

UNITED STATES DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

A ROUTINE FOR ESTIMATING THE SOLUBILITY OF METHANE
IN PURE WATER OR NaCl BRINES BY USING THE
TEXAS INSTRUMENTS TI-59 CALCULATOR -
WITH TABLES

by

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Open-file Report 80-371

1980

This report is preliminary and has not been edited or
reviewed for conformity with Geological Survey
standards and nomenclature

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INTRODUCTION

The program described herein will calculate the solubility of methane in either pure water or sodium chloride aqueous solutions for a wide range of temperature, pressure, and salinity conditions. This program was written for the Texas Instruments Programmable TI-59 calculator and can be used to predict the amount of dissolved methane present in geopressured-geothermal zones having temperatures less than 360°C, pressures less than 20,000 psi (pounds per square inch), and salinities less than 25 weight percent sodium chloride. At pressures as great as 10,000 psi, the solubility of methane is valid to ± 5 percent of the reported value. Pressure may be extrapolated to 20,000 psi, but the precision deteriorates. The precision also deteriorates as NaCl concentration increases. Temperature extrapolations above 360°C are not valid. No checks are built into the program to detect inputs outside these limits. The calculation scheme is based upon the empirical equations of Haas (1978). The constants used in those equations are derived from reported literature values for the solubility of methane in pure water as described in Haas (1978). The Setschenow or salting-out constant (A_s) was estimated from our recent unpublished experimental data and carries an uncertainty of ± 20 percent of the reported value. The numerical value for the salting-out constant is stored in data register no. 11 and can be easily changed or updated as required. All the equations and constants used herein are listed in the program record section following the program listing.

To use the program simply enter the temperature, pressure, and salinity of interest from the keyboard. For pure water solutions, only the temperature and pressure need be entered. The input temperature may be in either degrees Celsius or degrees Fahrenheit. Sodium chloride solution concentration can be entered as

/

either weight percent or molality. Pressure is entered as pounds per square inch. The units of output (methane concentration) are user selectable and may be molality, ppm (parts per million), or standard cubic feet/barrel. The vapor pressure of water is also available as an output for an entered temperature. When the optional PC-100A printer is used, all input and output are labeled.

Following the program description is a series of tables of methane solubility in various concentration units calculated for a variety of pressure, temperature, and salinity conditions by using the program described herein.

REFERENCE CITED IN INTRODUCTION

Haas, J.L., Jr., 1978, An empirical equation with tables of smoothed solubilities of methane in water and aqueous sodium chloride solutions up to 25 weight percent, 360°C, and 138 MPa: U.S. Geological Survey Open-File Report 78-1004, 42 p.

PROGRAMMER N. J. Susak DATE 10/17/79Partitioning (Op 17) 4,7,9,5,9 Library Module Master Printer Optional Cards 2 (4 sides)

PROGRAM DESCRIPTION

This program calculates the solubility of methane in water or brines from 25°C to 360°C, up to 20,000 psia, and up to 25 weight percent NaCl. Input temperature may be in °C or °F. NaCl concentration may be in Wt. % or molality. Methane concentration can be calculated in molality, ppm, or cubic feet/barrel. All input and output is labeled. The program uses the empirical methane solubility equations of Haas (1978, USGS Open-File Report 78-1004). The numerical value used for the Setschenow constant (A_s) is 0.129.

USER INSTRUCTIONS

STEP	PROCEDURE	ENTER	PRESS	DISPLAY*
1	Select units of methane concentration n = 1 for ppm, n = 2 for ft ³ /barrel; anything else gives mol/kg	n	E	n
2	a. for temperature in °C b. for temperature in °F	T°C T°F	A A	(T°C)* (T°F)*
3	Enter total pressure in psi	psi	C	(psi)*
4	Use either a or b a. for NaCl conc. in mol/kg b. for NaCl conc. in weight percent	m w	B B	(m)* w* (m)*
	Note: Steps 1-4 may be done in any order. Step 4 not necessary for methane solubility (soly) in pure water.			
5	a. for methane solubility in water b. for methane solubility in brine		D E	(x)* (x)*
	Modes are displayed briefly; (n) printed and displayed; n* printed only.			

USER DEFINED KEYS	DATA REGISTERS (INV) see page 8 of 8	LABELS (Op 08)
A enter T°C	0 pointer	0 conversion factor
B enter m_{NaCl}	1 pointer	1 Setschenow constant
C enter psi	2 pointer	
D calc soly in water	3 T°C	
E calc soly in brine	4 psi	
A' enter T°F	5 p - p _w	
B' enter Wt % NaCl	6 m_{NaCl}	
C' calc p _{H₂O}	7 A	
D' Used	8 B	
E' set units flag	9 soly of CH ₄	
FLAGS 0 ppm 1 ft ³ /bb1 3 4 5 6 iteration error 8 9		

