

Prediction of Formation Water Properties Using a Novel Predictive Tool Approach and Vandermonde Matrix

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Production of wet crude due to the raise in oil-water contact in many oil fields has been a growing field problem and consequently production of salty wet crude affects the quality of crudes. In this work a simple method using Arrhenius-type function and Vandermonde matrix is presented for estimation of formation water properties for temperatures above 30 °C and salt contents between 5 and 25% by mass. Estimations are found to be in excellent agreement with the reliable data in the literature with average absolute deviation varying between 0.08 to 2.7%. The method developed in this study is of immense practical value for petroleum engineers and practice engineers for a quick check on the formation water properties at various conditions without opting for any experimental measurements. In particular chemical and petroleum engineers would find the proposed approach to be user-friendly with transparent calculations involving no complex expressions.

Key words: formation water, correlation, production engineering, mathematical modelling

1. Introduction

Most oil wells eventually produce some quantity of formation water over their lifetime. Increased water production is usually indicated by a significant increase in the Water to Oil ratio (WOR) of the well. As the WOR of well increases it causes costly added water handling reduced efficiency of the depletion mechanism the afflicted well may be abandoned early loss of the total field overall recovery and formation water is corrosive and its disposal becomes expensive. Nearly all hydrocarbon reservoirs are surrounded by water-bearing rocks called aquifers.¹ These aquifers may be substantially larger than the oil or gas reservoirs they adjoin as to appear infinite in size or they may be small in size as to be negligible in their effect on reservoir performance.^{1,11} In hydrocarbon reservoirs water coning is underlying the upward movement of formation water into the perforations of a producing well and this can seriously impact the well productivity and influence the degree of depletion and the overall recovery efficiency of oil reservoirs. Production of wet crude due to the raise in oil-water contact in many oil fields has been a growing field problem and production of salty wet crude consequently affects the quality of crudes and a number of wells had to close down due to lack of adequate treating facilities.²⁰ The produced water with crude in oil fields usually contains salts in the concentration of 150 000 to 220 000 ppm (15 to 22 mass percent).¹⁹

The salinity of the connate water has been found to be a primary factor controlling the oil recovery.^{18,17} Quite a number of technical papers have been published to address the various technical points on formation water issues.^{14,3,12,5,9} Since there is no simple-to-use computer program exists to date in the literature for rapid estimation of formation water properties (namely liquid saturation pressure enthalpy and density) our efforts directed

at formulating simple-to-use computer programs using Matlab¹⁰ are expected to assist engineers for rapid calculation of the formation water properties (namely liquid saturation pressure, enthalpy and density) using an Arrhenius-type asymptotic exponential function which is easy-to-use. The proposed novel tools in the present work are simple and unique formulations which are non-existent in the literature. Furthermore the selected exponential function to develop the tool leads to well-behaved (i.e. smooth and non-oscillatory) equations enabling fast and more accurate predictions.

2. Methodology for the development of simple Matlab based computer program

The primary purpose of the present study is to accurately correlate the formation water properties data⁴ as a function of temperature and formation water salt content (mass fraction). This is done by a simple computer program using an Arrhenius-type asymptotic exponential function with a small modification of the Vogel-Tammann-Fulcher (VTF) equation.^{16,15,6}

This is important because such an accurate and mathematically simple correlation of the formation water properties as a function of temperature and formation water salt content is required frequently for quick engineering calculations to avoid additional computational burden of complicated calculations. The Vogel-Tammann-Fulcher (VTF) equation^{16,15,6} is an asymptotic exponential function that is given in the following general form:

$$\ln f = \ln(f_c) - \frac{E}{R(T - T_c)} \quad (1)$$

In equation (1) f is a properly defined temperature-dependent parameter the units for which are determined individually for a certain property; f_c is a pre-exponential coefficient having the same unit of the property of interest; T and T_c are the actual temperature and the characteristic-limit temperature respectively (both given in degrees Kelvin); E is referenced as the activation energy of the process causing parameter variation (given in units of J/kmol); and R is the universal gas constant (R) 8.314 J/(kmol K). A special case of the Vogel-Tammann-Fulcher (VTF) equation^{16,15,6} for $T_c = 0$ is the well-known Arrhenius² equation.

