A Simple Equation for the Temperature Dependence of the Surface Tension of Water

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Abstract

Three equations are compared for the temperature dependence of the surface tension of H_2O and D_2O.

As a simple but physical fundated equation was derived an extended form of the van der Waal's equation. With the aid of these three equation and the experimental data mean values of the surface tension of H_2O are calculated.

1. Introduction

In the past few years, new measurements of the surface tension of water from the triple point up till the critical point have been published by Vargaftik, Voljak and Volkov [1, 2, 3]. It appears to be desirable to analyse these new measurements and the values that are already known from literature and to investigate mean values from them. The known equations of Grigull and Bach [4] and Vargaftik et al. [1], which reproduce the surface tension in the complete temperature range, were adapted to all available measurements. Further more, the equation of the surface tension according to van der Waal's, which exactly fulfills the thermodynamic condition at the critical point, was expanded in such a manner that it becomes useful from the triple point up till the critical point ($T_C = 647.3$ K).

2. Temperature Dependence of the Suface Tension of Water

In order to set up the equations for the temperature dependence of the surface tension, all available measurements from literature which extend over a larger temperature range were considered [1, 2, 3, 5, 6, 7, 8], and the coefficients of the equations were recalculated according to Gauss's method.

The equation from Vargaftik, Voljak and Volkov [1] is a simple polynomial with n = 9 terms.

$$\sigma = \sum_{i=1}^{n} a_i (T_c - T)^i \qquad (1)$$

$$T_C = 647.3 \quad K$$

In addition one finds from precision measurements [9, 1o, 11] in the neighborhood of the critical temperature, that there is a high probability that the second derivative becomes very large:

$$\left(\frac{d^2}{dT^2}\right)_c \longrightarrow \infty$$

Equation (1) fulfills only the 1st condition, $\sigma = 0$, at the critical point, equation (2) fulfills the 1st at well as the 2nd condition exactly and the 3rd condition numerically well.

According to more secent experimental [9, 1o, 11] and theoretical [12] investigations, the modified van der Waal's equation for simple fluids proved to be well suited as an interpolation equation over a large temperature range, whereby the 3 thermodynamic conditions at the critical point are exactly reproduced. Since a point of inflection occurs for water as for other polar fluids in the σ - T - curve [4, 9] the van der Waal's equation must be expanded by an additional term:

$$\sigma = B \left(\frac{T_c - T}{T_c}\right)^{\mu} \left[1 + b_2 \frac{T_c - T}{T_c} \right] \quad (3)$$

The following values are abtained for the exponent μ and the coefficients for the adaptation to the measured values by the method of least squares:

$B = + 2.38240214419_{10}{+2}$
$b_2 = - 6.33572399671_{10}{-1}$
$\mu = + 1.262$

The exponent $\mu = 1.26$ lies very close to the values which were found for simple fluids from theory [12] and from experimental investigation [9, 10, 11] to be 1.28. The coefficient B is comporable to the value σ_0 from the relationship of Ferguson [13], which was set up for simple fluids,

$$\sigma_0 = 3.12 \cdot \frac{T_c}{V_c^{0.55}} \qquad (4)$$

and yields a value of 217.4 for water. It is thus shown that water also approximately follows the general correspondence principle in the neighborhood of the critical state. The importance of equation (3) found here, is, that this formulation, at least in part has physical significance.

By comparison with the existing values, which were used here a standard deviation of approx. 0.12 dyn/cm was obtained for all three equations (1), (2), (3). Fig. 1 and Fig. 2 also make clear that the three equations reproduce the measured values equally well and lie within an expected maximum experimental error (Fig. 1). It is assumed for the experimental error that the differences between the fluid levels in the capillaries, Δh, can be measured within 0.01 and 0.02 mm. accuracy, and the diameter of the capillaries r_1, r_2 are able to be accurately determined to within ± 0.1 % according to [1]. Errors caused by uncertainty in the density difference ($\varrho_{fl} - \varrho_g$) and the temperature measurement are not taken into consideration.