PROGRAMMER N.J. SusakDATE 10/17/79

LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
000	50	I×I		055	43	RCL	of water	110	01	1	
001	42	STD	Save flag #	056	37	37	AT +	111	54	)	
002	00	00		057	75	-	(see page 618)	112	54	)	
003	32	X:T		058	43	RCL		113	85	+	
004	03	3		059	03	03		114	43	RCL	
005	32	I×I	Check if	060	95	=		115	34	34	e ₄
006	77	GE	flag is legal	061	42	STD		116	65	x	
007	00	00	RTN if not	062	28	28	y	117	53	(	
008	12	12		063	43	RCL		118	43	RCL	
009	86	STF	Set flag if	064	03	03		119	35	35	e ₃
010	40	IND	0,1,2	065	85	+		120	65	x	
011	00	00		066	43	RCL		121	43	RCL	
012	92	RTN		067	38	38		122	28	28	y
013	76	LBL		068	95	=		123	45	YX	
014	10	E*		069	42	STD		124	01	1	
015	81	RST	Clear all flags	070	29	29	Z	125	93	.	
016	76	LBL	Labeled	071	33	X ²		126	02	2	
017	99	PRT	print routine	072	75	-		127	05	5	
018	69	DP	number in	073	43	RCL		128	54	)	
019	04	04	T-reg	074	36	36		129	22	INV	
020	32	X:T	label code	075	95	=		130	28	LOG	
021	69	DP	in display	076	42	STD		131	54	)	
022	06	06	Returns #	077	27	27	w	132	22	INV	P in bars
023	92	RTN	in display	078	53	(		133	23	LNx	
024	06	6	Routine to	079	43	RCL		134	65	x	change to
025	42	STD	compute	080	30	30	e ₀	135	43	RCL	ATMs.
026	00	00		081	85	+		136	39	39	
027	02	2	$\sum X_i T^i$	082	43	RCL		137	95	=	
028	94	+/-	i=2	083	31	31	e ₁	138	92	RTN	
029	42	STD	where	084	55	÷		139	76	LBL	T°C
030	02	02	x=a	085	43	RCL		140	11	A	entry
031	53	(	or b	086	29	29	Z	141	42	STD	
032	73	RC#		087	85	+		142	03	03	
033	01	01	R ₀ iteration	088	53	(		143	32	X:T	
034	65	x	count	089	43	RCL		144	43	RCL	
035	43	RCL		090	32	32	e ₂	145	41	41	
036	03	03	R ₁ pointer to	091	65	x		146	61	GTO	fall into PRT
037	45	YX	coeff.	092	43	RCL		147	99	PRT	Pressure
038	43	RCL		093	27	27	w	148	76	LBL	entry
039	02	02	R ₂ power	094	55	÷		149	13	C	
040	54	)	of +	095	43	RCL		150	42	STD	
041	85	+		096	29	29	Z	151	04	04	
042	69	DP		097	65	x		152	32	X:T	
043	21	21	} bump pointers	098	53	(		153	43	RCL	
044	69	DP		099	53	(		154	40	40	
045	22	22		100	43	RCL		155	49	FRD	convert to
046	97	DSZ		101	33	33	e ₃	156	04	04	ATMs.
047	00	00		102	65	x		157	43	RCL	
048	00	00		103	43	RCL		158	42	42	fail into PRT
049	31	31		104	27	27	w	159	61	GTO	
050	00	0		105	33	X ²		MERGED CODES			
051	95	=		106	54	)		62	STO	72	STO
052	92	RTN		107	22	INV		63	STO	73	RCL
053	76	LBL	Calculate	108	28	LOG		64	STO	74	SUM
054	18	C*	Vapor Pressure	109	75	-		83	GTO	92	INV

