a set computer programs constructed using modular principles was developed.

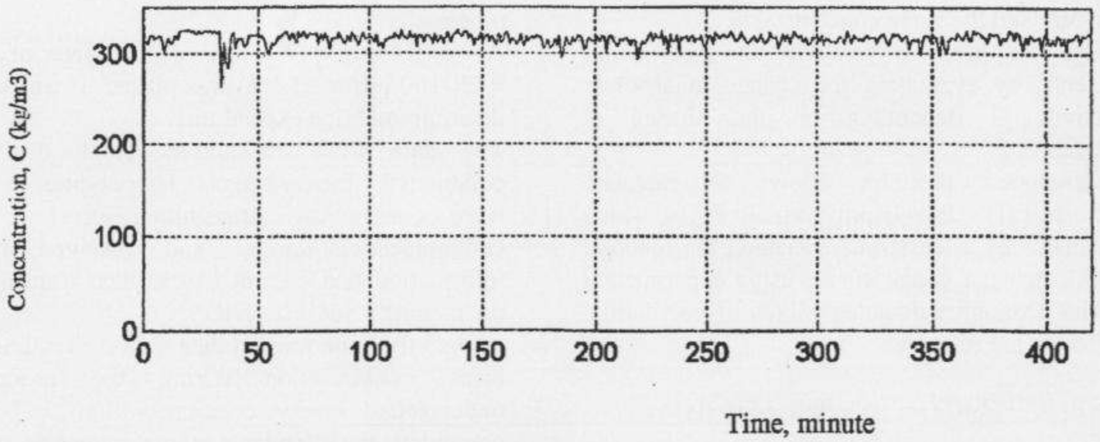
The package includes three programs:

- The program for data collection from the transmitters block of conductivity measurements, temperature, pressure and brine expenditure;
- The program for assimilation measurement data, calculation and array accumulation of the alteration of the brine concentration and consumption parameters;
- The monitoring program of underground reservoir process creation allowing to calculate the salt mass, obtained over time and to monitor the increase in underground cavity volume in every stage creation process

In fig. 4 the results of experimental data processing are shown. Based expenditure and measured brine concentrations the increase in capacity of the underground cavity is calculated from the moment when the trial was begun.

The monitoring of the growth of the underground reservoir volume allows gives the operator more influence on the creation process, periods of construction, and in time to introduce corrective measures in the creation process in order to obtain the desired cavity form.

From the results of trial and industrial tests it is possible to draw the following conclusion: the developed automated system and package software allows the control of the underground reservoir creation process.



Figurere 3. The brine concentration variety while meassurement comples testing

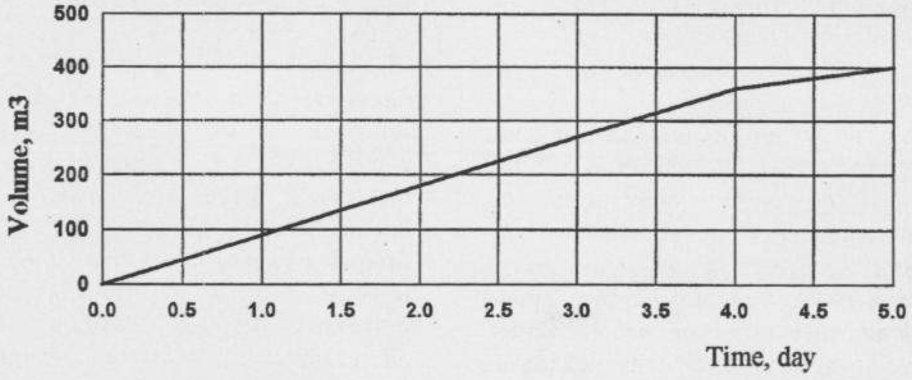


Figure 4. Volume alteration under cavern construction