From Fig. 2, one recognizes that the values of the different measured setes over the complete temperature range, utilizing equation(1) as a reference equation, vary by approx. ± 0.2 dyn/cm

In order to determine the final form of the formulas (1), (2), (3) and be able to compare their values with regard to their approximations, the number of terms was varied. Because of the wide distribution of the measured values, the previously evaluated mean values were utilized for approcimation instead of the measured values themselves.

With a standard deviation of $\Delta\sigma = 0.06$ dyn/cm for the mean values the measured values are reproduced within the measurement error limit, as discussed. For this reason equation (1) was terminated after 7 terms and equation (2) was terminated after 5 terms, as mentioned above.
A comparable standard deviation for equation (3) is reached with the second term b_2.

In Table 1, the mean values and the mean distribution of measured values as well as the deviations of the three equations from the mean values are represented next to one another. The deviations of equations (1), (2), (3) lie within the distribution of the measured values, with exception of the small region between 75 °C and 90 °C, in which the three equations exhibit an even systematic deviation. The mean values appear to be somewhat uncertain here.

Equation (3) was investigated to find out what influence the exponent μ_2 had on the term b_2, according to a more general form:

$$\sigma = B\left(\frac{T_c - T}{T_c}\right)^{\mu}\left[1 + b_2\left(\frac{T_c - T}{T_c}\right)^{\mu_2}\right] \qquad (3a)$$

In this investigation, the exponent μ_2 was varied from 0.5 to 1.3, and the exponent μ as well as the standard deviation were calculated. (Fig. 4). The minimum of the standard deviation lies approx. at $\mu_2 = 0.82$ and a value of $\mu = 1.288$ corresponds to this. Since this approx. is only slightly better than the assumption of $\mu_2 = 1.0$ it appears justified to let $\mu_2 = 1$ in equation (3).

3. Mean Values of Water

The large numbers of available measured values at this time, permit mean values and their tolerances to be calculated for integer temperatures. This is facilitated through interpolation of all measured values in the ranges ± 10 K to these integer temperatures with equations (1), (2), (3). The interpolated values were weighted diminishing with the distance from the actual interpolation temperatures.

The final mean values as they are entered in Table 2 were calculated in such a meannes so that values which deviated extremely from the mean values were taken less into consideration. In this way, the values of Table 2, with one degree graduation are considered to represent the best level of the surface tension of water at this time. Their tolerances in Column 4 of Table 2 represent the error limit of the mean values according to the statistic laws [14], and are calculated according to the following equation:

$$\Delta \sigma_m = \sqrt{\left(\sum_i^n [(\sigma_i - \sigma_m)^2 \, p_i]\right) \Big/ \left[(n-1) \sum_i^n p_i\right]} \qquad (5)$$

σ_i = interpolated measured value
σ_m = mean value
p_i = weight of σ_i
n = number of σ_i

These tolerances are not to be confused with the distribution of the measurement error according to Table 1, Column 4, which yield according to the equation:

$$\Delta \sigma_{dist} = \sqrt{\left(\sum_{i}^{n} [(\sigma_i - \sigma_m)^2 p_i] \right) / (n-1)} \qquad (6)$$

and are approximately three times larger than the above tolerances of the mean values.

The number of the available measured values of the surface tension of water is around 3oo.