TEXAS INSTRUMENTS
INCORPORATED

TI-24151



LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
160	99	PRT		215	01	1	Pointer to	270	95	=	New X
161	76	LBL	WT% NaCl	216	02	2	a,b coeff.	271	69	OP	set FZ
162	17	B'	entry	217	42	STO		272	19	19	if error
163	42	STO		218	01	01		273	87	IFF	
164	06	06		219	71	SBR	calc. A	274	07	07	new guess
165	32	XIT		220	00	00	term	275	02	02	if error
166	43	RCL		221	24	24		276	92	92	
167	44	44		222	42	STO		277	52	EE	Truncate
168	71	SBR	Print it	223	07	07		278	22	INV	extra digits
169	99	PRT		224	71	SBR	calc. B	279	52	EE	
170	65	x	convert	225	00	00	term	280	32	XIT	
171	03	3	wt % to	226	24	24		281	43	RCL	
172	22	INV	molarity	227	42	STO		282	00	00	
173	28	LOG		228	08	08		283	67	EQ	$X_n = X_{old}$
174	55	÷		229	43	RCL		284	03	03	go if true
175	53	(		230	05	05		285	07	07	
176	43	RCL		231	28	LOG		286	32	XIT	
177	25	25		232	44	SUM	calc	287	42	STO	new x becomes
178	65	x		233	07	07	$C = A + \log(AP)$	288	00	00	old x
179	53	(		234	01	1	1st guess	289	61	GTO	do another
180	01	1		235	42	STO	for N-R	290	02	02	iteration
181	00	0		236	00	00	iteration	291	41	41	
182	00	0		237	42	STO		292	25	CLR	clear error
183	75	-		238	01	01		293	93	.	new 1st guess
184	43	RCL		239	58	FIX	SET limit	294	01	1	= old/10
185	06	06		240	06	06		295	49	PRD	
186	95	=		241	43	RCL	N-R iteration	296	01	01	
187	76	LBL	molarity of	242	00	00		297	43	RCL	
188	12	B	NaCl	243	66	PAU	display root	298	01	01	
189	42	STO	entry	244	75	-		299	42	STO	
190	06	06		245	53	(	$X_n = X_{old} - \frac{f(X)}{f'(X)}$	300	00	00	
191	32	XIT		246	43	RCL		301	22	INV	reset flag 7
192	43	RCL		247	00	00		302	86	STF	
193	43	43		248	28	LOG		303	07	07	
194	61	GTO	fail into PRT	249	75	-		304	61	GTO	go iterate
195	99	PRT		250	43	RCL		305	02	02	
196	76	LBL	internal	251	00	00		306	41	41	
197	19	D'	routine to	252	65	x		307	22	INV	clear fix
198	43	RCL	calc. X_{H_2O}	253	43	RCL		308	58	FIX	
199	04	04		254	08	08		309	92	RTN	
200	42	STO	$P \rightarrow \Delta P$	255	75	-		310	25	CLR	get 0
201	05	05		256	43	RCL		311	22	INV	
202	32	XIT		257	07	07		312	58	FIX	
203	18	C'	P_{water}	258	54	)		313	35	1/X	flashing display
204	77	GE	error if	259	55	÷		314	01	1	
205	03	03	$P_w > P$	260	53	(		315	32	XIT	
206	10	10		261	43	RCL		316	43	RCL	error message
207	22	INV	calc. ΔP	262	00	00		317	48	48	
208	44	SUM		263	35	1/X		318	71	SBR	
209	05	05		264	65	x		319	99	PRT	go print
210	00	0	clear A	265	43	RCL					
211	42	STO	and B terms	266	26	26					
212	07	07		267	75	-					
213	42	STO		268	43	RCL					
214	08	08		269	08	08					

$$f(x) = \log x - \log x - C = 0$$

$$C = A + \log(P_{total} - P_{H_2O})$$

$$f'(x) = \frac{1}{x} - \frac{\log e}{x}$$

62 ☐ ☐ 72 ☐ ☐ 83 ☐ ☐

63 ☐ ☐ 73 ☐ ☐ 84 ☐ ☐

64 ☐ ☐ 74 ☐ ☐ 92 ☐ ☐

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LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS	LOC	CODE	KEY	COMMENTS
320	91	R/S	halt	375	46	46	get label	430	43	RCL	
321	76	LBL	T ^o E	376	61	GTO	go adjust	431	06	06	
322	16	A'	entry	377	03	03		432	65	X	
323	42	STD		378	43	43		433	53	(	
324	03	03		379	85	+	correct	434	43	RCL	
325	36	PGM	convert	380	03	3	for ppm	435	51	51	ϕ^*
326	25	25	to °C	381	95	=		436	85	+	
327	11	A		382	32	XIT	get m/kg	437	43	RCL	
328	48	EXC	save °C	383	65	X		438	52	52	R
329	03	03		384	43	RCL	convert to	439	65	X	
330	32	XIT		385	24	24	ppm	440	43	RCL	
331	43	RCL		386	55	÷		441	06	06	M_{NaCl}
332	49	49		387	53	(		442	34	FX	
333	61	GTO	fall into	388	24	CE		443	95	=	
334	99	PRT	print	389	85	+		444	61	GTO	
335	76	LBL	soly in H ₂ O	390	43	RCL		445	04	04	
336	14	D		391	10	10		446	50	50	
337	19	D'	calc. m/kg	392	54	)		447	55	÷	if H ₂ O density
338	86	STF	set F3	393	65	X		448	43	RCL	of H ₂ O
339	03	03	if in H ₂ O	394	06	6		449	50	50	$d = 1/v_0$
340	32	XIT		395	22	INV		450	65	X	
341	43	RCL	get label	396	28	LOG		451	43	RCL	complete
342	45	45		397	95	=		452	47	47	conversion
343	87	IFF	go if ppm	398	32	XIT		453	95	=	
344	01	01		399	61	GTO	restore label	454	32	XIT	restore label
345	03	03		400	03	03	go print	455	61	GTO	
346	79	79		401	51	51		456	03	03	go print
347	87	IFF	go if ct/bbl	402	75	-		457	51	51	
348	02	02		403	01	1	convert				
349	04	04		404	05	5	label ct/bbl				
350	02	02		405	95	=					
351	71	SBR	print it	406	32	XIT	convert				
352	99	PRT		407	87	IFF	m → ct/bbl				
353	42	STD	save it	408	03	03					
354	09	09		409	04	04	go if in H ₂ O				
355	22	INV	reset flag	410	47	47					
356	86	STF		411	65	X	calc. density				
357	03	03		412	53	(	of brine				
358	98	ADV		413	43	RCL					
359	92	RTN		414	10	10					
360	76	LBL	Soly in brine	415	85	+					
361	15	E		416	43	RCL					
362	19	D'	mol/kg	417	25	25					
363	28	LOG		418	65	X					
364	75	-		419	43	RCL					
365	43	RCL		420	06	06					
366	06	06		421	54	)					
367	65	X		422	55	÷					
368	43	RCL		423	53	(					
369	11	11		424	43	RCL					
370	95	=		425	10	10					
371	22	INV		426	65	X					
372	28	LOG		427	43	RCL					
373	32	XIT		428	50	50					
374	43	RCL		429	85	+					