For the purpose of the present application which involves the correlation of formation water properties as a function of temperature the Vogel-Tammann-Fulcher (VTF) equation^{16,15,6}; has been modified in the following form by adding second-order and third order terms:

$$\ln f = \ln f_c + \frac{b}{T - T_c} + \frac{c}{(T - T_c)^2} + \frac{d}{(T - T_c)^3} \tag{2}$$

In equation (2) T_c has been considered zero to convert equation (2) to the well-known Arrhenius equation² type. (See equation 3)

$$\ln f = \ln f_c + \frac{b}{T} + \frac{c}{T^2} + \frac{d}{T^3} \tag{3}$$

The required data to develop this correlation includes the reported data for the reservoir formation water (brine) properties as a function of temperature and formation water salt content. The following methodology has been applied to develop this correlation.

2.1. Vandermonde matrix

Vandermonde matrix is a matrix with the terms of a geometric progression in each row i.e. an $m \times n$ matrix⁸:

$$V = \begin{bmatrix} 1 & \alpha_1 & \alpha_1^2 & \dots & \alpha_1^{n-1} \\ 1 & \alpha_2 & \alpha_2^2 & \dots & \alpha_2^{n-1} \\ 1 & \alpha_3 & \alpha_3^2 & \dots & \alpha_3^{n-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & \alpha_m & \alpha_m^2 & \dots & \alpha_m^{n-1} \end{bmatrix} \tag{4}$$

or

$$V_{i,j} = \alpha_i^{j-1} \tag{5}$$

For all indices i and j the determinant of a square Vandermonde matrix (where $m=n$) can be expressed as⁸ (Horn and Johnson 1991):

$$\det(V) = \prod_{i < j \leq n} (\alpha_j - \alpha_i) \tag{6}$$

The Vandermonde matrix evaluates a polynomial $a_0 + a_1x + a_2x^2 + \dots + a_{n-1}x^{n-1}$ at a set of points; formally it transforms *coefficients* of a polynomial to the values the polynomial takes at the point's α_i . The non-vanishing of the Vandermonde determinant for distinct points α_i shows that for distinct points the map from coefficients to values at those points is a one-to-one correspondence and thus that the polynomial interpolation problem is solvable with unique solution; this result is called the unisolvence theorem.⁷ They are thus useful in polynomial interpolation since solving the system of linear equations $Vu = y$ for u with V and $m \times n$ Vandermonde matrix is equivalent to finding the coefficients u_j of the polynomial (s).⁷

$$P'(x) = \sum_{j=0}^{n-1} u_j x^j \tag{7}$$

of degree $\leq n-1$ which has (have) the property:

$$P'(\alpha_i) = y_i \text{ for } i=1 \dots m \tag{8}$$

The Vandermonde matrix can easily be inverted in terms of Lagrange basis polynomials: each *column* is the coefficients of the Lagrange basis polynomial with terms

Tablica 1.			
Coefficient	Values for formation water density	Values for formation water vapor pressure	Values for formation water enthalpy
A_1	4.063244865	-7.04556549	1.797809351x10 ¹
B_1	1.000079593x10 ¹	1.307249067x10 ²	-2.655643093
C_1	-8.795847952	-9.95570818x10 ²	-2.150551077
D_1	-1.577395814x10 ¹	2.249083079x10 ³	1.048046517x10 ¹
A_2	2.558887165x10 ³	3.089756019x10 ⁴	-3.689786089x10 ³
B_2	-9.052509303x10 ³	-1.896459828x10 ⁵	1.445893286x10 ³
C_2	9.904460862x10 ³	1.440423792x10 ⁶	1.556796014x10 ³
D_2	1.196976637x10 ⁴	-3.267875129x10 ⁷	-7.015035019x10 ³
A_3	-7.950125161x10 ⁵	-1.721360113x10 ⁷	1.188424501x10 ⁶
B_3	2.990313240x10 ⁶	9.032945444x10 ⁶	-4.657607524x10 ⁵
B_4	-3.408171801x10 ⁸	-1.418915942x10 ¹⁰	7.542204755x10 ⁷
C_4	4.617706624x10 ⁸	1.084009226x10 ¹¹	8.114755519x10 ⁷
D_4	2.507241284x10 ⁸	-2.472823251x10 ¹¹	-3.657489476x10 ⁸

in increasing order going down. The resulting solution to the interpolation problem is called the Lagrange polynomial.⁷

2.2 Developing the Computer program

Firstly formation water property data⁴ (Denver Research Institute 1964 Dittman 1977) namely liquid saturation pressure enthalpy and density are correlated as a function of temperature for several formation water salt content mass fractions (ψ). Then the calculated coefficients for these equations are correlated as a function of formation water salt content mass fractions (ψ). The derived equations are applied to calculate new coefficients for equations (9) (10) and (11) to predict formation water property. Table 1 shows the tuned coefficients for equations (12) to (15) for predicting formation water properties.