4. Temperatur Dependence of the Surface Tension for Heavy Water

Only a few new measured values exist for D_2C at this time [3 , 7] . Therefore, it appeared to be too early to calculate mean values. In [3] , measurements are available for the whole range, from the triple point up till the critical point, so it was also possible to formulate simple interpolation equations. This was done in the same way as described above for H_2O, whereby the formulas were fitted to the measured values for D_2O. The formulated equations and their coefficients yielded the following:

$$\sigma = \sum_{i=1}^{9} a_i (T_c - T)^i \qquad (1/I)$$

$$
\begin{aligned}
a_1 &= +7.84614173463\,{}_{10}{}^{-2}\\
a_2 &= +4.73614216753\,{}_{10}{}^{-3}\\
a_3 &= -9.16510853551\,{}_{10}{}^{-5}\\
a_4 &= +1.08617092970\,{}_{10}{}^{-6}\\
a_5 &= -7.77722386860\,{}_{10}{}^{-9}\\
a_6 &= +3.37034313727\,{}_{10}{}^{-11}\\
a_7 &= -8.65283276763\,{}_{10}{}^{-14}\\
a_8 &= +1.21068672741\,{}_{10}{}^{-16}\\
a_9 &= -7.11141604380\,{}_{10}{}^{-20}
\end{aligned}
$$

Standarddeviation : $\Delta\sigma = 0.16$ dyn/cm

$$\sigma = A_1 \frac{(T_c-T)^2}{1+\beta(T_c-T)} + \sum_{i=2}^{5} A_i (T_c-T)^i \qquad (2/I)$$

$$
\begin{aligned}
\beta &= +0.216787\\
A_1 &= +3.52033753575\,{}_{10}{}^{-2}\\
A_2 &= +8.26760210956\,{}_{10}{}^{-4}\\
A_3 &= -3.81388016479\,{}_{10}{}^{-6}\\
A_4 &= +7.28781709872\,{}_{10}{}^{-9}\\
A_5 &= -5.87456358679\,{}_{10}{}^{-12}
\end{aligned}
$$

$\Delta\sigma = 0.16$ dyn/cm

$$\sigma = B \left|\frac{T_c-T}{T_c}\right|^{\mu} \left[1 + b_2 \left(\frac{T_c-T}{T_c}\right)\right] \qquad (3/I)$$

$$
\begin{aligned}
B &= +2.45335281003\,{}_{10}{}^{+2}\\
b_2 &= -6.62513863961\,{}_{10}{}^{-1}\\
\mu &= 1.27
\end{aligned}
$$

$\Delta\sigma = 0.16$ dyn/cm

with the crit. temperature $T_c = 644.65$ K
$t_c = 371.5$ °C

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Table 1 :

Surface Tension of Water

Comparison of Measurements and Equations

σ = mean-interpol. measurement (mean value)
$\Delta\sigma_d$ = distribution of measurements
$\Delta\sigma 3,2,1$ = deviations of equ.(3),(2),(1) from the mean value

t °C	T K	σ $\frac{dyn}{cm}$	$\Delta\sigma_d$	$\Delta\sigma 3$ 10^{-2}	$\Delta\sigma 2$ $\frac{dyn}{cm}$	$\Delta\sigma 1$
0	273,15	75,62	10	-2	-10	-5
5	278,15	74,91	7	-1	-4	+1
10	283,15	74,20	6	-1	+0	+5
15	288,15	73,47	8	-1	+3	+6
20	293,15	72,74	11	-2	+4	+6
25	298,15	71,97	12	-2	+6	+5
30	303,15	71,21	14	-2	+6	+3
35	308,15	70,42	15	-2	+6	+0
40	313,15	69,58	12	+2	+10	+3
45	318,15	68,78	11	+0	+7	-2
50	323,15	67,94	13	+2	+7	-2
55	328,15	67,08	12	+3	+7	-3
60	333,15	66,21	11	+5	+7	-2
65	338,15	65,33	12	+5	+6	-3
70	343,15	64,42	7	+8	+7	-1
75	348,15	63,51	6	+9	+7	+0
80	353,15	62,59	5	+11	+7	+2
85	358,15	61,66	4	+12	+6	+3
90	363,15	60,75	8	+10	+3	+1
95	368,15	59,82	9	+8	+1	+1
100	373,15	58,96	13	-2	-10	-8
105	378,15	58,01	12	-3	-13	-9
110	383,15	56,98	13	+1	-8	-3
115	388,15	56,00	13	+1	-9	-3
120	393,15	54,92	9	+8	-2	+5
125	398,15	53,91	8	+8	-2	+6
130	403,15	52,90	15	+7	-3	+6
135	408,15	51,86	15	+7	-2	+7
140	413,15	50,83	15	+6	-2	+6
145	418,15	49,77	15	+6	-1	+7
150	423,15	48,71	11	+7	+0	+8
155	428,15	47,67	11	+3	-2	+5
160	433,15	46,59	10	+3	-1	+5
165	438,15	45,56	10	-3	-6	-1
170	443,15	44,46	9	-2	-3	-0
175	448,15	43,35	17	-2	-3	-1
180	453,15	42,24	18	-2	-1	-1
185	458,15	41,09	17	+1	+3	+1
190	463,15	39,98	16	-1	+2	-0
195	468,15	38,80	13	+4	+8	+4
200	473,15	37,67	12	+3	+8	+3