62 72 83

63 73 84

64 74 92

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ADDITIONAL NOTES

1. The master library is necessary only if temperature input in °F is desired.
2. Routines will affect pending calculations.
3. Solubility output is labeled as

SWi or SBi

for solubility in water or in brine respectively.

i may be any of the following depending on the units selected:

M = molality

P = ppm

C = cubic feet/barrel

4. Pressing C' will return the vapor pressure of water (in atmospheres) in the display for an entered temperature.
5. The solubility of methane in water is valid between 25°C and 360°C and at pressures as great as 10,000 psia with a precision of ±5% of the calculated value. Temperature extrapolations are not valid. Pressure may be extrapolated to 20,000 psi but precision deteriorates. Precision also deteriorates as NaCl concentration increases. No checks are made in the program for inputs outside of the stated limits.
6. Registers 3, 4, and 6 (T°C, P atms, and M (NaCl), respectively) are not altered by the program. After the initial entry, the values for these registers need not be re-entered for each calculation unless the values change.
7. The iteration routine will briefly display each successive approximation. To eliminate this display, change step 243 PAU to NOP (or to PRT to list each approximation).



EQUATIONS USED

1. Vapor pressure of water -

(from J.L. Haas, Jr., 1976, USGS Bulletin 1421A, p. A8, equation 6)

$$\ln P = e_0 + \frac{e_1}{Z} + \frac{e_2 w}{Z} \left(10^{(e_3 w^2)} - 1 \right) + e_4 10^{(e_5 y^{1.25})}$$

P is in bars, T in °C

$$w = Z^2 - e_6, \quad Y = 374.12 - T, \quad Z = T + 273.16$$

2. The following equations are from Haas (1978, USGS Open-File Report 78-1004), and the values for the a and b coefficients and the Setschenow constant have been updated from our new unpublished experimental data. The values for all constants are listed on the data register page.

a. $Q = X(\text{CH}_4)/P(\text{CH}_4)$

b. $P(\text{CH}_4) = P_{\text{total}} - P_{(\text{H}_2\text{O})}$

c. $\log Q = A + B X(\text{CH}_4)$

d. $A = a_{-2}t^{-2} + a_{-1}t^{-1} + a_0 + a_2t^2 + a_3t^3$

e. $B = b_{-1}t^{-1} + b_0 + b_1t + b_2t^2 + b_3t^3$

f. $P_{\text{total}} = P_{(\text{H}_2\text{O})} + 10^{(\log X(\text{CH}_4) - A - B X(\text{CH}_4))}$

g. $\log X(\text{CH}_4)_{\text{brine}} = \log X(\text{CH}_4)_{\text{water}} - A_s I$

where A_s = Setschenow constant

I = Ionic strength

EQUATIONS USED (CONT'D)

3. Cubic feet / barrel calculations -

a. Density

1. Equations from Haas (1976, USGS Bulletin 1421-A, p. A9-A10)

$$d = \frac{1000 + (m_{\text{NaCl}})(\text{GFW}_{\text{NaCl}})}{1000v_o + (m_{\text{NaCl}})(\phi)}$$

$$\phi = \phi^* + (k)(m_{\text{NaCl}})^{0.5}$$

$$k = (c_3 + c_4 v_o) \left[\frac{v_c}{v_c - v_o} \right]^2$$

where v_o is the specific volume of water at 60°F, v_c is the specific volume of water at the critical point, ϕ^* is the limiting apparent molal volume of NaCl as the concentration in the liquid goes to 0, c_3 is -13.644, and c_4 is 13.97.

2. for water $d = 1/v_o$

b. The conversion factor in register 47 was calculated from the following conversions taken from the Handbook of Chemistry and Physics (47th ed.)