In brief the following steps are repeated to tune the correlation's coefficients:

1. Correlate the formation water property data (namely liquid saturation pressure, enthalpy and density) as a function of temperature (T) for a given formation water salt content in mass fraction (ψ).
2. Repeat step 1 for other formation water salt content in mass fractions (ψ).
3. Correlate corresponding polynomial coefficients which were obtained for different temperature versus formation water salt content in mass fractions (ψ) $a = f(\psi)$ $b = f(\psi)$ $c = f(\psi)$ $d = f(\psi)$ [see equations (12)-(15)].

Equations (9-11) represent the proposed governing equation in which four coefficients are used to correlate the formation water property data (namely liquid saturation pressure enthalpy and density) as a function of tem-

perature (T) for a given formation water salt content where the relevant coefficients have been reported in Table 1.

$$\ln(H) = a + \frac{b}{T} + \frac{c}{T^2} + \frac{d}{T^3} \tag{9}$$

$$\ln(\rho) = a + \frac{b}{T} + \frac{c}{T^2} + \frac{d}{T^3} \tag{10}$$

$$\ln(p) = a + \frac{b}{T} + \frac{c}{T^2} + \frac{d}{T^3} \tag{11}$$

where:

$$a = A_1 + B_1\psi + C_1\psi^2 + D_1\psi^3 \tag{12}$$

$$b = A_2 + B_2\psi + C_2\psi^2 + D_2\psi^3 \tag{13}$$

$$c = A_3 + B_3\psi + C_3\psi^2 + D_3\psi^3 \tag{14}$$

$$d = A_4 + B_4\psi + C_4\psi^2 + D_4\psi^3 \tag{15}$$

These optimum tuned coefficients help to cover the temperatures above 30 °C and formation water salt contents up to 0.30 mass fraction. The optimum tuned coefficients given in Table 1 can be further retuned quickly according to the proposed approach if more reliable data are available in the future. The proposed novel tool developed in the present work is simple and unique expression which is non-existent in the literature. Furthermore the selected exponential function to develop the tool leads to well-behaved (i.e. smooth and non-oscillatory) equations enabling fast and more accurate predictions.