Table 1 (continued) :

t °C	T K	σ $\frac{dyn}{cm}$	$\Delta\sigma_d$	$\Delta\sigma 3$	$\Delta\sigma 2$ $10^{-2}\ \frac{dyn}{cm}$	$\Delta\sigma 1$
205	478,15	36.52	12	+3	+9	+3
210	483,15	35.39	13	+0	+7	+0
215	488,15	34.31	13	-7	-0	-8
220	493,15	33.17	13	-9	-1	-9
225	498,15	32.00	18	-9	-1	-9
230	503,15	30.83	17	-9	-1	-8
235	508,15	29,63	16	-6	+2	-6
240	513,15	28,46	15	-7	+1	-6
245	518,15	27.32	11	-10	-3	-8
250	523,15	26.16	11	-12	-5	-10
255	528,15	24.94	16	-7	-2	-5
260	533,15	23.75	16	-7	-2	-4
265	538,15	22.54	16	-3	+1	+1
270	543,15	21.36	17	-3	-1	+0
275	548,15	20.19	16	-3	-2	+1
280	553,15	19.00	17	-2	-2	+2
285	558,15	17.81	20	+0	-1	+4
290	563,15	16.64	16	+2	-0	+5
295	568,15	15.48	14	+1	-2	+4
300	573,15	14.34	11	+1	-3	+3
305	578,15	13.20	10	+0	-4	+2
310	583,15	12.07	11	+1	-4	+1
315	588,15	10,95	10	+0	-4	-1
320	593,15	9.83	10	+3	-2	+0
325	598,15	8.71	10	+5	+1	+2
330	603,15	7.65	9	+4	+0	-0
335	608,15	6,60	9	+5	+2	-0
340	613,15	5.60	9	+2	+1	-3
345	618,15	4.63	8	-0	-0	-5
350	623,15	3.67	9	-1	+1	-3
355	628,15	2.75	8	-0	+2	-1
360	633,15	1.90	8	-1	+1	+2
365	638,15	1.10	9	-1	-1	+6
370	643,15	0,41	9	-1	-4	+7
374.15	647,30	0,02	6	0	0	0

TABLE 2 :

MEAN VALUES OF SURFACE TENSION OF WATER

t = TEMPERATURE °C
T = " K
σ = SURFACE TENSION dyn/cm = 10^{-3}N/m = 10^{-3}J/m^2
$\Delta\sigma$ = TOLERANCE OF σ 10^{-2}dyn/cm