1. 23.6905 l/mole (for an ideal gas at 60°F and 1 atm)

2. 158.98 liters/barrel

3. 0.03532 cubic feet/liter

$$\text{cubic feet/barrel} = (\text{mol/kg})(\text{kg/l})(1_{\text{gas}}/\text{mol})(1/\text{barrel})(\text{ft}^3/\text{l}_{\text{gas}})$$

$$\text{cubic feet/barrel} = (m)(d)(133.012)$$



DATA REGISTERS

0.	00	} used
0.	01	
0.	02	
0.	03	T°C
0.	04	P in atms
0.	05	P(total) - P(H ₂ O)
0.	06	m (NaCl)
0.	07	A
0.	08	B
0.	09	Solubility of CH ₄
1000.	10	conversion factor
0.129	11	salting-out constant (A _s)
-433.45	12	a ₋₂
35.7727	13	a ₋₁
-3.56262	14	a ₀
0.	15	a ₁
.0000219921	16	a ₂
-.0000000268	17	a ₃
0.	18	b ₋₂
40.3932	19	b ₋₁
-4.04655	20	b ₀
0.0285046	21	b ₁
-.0000708934	22	b ₂
.0000000614	23	b ₃
16.0426	24	GFW CH ₄
58.44277	25	GFW NaCl
.4342944819	26	log ₁₀ e
0.	27	w
0.	28	y
0.	29	z
12.50849	30	e ₀
-4616.913	31	e ₁
.0003193455	32	e ₂
1.1965-11	33	e ₃
-0.01013137	34	e ₄
-0.0057148	35	e ₅
293700.	36	e ₆
374.12	37	T ^{critical} °C
273.16	38	t correction
.9869283269	39	atms/bar
.0680461898	40	atms/psi
376515.	41	'T°C'
333624.	42	'psi'
30632622.	43	'm/kg'
433761.	44	'wt %'
364330.	45	'SWM'
361430.	46	'SBM'
133.0120541	47	(scf/bbl)/(mol/kg)
33553343.	48	'p pw'
326521.	49	T°F
1.001263255	50	specific volume of water at 60°F
20.16762044	51	limiting apparent molal volume NaCl @ 60°F
.7284105161	52	Masson Rule slope at 60°F

Methane Solubility in Pure Water

[scf = standard cubic feet]

Temp.	<u>1000 psi</u>			<u>2500 psi</u>			<u>5000 psi</u>		
	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbt	<u>Moles</u> kilogram	ppm	<u>SCF</u> bbt	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbt
25°C	.07681	1230.7	10.20	.14541	2327.4	19.32	.21730	3473.9	28.87
45°C	.05937	951.6	7.89	.11495	1840.7	15.27	.17461	2793.4	23.20
60°C	.05230	838.3	6.95	.10427	1670.0	13.85	.16199	2592.1	21.52
75°C	.04942	792.2	6.57	.10085	1615.3	13.40	.15955	2553.1	21.19
100°C	.05003	801.9	6.65	.10513	1683.7	13.97	.17004	2720.5	22.59
125°C	.05517	884.2	7.33	.11895	1904.6	15.80	.19560	3128.1	25.98
150°C	.06394	1024.8	8.49	.14223	2276.5	18.90	.23742	3794.4	31.54
175°C	.07574	1213.6	10.06	.17657	2824.6	23.46	.29995	4788.9	39.85
200°C	.08892	1424.5	11.81	.22429	3585.3	29.80	.39058	6226.9	51.89
225°C	.09865	1580.1	13.11	.28736	4588.8	38.17	.51989	8271.4	69.06
250°C	.09268	1484.6	12.31	.36477	5817.8	48.46	.70188	11134.6	93.24
275°C	.04278	685.8	5.68	.44622	7107.6	59.28	.95256	15051.5	126.54
300°C	--	--	--	.49789	7924.2	66.14	1.28413	20185.0	170.59
325°C	--	--	--	.43449	6922.1	57.72	1.68688	26348.9	224.09
350°C	--	--	--	.08306	1330.7	11.03	2.07765	32255.7	276.0

	<u>10,000 psi</u>			<u>15,000 psi</u>			<u>20,000 psi</u>		
	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbt	<u>Moles</u> kilogram	ppm	<u>SCF</u> bbt	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbt
25°C	.30478	4865.7	40.49	.36220	5777.1	48.12	.40536	6461.0	53.85
45°C	.24843	3969.7	33.00	.29735	4747.7	39.50	.33431	5334.6	44.41
60°C	.23513	3758.0	31.24	.28430	4540.3	37.77	.32172	5134.6	42.74
75°C	.23544	3762.9	31.28	.28709	4584.6	38.14	.32664	5212.8	43.39
100°C	.25608	4091.4	34.02	.31554	5036.6	41.92	.36144	5765.0	48.01
125°C	.29880	4770.7	39.69	.37087	5914.5	49.27	.42678	6800.1	56.70
150°C	.36683	5850.5	48.73	.45780	7290.8	60.82	.52861	8409.0	70.22
175°C	.46869	7462.9	62.26	.58774	9340.8	78.08	.68062	10801.0	90.42
200°C	.61876	9829.0	82.20	.78016	12361.1	103.64	.90626	14330.4	120.39
225°C	.83995	13295.8	111.58	1.06684	16826.9	141.72	1.24433	19571.6	165.30
250°C	1.16825	18397.0	155.20	1.50012	23500.3	199.28	1.76030	27464.2	233.85
275°C	1.66131	25960.0	220.70	2.16983	22638.8	288.25	2.57035	39602.1	341.46
300°C	2.41606	37313.6	320.96	3.24431	49472.3	430.99	3.90374	58935.3	518.60
325°C	3.62042	54892.7	480.95	5.10996	75765.9	678.83	6.33110	92202.5	841.05
350°C	5.80514	85195.3	771.18	9.23538	129040.8	1226.87	12.41651	166106.0	1649.46