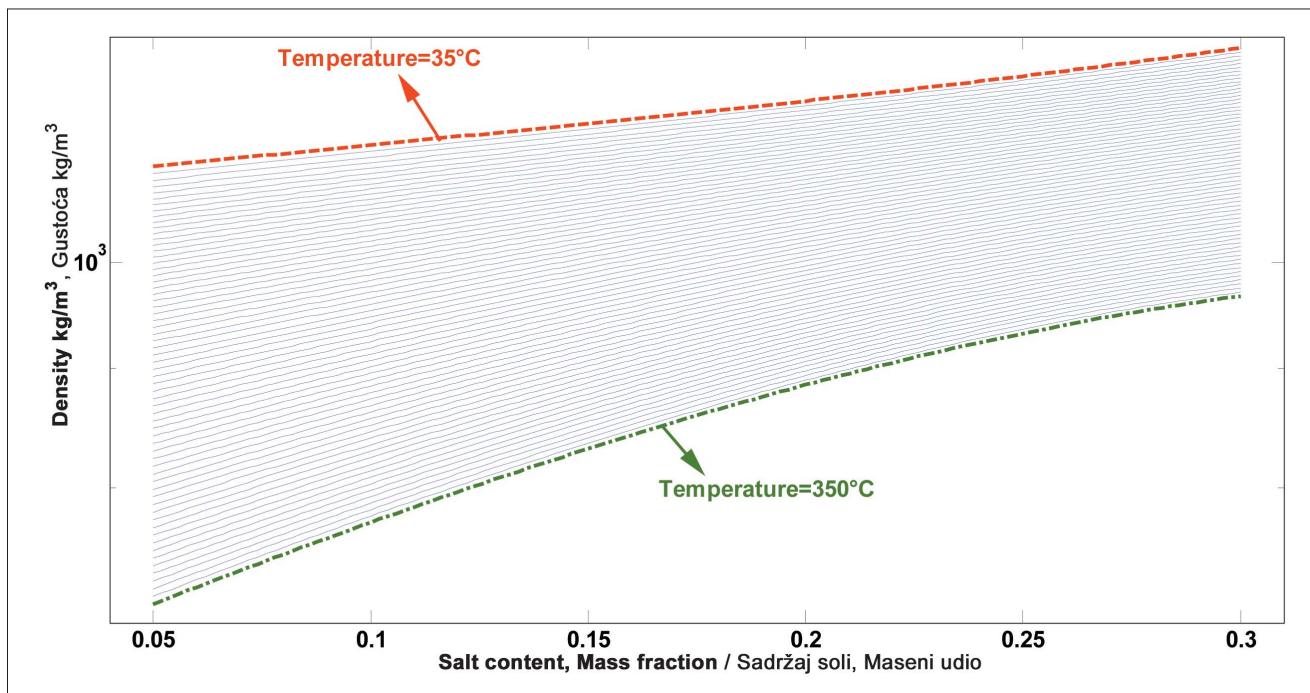


Fig. 1. Performance of proposed computer program for calculating formation water saturated density
 Sl. 1. Izvedba predloženog računalnog programa za izračunavanje gustoće slojne vode

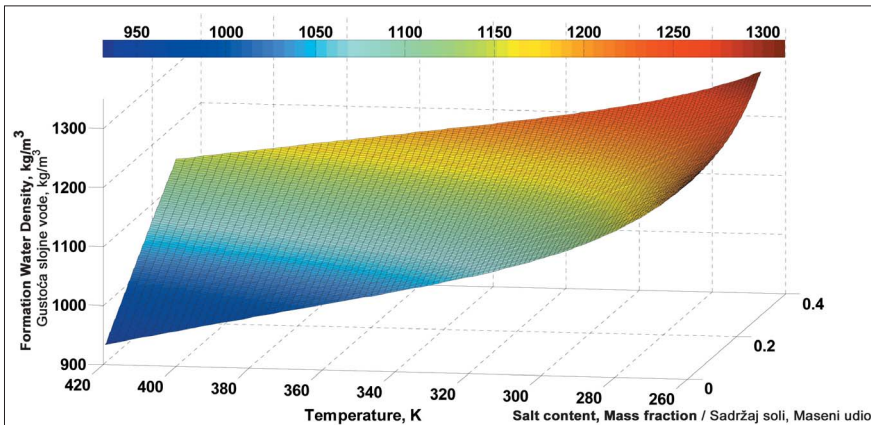


Fig. 2. Performance of proposed computer program for calculating formation water in another view point (color bar shows density)

Sl. 2. Izvedba predloženog računalnog programa za izračunavanje gustoće slojne vode na drugoj točki osmatranja (boja pokazuje gustoću)

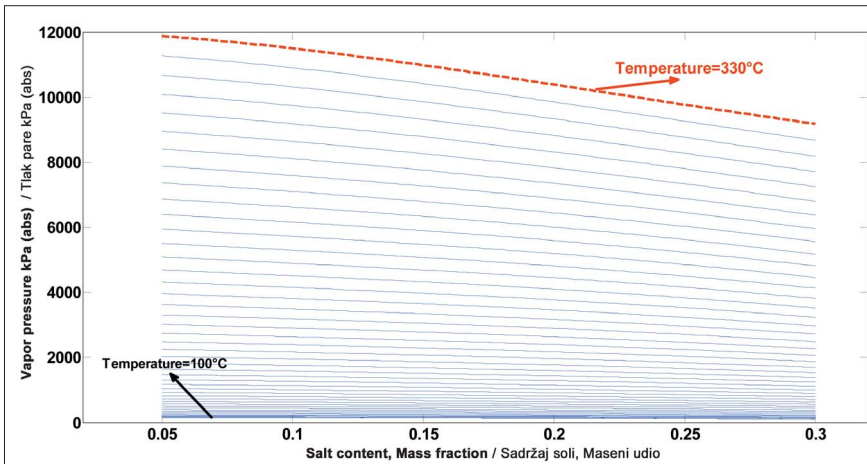


Fig. 3. Performance of proposed computer program for calculating formation water vapor pressure

Sl. 3. Izvedba predloženog računalnog programa za izračunavanje tlaka pare slojne vode