t	T	σ	$\Delta\sigma$	t	T	σ	$\Delta\sigma$	t	T	σ	$\Delta\sigma$
0	273.15	75.62	3	50	323.15	67.94	3	100	373.15	58.95	3
1	274.15	75.45	2	51	324.15	67.75	3	101	374.15	58.79	3
2	275.15	75.33	2	52	325.15	67.59	4	102	375.15	58.59	3
3	276.15	75.19	2	53	326.15	67.42	4	103	376.15	58.40	3
4	277.15	75.05	2	54	327.15	67.25	4	104	377.15	58.21	3
5	278.15	74.91	2	55	328.15	67.08	4	105	378.15	58.01	3
6	279.15	74.77	2	56	329.15	66.91	4	106	379.15	57.81	3
7	280.15	74.63	2	57	330.15	66.74	4	107	380.15	57.62	3
8	281.15	74.49	2	58	331.15	66.57	4	108	381.15	57.43	3
9	282.15	74.35	2	59	332.15	66.40	4	109	382.15	57.23	3
10	283.15	74.20	1	60	333.15	66.21	3	110	383.15	56.98	3
11	284.15	74.05	1	61	334.15	66.03	3	111	384.15	56.80	3
12	285.15	73.91	1	62	335.15	65.86	3	112	385.15	56.60	3
13	286.15	73.76	1	63	336.15	65.68	3	113	386.15	56.40	3
14	287.15	73.61	1	64	337.15	65.51	3	114	387.15	56.20	3
15	288.15	73.47	2	65	338.15	65.33	3	115	388.15	56.00	3
16	289.15	73.32	2	66	339.15	65.15	4	116	389.15	55.75	3
17	290.15	73.18	2	67	340.15	64.98	4	117	390.15	55.55	3
18	291.15	73.03	2	68	341.15	64.80	4	118	391.15	55.33	3
19	292.15	72.88	2	69	342.15	64.62	4	119	392.15	55.13	3
20	293.15	72.74	2	70	343.15	64.42	2	120	393.15	54.92	3
21	294.15	72.59	2	71	344.15	64.23	2	121	394.15	54.71	2
22	295.15	72.43	2	72	345.15	64.05	2	122	395.15	54.51	2
23	296.15	72.28	2	73	346.15	63.87	2	123	396.15	54.32	2
24	297.15	72.13	2	74	347.15	63.69	2	124	397.15	54.11	2
25	298.15	71.97	3	75	348.15	63.51	2	125	398.15	53.91	2
26	299.15	71.82	3	76	349.15	63.33	2	126	399.15	53.70	3
27	300.15	71.67	3	77	350.15	63.15	2	127	400.15	53.49	3
28	301.15	71.52	3	78	351.15	62.97	2	128	401.15	53.29	3
29	302.15	71.37	3	79	352.15	62.78	2	129	402.15	53.10	3
30	303.15	71.21	3	80	353.15	62.59	2	130	403.15	52.90	4
31	304.15	71.07	3	81	354.15	62.40	2	131	404.15	52.70	4
32	305.15	70.91	3	82	355.15	62.22	2	132	405.15	52.49	4
33	306.15	70.75	3	83	356.15	62.03	2	133	406.15	52.28	4
34	307.15	70.59	3	84	357.15	61.85	2	134	407.15	52.07	4
35	308.15	70.42	3	85	358.15	61.65	2	135	408.15	51.85	4
36	309.15	70.26	4	86	359.15	61.49	3	136	409.15	51.65	4
37	310.15	70.09	4	87	360.15	61.31	3	137	410.15	51.45	4
38	311.15	69.93	4	88	361.15	61.13	2	138	411.15	51.24	4
39	312.15	69.78	4	89	362.15	60.94	2	139	412.15	51.03	4
40	313.15	69.58	3	90	363.15	60.75	2	140	413.15	50.83	4
41	314.15	69.44	4	91	364.15	60.58	3	141	414.15	50.63	4
42	315.15	69.27	4	92	365.15	60.39	3	142	415.15	50.41	4
43	316.15	69.11	4	93	366.15	60.20	3	143	416.15	50.20	5
44	317.15	68.95	4	94	367.15	60.01	3	144	417.15	49.99	4
45	318.15	68.78	4	95	368.15	59.82	3	145	418.15	49.77	4
46	319.15	68.62	3	96	369.15	59.70	3	146	419.15	49.58	3
47	320.15	68.45	3	97	370.15	59.51	3	147	420.15	49.36	3
48	321.15	68.27	3	98	371.15	59.33	3	148	421.15	49.15	3
49	322.15	68.10	3	99	372.15	59.14	3	149	422.15	48.91	3