Methane Solubility in NaCl - 1000 psi

[scf = standard cubic feet; % = weight percent]

Temp.	<u>5% NaCl</u>			<u>10% NaCl</u>		
	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bb1	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bb1
25°C	.05878	942.1	8.07	.04367	700.1	6.20
45°C	.04544	728.4	6.24	.03375	541.2	4.79
60°C	.04002	641.7	5.49	.02973	476.8	4.22
75°C	.03782	606.4	5.19	.02810	450.5	3.99
100°C	.03829	613.9	5.26	.02844	456.1	4.04
125°C	.04222	676.9	5.79	.03137	502.9	4.45
150°C	.04893	784.4	6.72	.03635	582.8	5.16
175°C	.05796	929.0	7.96	.04306	690.3	6.11
200°C	.06805	1090.5	9.34	.05055	810.3	7.17
225°C	.07550	1209.7	10.36	.05608	898.9	7.96
250°C	.07093	1136.6	9.74	.05269	844.6	7.48
275°C	.03274	524.9	4.49	.02432	390.0	3.45
300°C	--	--	--	--	--	--
325°C	--	--	--	--	--	--

Temp.	<u>15% NaCl</u>			<u>20% NaCl</u>		
	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bb1	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bb1
25°C	.03133	502.3	4.60	.02156	345.7	3.28
45°C	.02421	388.3	3.55	.01666	267.3	2.53
60°C	.02133	342.1	3.13	.01468	235.4	2.23
75°C	.02015	323.2	2.96	.01387	222.5	2.11
100°C	.02040	327.2	3.00	.01404	225.2	2.13
125°C	.02250	360.8	3.30	.01548	248.3	2.35
150°C	.02608	418.2	3.83	.01795	287.8	2.73
175°C	.03089	495.3	4.53	.02126	340.9	3.23
200°C	.03626	581.4	5.32	.02496	400.2	3.79
225°C	.04023	645.0	5.91	.02769	444.0	4.21
250°C	.03780	606.0	5.55	.02601	417.1	3.95
275°C	.01745	279.8	2.56	.01201	192.6	1.82
300°C	--	--	--	--	--	--
325°C	--	--	--	--	--	--

Methane Solubility in NaCl -- 2500 psi

[scf = standard cubic feet; % = weight percent]

Temp.	<u>5% NaCl</u>			<u>10% NaCl</u>		
	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbf	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbf
25°C	.11128	1782.1	15.27	.08267	1324.5	11.73
45°C	.08797	1409.2	12.07	.06535	1047.3	9.27
60°C	.07980	1278.6	10.95	.05928	950.1	8.41
75°C	.07718	1236.6	10.59	.05734	919.0	8.14
100°C	.08046	1289.0	11.04	.05977	957.9	8.48
125°C	.09103	1458.3	12.50	.06763	1083.7	9.60
150°C	.10885	1743.2	14.94	.08086	1295.5	11.47
175°C	.13513	2163.1	18.55	.10038	1607.8	14.24
200°C	.17165	2746.1	23.56	.12751	2041.5	18.09
225°C	.21991	3515.6	30.19	.16337	2614.0	23.18
250°C	.27916	4458.4	38.32	.20738	3315.9	29.43
275°C	.34149	5448.5	46.87	.25369	4053.3	36.00
300°C	.38103	6075.6	52.30	.28306	4520.5	40.17
325°C	.33251	5306.0	45.64	.24701	3947.1	35.05

Temp.	<u>15% NaCl</u>			<u>20% NaCl</u>		
	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbf	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbf
25°C	.05930	950.5	8.71	.04081	654.3	6.20
45°C	.04688	751.5	6.88	.03226	517.3	4.90
60°C	.04253	681.8	6.24	.02927	469.3	4.45
75°C	.04113	659.4	6.04	.02830	453.9	4.30
100°C	.04288	687.4	6.29	.02951	473.1	4.48
125°C	.04851	777.6	7.12	.03338	535.3	5.07
150°C	.05801	929.7	8.52	.03992	640.0	6.07
175°C	.07201	1153.9	10.57	.04956	794.4	7.53
200°C	.09147	1465.3	13.43	.06295	1008.8	9.57
225°C	.11719	1876.6	17.20	.08065	1292.2	12.26
250°C	.14876	2380.9	21.84	.10238	1639.7	15.56
275°C	.18198	2911.0	26.71	.12524	2005.1	19.03
300°C	.20305	3246.9	29.81	.13974	2236.7	21.24
325°C	.17720	2834.6	26.01	.12194	1952.5	18.53