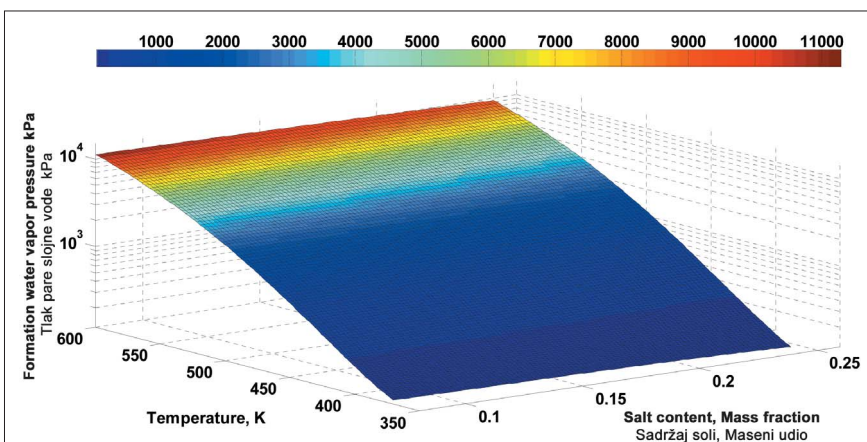


Fig. 4. Performance of proposed computer program for calculating formation water vapor pressure in another view point (color bar shows vapor pressure)

Sl. 4. Izvedba predloženog računalnog programa za izračunavanje predviđanje tlaka pare slojne vode na drugoj točki osmatranja (boja pokazuje tlak pare)

3. Results

Figures 1 and 2 illustrate the performance of proposed computer program for calculating formation water density in two different view points for formation water salt content up to 0.30 mass fraction. Figures 3 and 4 show the proposed computer program performance in the prediction of formation water vapor pressure in two different view points for wide range of conditions. Figures 5 and 6 show the proposed computer program performance in the prediction of formation water enthalpy in two different view points for wide range of conditions. Tables 2-4 illustrate the accuracy of proposed computer programs for predicting the formation water density, enthalpy and vapor pressure in comparison with reported data in the literature.⁴ The accuracy of correlation in terms of average absolute deviations for formation water density enthalpy and vapor pressure were found to be 0.08, 0.19 and 2.7% respectively. In this study our efforts have been directed at formulating a simple-to-use method that can help engineers and researchers. It is expected that our efforts in this investigation will pave the way for arriving at an accurate prediction of formation water properties at various conditions which can be used by engineers and scientists for monitoring the key parameters periodically.

4. Conclusions

In this work a simple-to-use and Arrhenius-type computer program is presented here for the estimation of formation water properties (namely liquid saturation pressure, enthalpy and density) for temperatures above 30 °C and for salt contents between 5 and 25% by mass. Unlike complex mathematical approaches for estimation of these properties the proposed computer program is simple-to-use and would be of immense help for process engineers especially those dealing with petroleum production and reservoir engineers. Additionally the level of mathematical formulations associated with the estimation of formation water (brine) properties can be easily handled by an oil and gas practitioners as well as petroleum engineers without any in-depth mathematical abilities. Example

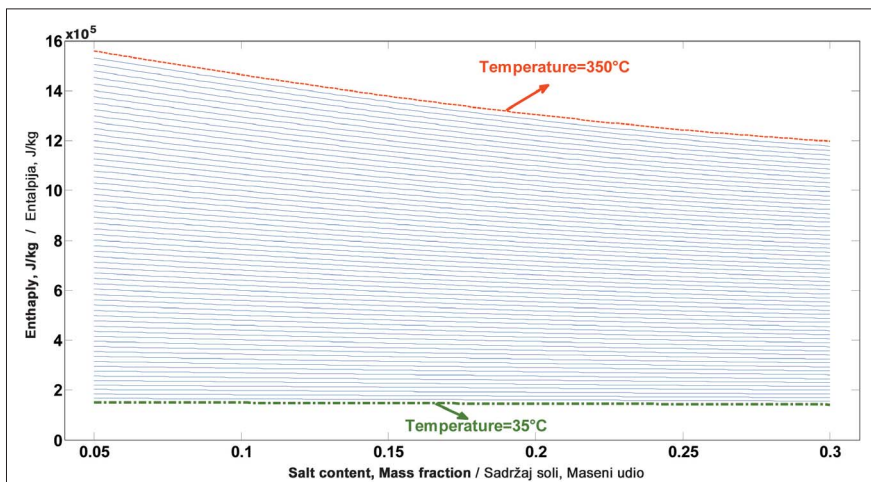


Fig. 5. Performance of proposed computer program for calculating formation water enthalpy

Sl. 5. Izvedba predloženog računalnog programa za izračunavanje entalpije slojne vode