Methane Solubility in NaCl -- 5000 psi

[scf = standard cubic feet; % = weight percent]

Temp.	<u>5% NaCl</u>			<u>10% NaCl</u>		
	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbf	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbf
25°C	.16630	2660.8	22.83	.12354	1978.0	17.53
45°C	.13363	2139.2	18.34	.09927	1590.0	14.09
60°C	.12397	1984.9	17.02	.09210	1475.3	13.07
75°C	.12210	1955.0	16.76	.09071	1453.1	12.87
100°C	.13013	2083.3	17.86	.09667	1548.5	13.72
125°C	.14969	2395.7	20.55	.11120	1780.8	15.78
150°C	.18170	2906.4	24.94	.13498	2160.7	19.15
175°C	.22955	3669.1	31.51	.17053	2728.2	24.20
200°C	.29891	4772.4	41.03	.22205	3549.7	31.51
225°C	.39787	6342.3	54.61	.29557	4719.3	41.94
250°C	.53714	8543.5	73.73	.39903	6360.8	56.62
275°C	.72899	11559.6	100.06	.54155	8613.0	76.85
300°C	.98273	15520.9	134.89	.73005	11576.4	103.59
325°C	1.29096	20290.1	177.20	.95903	15152.2	136.09

Temp.	<u>15% NaCl</u>			<u>20% NaCl</u>		
	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbf	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbf
25°C	.08862	1419.7	13.01	.06099	977.4	9.27
45°C	.07121	1141.1	10.45	.04901	785.6	7.45
60°C	.06607	1058.7	9.70	.04546	728.8	6.91
75°C	.06507	1042.8	9.55	.04478	717.9	6.81
100°C	.06935	1111.3	10.18	.04772	765.0	7.25
125°C	.07977	1278.1	11.71	.05490	879.9	8.34
150°C	.09683	1550.9	14.21	.06663	1067.8	10.13
175°C	.12233	1958.6	17.96	.08418	1348.7	12.79
200°C	.15929	2548.9	23.38	.10962	1755.5	16.66
225°C	.21203	3389.9	31.13	.14591	2335.3	22.18
250°C	.28625	4571.2	42.02	.19699	3150.2	29.94
275°C	.38848	6193.7	57.03	.26734	4270.6	40.63
300°C	.52371	8331.6	76.88	.36040	5748.5	54.77
325°C	.68796	10916.2	100.99	.47344	7537.9	71.95

Methane Solubility in NaCl -- 10,000 psi

[scf = standard cubic feet; % = weight percent]

Temp.	<u>5% NaCl</u>			<u>10% NaCl</u>		
	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbl	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbl
25°C	.23325	3727.9	32.02	.17327	2772.1	24.59
45°C	.19012	3040.8	26.10	.14124	2260.7	20.04
60°C	.17995	2878.5	24.70	.13368	2140.0	18.97
75°C	.18018	2882.2	24.73	.13385	2142.7	18.99
100°C	.19598	3134.1	26.90	.14559	2330.1	20.66
125°C	.22867	3655.0	31.39	.16987	2717.8	24.10
150°C	.28073	4483.5	38.53	.20855	3334.6	29.59
175°C	.35868	5721.3	49.23	.26646	4256.5	37.81
200°C	.47353	7539.5	65.00	.35178	5611.8	49.92
225°C	.64281	10207.0	88.23	.47753	7602.5	67.76
250°C	.89405	14140.1	122.72	.66417	10542.8	94.25
275°C	1.27139	19988.7	174.51	.94449	14925.9	134.02
300°C	1.84899	28808.1	253.79	1.37358	21560.7	194.91
325°C	2.77068	42557.2	380.31	2.05828	31964.7	292.07

Temp.	<u>15% NaCl</u>			<u>20% NaCl</u>		
	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbl	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbl
25°C	.12430	1990.1	18.25	.08554	1370.4	13.00
45°C	.10132	1622.8	14.87	.06972	1117.3	10.60
60°C	.09589	1536.0	14.08	.06599	1057.6	10.03
75°C	.09602	1538.0	14.10	.06608	1058.9	10.04
100°C	.10444	1672.6	15.33	.07187	1151.7	10.92
125°C	.12186	1951.1	17.89	.08386	1343.5	12.75
150°C	.14960	2394.3	21.96	.10295	1648.9	15.65
175°C	.19115	3057.1	28.06	.13154	2105.8	19.99
200°C	.25235	4032.0	37.04	.17366	2778.2	26.39
225°C	.34256	5465.4	50.29	.23574	3767.6	35.83
250°C	.47645	7585.5	69.94	.32788	5232.5	49.83
275°C	.67753	10752.5	99.46	.46626	7424.5	70.86
300°C	.98534	15561.4	144.65	.67809	10761.2	103.06
325°C	1.47651	23139.0	216.75	1.01610	16039.4	154.43