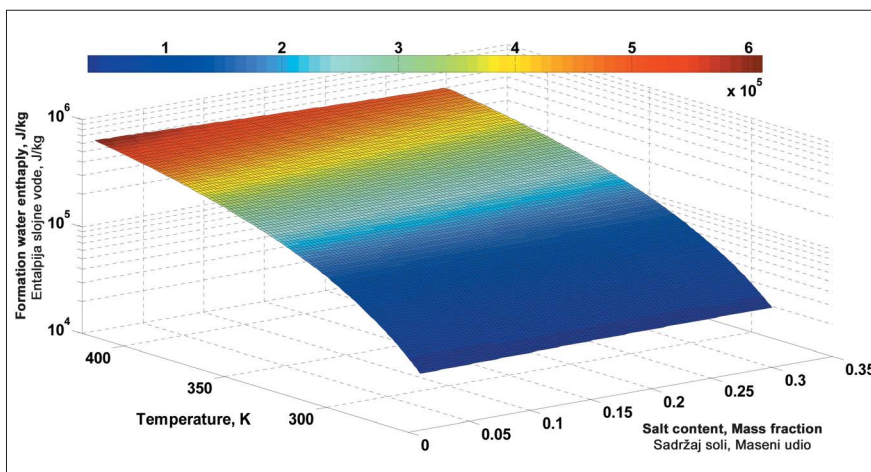


Fig. 6. Performance of proposed computer program for calculating formation water enthalpy in another view point (color bar shows enthalpy)

Sl. 6. Izvedba predloženog računalnog programa za izračunavanje entalpije slojne vode na drugoj točki osmatranja (boja pokazuje entalpiju)

shown for the benefit of engineers clearly demonstrates the usefulness of the proposed tools. Furthermore the estimations are quite accurate as evidenced from the comparisons with literature data with acceptable average absolute deviations and would help in attempting design tasks as well as modification of operations within short time frame.

Nomenclature

- A Tuned coefficient
- B Tuned coefficient
- C Tuned coefficient
- D Tuned coefficient
- E The activation energy of the process causing parameter variation (J/kmol);
- f a properly defined temperature-dependent parameter the units for which are determined individually for a certain property;

- f_c is a pre-exponential coefficient having the same unit of the property of interest;
- H formation water enthalpy J/kg
- i index
- j index
- m matrix row index for $m \times n$ matrix
- n matrix column index for $m \times n$ matrix
- p formation water vapor pressure kPa(abs)
- P^i Polynomial
- R The universal gas constant (R) 8.314 J/(kmol K).
- T Temperature K, °C
- T_c The characteristic-limit temperature K, °C
- u coefficient of polynomial
- V Vandermonde matrix
- α Matrix element
- ψ Formation water (brine) salinity mass fraction
- ρ formation water (brine) density kg/m

Table 2. Accuracy of the computer program for calculating Brine density				
Temperature °C	Brine salt content fraction	Reported Density kg/m (Denver Research Institute 1964 Dittman 1977)	Calculated Density kg/m³	Absolute Deviation (%)
38	0.05	1094	1094.78	0.07
66	0.05	1059	1057.26	0.22
93	0.05	1025	1024.31	0.08
121	0.05	991	991.43	0.07
149	0.05	956	957.43	0.12
177	0.05	922	922.42	0.06
204	0.05	887	886.94	0.05
232	0.05	853	851.57	0.17
260	0.05	819	816.85	0.21
288	0.05	784	783.18	0.12
316	0.05	750	750.83	0.16
38	0.1	1118	1118.85	0.04
66	0.1	1087	1085.19	0.18
93	0.1	1056	1055.22	0.07
121	0.1	1025	1025.31	0.06
149	0.1	993	994.49	0.10
177	0.1	962	962.84	0.06
204	0.1	931	930.80	0.02
232	0.1	900	898.86	0.10
260	0.1	869	867.45	0.12
288	0.1	837	836.91	0.04
316	0.1	806	807.47	0.18
38	0.15	1143	1143.35	0.02
66	0.15	1115	1113.24	0.16
93	0.15	1087	1086.14	0.08
121	0.15	1059	1059.08	0.01
149	0.15	1031	1031.27	0.03
177	0.15	1003	1002.79	0.01
204	0.15	975	973.99	0.09
232	0.15	947	945.27	0.17
260	0.15	919	916.98	0.20
288	0.15	891	889.42	0.15
316	0.15	863	862.78	0.00
38	0.2	1169	1169.57	0.01
66	0.2	1144	1142.31	0.14
93	0.2	1118	1117.58	0.06
121	0.2	1093	1092.88	0.02
149	0.2	1067	1067.55	0.05
177	0.2	1041	1041.65	0.03
204	0.2	1016	1015.49	0.02
232	0.2	990	989.39	0.07
260	0.2	965	963.66	0.08
288	0.2	939	938.55	0.03
316	0.2	913	914.23	0.11
38	0.25	1199	1198.93	0.00
66	0.25	1175	1173.40	0.13
93	0.25	1151	1150.12	0.07
121	0.25	1127	1126.87	0.00
149	0.25	1103	1103.05	0.02
177	0.25	1079	1078.73	0.01
204	0.25	1055	1054.16	0.06
232	0.25	1031	1029.65	0.11
260	0.25	1007	1005.48	0.13
288	0.25	983	981.86	0.09
316	0.25	959	958.95	0.03
Average deviation %				0.08