Methane Solubility in NaCl -- 15,000 psi

[scf = standard cubic feet; % = weight percent]

Temp.	<u>5% NaCl</u>			<u>10% NaCl</u>		
	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbl	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbl
25°C	.27719	4427.1	38.05	.20592	3292.6	29.22
45°C	.22756	3637.4	31.24	.16905	2704.7	23.99
60°C	.21757	3478.3	29.86	.16153	2586.3	22.94
75°C	.21971	3512.3	30.16	.16322	2611.6	23.16
100°C	.24148	3859.1	33.15	.17939	2869.7	25.46
125°C	.28382	4532.6	38.96	.21085	3371.1	29.92
150°C	.35035	5589.1	48.09	.26027	4158.0	36.93
175°C	.44980	7164.1	61.74	.33414	5331.9	47.41
200°C	.59705	9487.4	81.95	.44354	7065.2	62.94
225°C	.81644	12928.5	112.07	.60652	9636.4	86.07
250°C	1.14803	18084.3	157.58	.85285	13497.2	121.02
275°C	1.66055	25948.4	227.93	1.23359	19406.0	175.05
300°C	2.48284	38305.5	340.80	1.84446	28739.5	261.73
325°C	3.91061	59032.8	536.77	2.90511	44530.2	412.24

Temp.	<u>15% NaCl</u>			<u>20% NaCl</u>		
	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbl	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbl
25°C	.14772	2364.1	21.68	.10165	1628.1	15.45
45°C	.12127	1941.7	17.80	.08345	1337.0	12.68
60°C	.11595	1856.6	17.02	.07979	1278.4	12.13
75°C	.11708	1874.8	17.20	.08057	1291.0	12.25
100°C	.12869	2060.2	18.89	.08856	1418.7	13.46
125°C	.15125	2420.6	22.20	.10409	1667.0	15.82
150°C	.18670	2986.2	27.41	.12849	2057.0	19.53
175°C	.23970	3830.6	35.19	.16495	2639.3	25.07
200°C	.31817	5078.4	46.71	.21896	3500.4	33.28
225°C	.43509	6931.6	63.87	.29942	4780.5	45.51
250°C	.61179	9719.3	89.81	.42102	6709.0	63.99
275°C	.88492	13997.7	129.91	.60898	9675.1	92.55
300°C	1.32313	20785.2	194.23	.91054	14397.2	138.39
325°C	2.08399	32351.1	305.93	1.43415	22490.1	217.97

Methane Solubility in NaCl -- 20,000 psi

[scf = standard cubic feet; % = weight percent]

Temp.	<u>5% NaCl</u>			<u>10% NaCl</u>		
	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbf	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbf
25°C	.31022	4952.1	42.58	.23046	3683.6	32.70
45°C	.25585	4087.7	35.12	.19006	3039.8	26.97
60°C	.24621	3934.2	33.79	.18290	2925.6	25.95
75°C	.24997	3994.2	34.31	.18570	2970.3	26.35
100°C	.27661	4417.9	37.97	.20549	3285.8	29.16
125°C	.32661	5212.3	44.83	.24263	3877.3	34.43
150°C	.40454	6448.0	55.53	.30052	4798.1	42.64
175°C	.52087	8286.9	71.50	.38695	6169.4	54.91
200°C	.69355	11003.9	92.20	.51523	8197.9	73.11
225°C	.95228	15047.2	130.71	.70743	11221.7	100.38
250°C	1.34714	21154.4	184.91	1.00077	15801.3	142.01
275°C	1.96707	30591.5	270.00	1.46130	22906.1	207.36
300°C	2.98750	45735.3	410.07	2.21935	34380.1	314.93
325°C	4.84514	72122.6	665.05	3.59936	54590.8	510.75

Temp.	<u>15% NaCl</u>			<u>20% NaCl</u>		
	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbf	<u>Moles</u> Kilogram	ppm	<u>SCF</u> bbf
25°C	.16532	2645.1	24.27	.11377	1821.8	17.29
45°C	.13634	2182.5	20.01	.09383	1503.0	14.26
60°C	.13120	2100.4	19.26	.09029	1446.4	13.72
75°C	.13321	2132.5	19.56	.09167	1468.5	13.93
100°C	.14741	2359.3	21.64	.10144	1624.7	15.42
125°C	.17405	2784.4	25.55	.11978	1917.9	18.20
150°C	.21558	3446.5	31.65	.14836	2374.4	22.55
175°C	.27758	4433.4	40.75	.19102	3055.1	29.03
200°C	.36960	5894.4	54.26	.25434	4063.7	38.66
225°C	.50747	8075.4	74.50	.34923	5571.3	53.08
250°C	.71790	11385.9	105.39	.49404	7863.4	75.09
275°C	1.04826	16538.7	153.88	.72139	11440.6	109.64
300°C	1.59206	24904.7	233.71	1.09562	17273.0	166.51
325°C	2.58201	39774.6	379.05	1.77688	27715.7	270.05