Table 3. Accuracy of the computer program for calculating brine enthalpy

Temperature °C	Brine salt content fraction	Reported Enthalpy J/kg (Denver Research Institute 1964 Dittman 1977)	Calculated Enthalpy J/kg	Absolute Deviation (%)
38	0.05	160269	160550.28	0.18
66	0.05	260669	259265.70	0.54
93	0.05	368100	368093.94	0.00
121	0.05	481082	482389.67	0.27
149	0.05	598695	600081.11	0.23
177	0.05	720302	720659.76	0.05
204	0.05	845438	844275.61	0.14
232	0.05	973743	971459.76	0.23
260	0.05	1104931	1102636.50	0.21
288	0.05	1238768	1238206.71	0.05
316	0.05	1375058	1378473.39	0.25
38	0.1	157903	158367.75	0.29
66	0.1	254231	253115.55	0.44
93	0.1	356436	356660.23	0.06
121	0.1	463246	464691.88	0.31
149	0.1	573876	575354.31	0.26
177	0.1	687787	688245.37	0.07
204	0.1	804584	803557.07	0.13
232	0.1	923964	921817.62	0.23
260	0.1	1045687	1043441.31	0.21
288	0.1	1169558	1168811.15	0.06
316	0.1	1295413	1298213.10	0.22
38	0.15	156241	156298.32	0.04
66	0.15	248857	247332.90	0.61
93	0.15	346241	345983.27	0.07
121	0.15	447334	448255.22	0.21
149	0.15	551483	552491.55	0.18
177	0.15	658244	658387.07	0.02
204	0.15	767294	766171.78	0.15
232	0.15	878385	876371.43	0.23
260	0.15	991322	989391.77	0.19
288	0.15	1105945	1105600.51	0.03
316	0.15	1222122	1225269.23	0.26
38	0.2	153803	154234.68	0.28
66	0.2	242935	241905.65	0.42
93	0.2	336006	336196.86	0.06
121	0.2	432119	433394.97	0.30
149	0.2	530728	532015.32	0.24
177	0.2	631463	631834.95	0.06
204	0.2	734054	733115.17	0.13
232	0.2	838297	836378.81	0.23
260	0.2	944028	942024.06	0.21
288	0.2	1051116	1050405.73	0.07
316	0.2	1159454	1161783.60	0.20
38	0.25	151849	152075.12	0.15
66	0.25	238037	236822.48	0.51
93	0.25	327465	327419.17	0.01
121	0.25	419381	420383.51	0.24
149	0.25	513331	514368.36	0.20
177	0.25	609006	609213.81	0.03
204	0.25	706183	705203.72	0.14
232	0.25	804693	802856.68	0.23
260	0.25	904402	902563.88	0.20
288	0.25	1005202	1004669.38	0.05
316	0.25	1107005	1109423.52	0.22
Average deviation %				0.19

Table 4. Accuracy of the computer program for calculating Brine vapor pressure

Temperature °C	Brine salt content fraction	Reported vapor pressure kPa (Denver Research Institute 1964 Dittman 1977)	Calculated vapor pressure kPa	Absolute Deviation (%)
93	0.05	135	129.87	4.27
130	0.05	261	276.84	5.81
140	0.05	348	352.16	0.95
150	0.05	465	449.94	3.26
160	0.05	600	575.19	4.26
170	0.05	765	733.62	4.17
180	0.05	969	931.44	3.88
190	0.05	1221	1175.28	3.74
200	0.05	1511	1471.90	2.63
210	0.05	1851	1828.03	1.23
220	0.05	2248	2249.99	0.08
230	0.05	2713	2743.44	1.11
240	0.05	3246	3313.05	2.06
250	0.05	3856	3962.22	2.74
260	0.05	4544	4692.84	3.26
270	0.05	5339	5505.06	3.11
280	0.05	6221	6397.21	2.83
290	0.05	7209	7365.72	2.17
300	0.05	8323	8405.16	0.98
310	0.05	9564	9508.32	0.58
320	0.05	10940	10666.41	2.50
330	0.05	12461	11869.26	4.75
93	0.1	131	123.78	5.34
130	0.1	252	267.54	6.09
140	0.1	336	340.61	1.30
150	0.1	448	435.23	2.92
160	0.1	579	556.21	3.95
170	0.1	738	708.96	3.92
180	0.1	934	899.43	3.70
190	0.1	1177	1133.91	3.65
200	0.1	1457	1418.90	2.62
210	0.1	1784	1760.86	1.29
220	0.1	2167	2165.92	0.04
230	0.1	2615	2639.65	0.94
240	0.1	3129	3186.75	1.85
250	0.1	3717	3810.77	2.51
260	0.1	4380	4513.93	3.05
270	0.1	5146	5296.89	2.93
280	0.1	5996	6158.65	2.71
290	0.1	6949	7096.45	2.12
300	0.1	8023	8105.82	1.03
310	0.1	9218	9180.63	0.41
320	0.1	10545	10313.22	2.20
330	0.1	12011	11494.62	4.30
93	0.15	125	119.64	4.41
130	0.15	241	256.09	6.09
140	0.15	321	325.74	1.21
150	0.15	429	416.05	3.05
160	0.15	554	531.61	4.09
170	0.15	706	677.66	4.05
180	0.15	894	859.88	3.82
190	0.15	1126	1084.36	3.74
200	0.15	1394	1357.33	2.67
210	0.15	1707	1684.98	1.32
220	0.15	2074	2073.18	0.04
230	0.15	2503	2527.21	0.96

Table 4. Continued...

Temperature °C	Brine salt content fraction	Reported vapor pressure kPa (Denver Research Institute 1964 Dittman 1977)	Calculated vapor pressure kPa	Absolute Deviation (%)
240	0.15	2994	3051.50	1.89
250	0.15	3558	3649.35	2.56
260	0.15	4192	4322.71	3.10
270	0.15	4925	5072.02	2.97
280	0.15	5739	5896.04	2.73
290	0.15	6651	6791.86	2.11
300	0.15	7679	7754.85	0.98
310	0.15	8823	8778.80	0.51
320	0.15	10093	9856.02	2.35
330	0.15	11496	10977.53	4.52
93	0.2	118	113.73	4.09
130	0.2	228	242.35	5.97
140	0.2	304	308.22	1.08
150	0.2	406	393.70	3.16
160	0.2	525	503.18	4.18
170	0.2	669	641.62	4.11
180	0.2	847	814.46	3.84
190	0.2	1067	1027.47	3.72
200	0.2	1321	1286.58	2.63
210	0.2	1617	1597.65	1.24
220	0.2	1965	1966.24	0.06
230	0.2	2371	2397.29	1.08
240	0.2	2837	2894.93	2.03
250	0.2	3371	3462.17	2.70
260	0.2	3972	4100.71	3.23
270	0.2	4667	4810.76	3.08
280	0.2	5437	5590.92	2.82
290	0.2	6301	6438.16	2.17
300	0.2	7275	7347.83	0.99
310	0.2	8359	8313.72	0.55
320	0.2	9562	9328.24	2.45
330	0.2	10892	10382.58	4.68
93	0.25	111	103.10	7.25
130	0.25	214	226.33	5.57
140	0.25	285	288.71	1.00
150	0.25	381	369.42	3.07
160	0.25	492	472.53	4.01
170	0.25	627	602.65	3.92
180	0.25	794	764.79	3.68
190	0.25	1000	964.27	3.62
200	0.25	1238	1206.59	2.59
210	0.25	1516	1497.19	1.28
220	0.25	1842	1841.26	0.04
230	0.25	2223	2243.50	0.91
240	0.25	2659	2707.91	1.80
250	0.25	3160	3237.52	2.45
260	0.25	3723	3834.25	2.96
270	0.25	4374	4498.74	2.83
280	0.25	5097	5230.22	2.60
290	0.25	5907	6026.50	2.02
300	0.25	6820	6883.93	0.93
310	0.25	7836	7797.50	0.50
320	0.25	8964	8760.89	2.27
330	0.25	10210	9766.71	4.35
Average deviation %				2.7

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