TABLE 2 (cont.):

t	T	σ	Δσ	t	T	σ	Δσ	t	T	σ	Δσ
150	423.15	48.71	3	225	498.15	32.00	5	300	573.15	14.34	3
151	424.15	48.52	3	226	499.15	31.77	5	301	574.15	14.11	3
152	425.15	48.31	3	227	500.15	31.54	5	302	575.15	13.88	2
153	426.15	48.10	3	228	501.15	31.30	5	303	576.15	13.65	2
154	427.15	47.89	3	229	502.15	31.07	5	304	577.15	13.43	2
155	428.15	47.67	3	230	503.15	30.83	4	305	578.15	13.20	2
156	429.15	47.45	3	231	504.15	30.61	5	306	579.15	12.97	3
157	430.15	47.24	3	232	505.15	30.35	4	307	580.15	12.75	3
158	431.15	47.03	3	233	506.15	30.11	4	308	581.15	12.52	3
159	432.15	46.82	3	234	507.15	29.87	4	309	582.15	12.31	3
160	433.15	46.59	3	235	508.15	29.63	4	310	583.15	12.07	3
161	434.15	46.40	3	236	509.15	29.40	4	311	584.15	11.83	3
162	435.15	46.20	3	237	510.15	29.15	4	312	585.15	11.62	2
163	436.15	45.98	3	238	511.15	28.93	4	313	586.15	11.39	3
164	437.15	45.78	3	239	512.15	28.69	4	314	587.15	11.18	2
165	438.15	45.55	3	240	513.15	28.45	4	315	588.15	10.95	2
166	439.15	45.35	3	241	514.15	28.27	3	316	589.15	10.73	2
167	440.15	45.13	3	242	515.15	28.02	3	317	590.15	10.50	2
168	441.15	44.91	3	243	516.15	27.79	3	318	591.15	10.27	2
169	442.15	44.69	3	244	517.15	27.55	3	319	592.15	10.05	2
170	443.15	44.45	3	245	518.15	27.32	3	320	593.15	9.83	2
171	444.15	44.25	3	246	519.15	27.08	3	321	594.15	9.61	2
172	445.15	44.04	3	247	520.15	26.84	3	322	595.15	9.38	2
173	446.15	43.79	4	248	521.15	26.61	3	323	596.15	9.15	2
174	447.15	43.57	4	249	522.15	26.37	3	324	597.15	8.93	2
175	448.15	43.35	4	250	523.15	26.15	3	325	598.15	8.71	2
176	449.15	43.13	4	251	524.15	25.92	3	326	599.15	8.51	2
177	450.15	42.91	4	252	525.15	25.68	4	327	600.15	8.29	2
178	451.15	42.68	5	253	526.15	25.44	4	328	601.15	8.08	2
179	452.15	42.45	5	254	527.15	25.18	4	329	602.15	7.87	2
180	453.15	42.24	5	255	528.15	24.94	4	330	603.15	7.65	2
181	454.15	41.98	4	256	529.15	24.70	4	331	604.15	7.45	2
182	455.15	41.75	4	257	530.15	24.46	4	332	605.15	7.23	2
183	456.15	41.54	4	258	531.15	24.22	4	333	606.15	7.02	2
184	457.15	41.31	4	259	532.15	23.98	4	334	607.15	6.80	2
185	458.15	41.09	4	260	533.15	23.75	4	335	608.15	6.60	2
186	459.15	40.87	4	261	534.15	23.41	5	336	609.15	6.39	2
187	460.15	40.64	4	262	535.15	23.25	4	337	610.15	6.20	2
188	461.15	40.42	4	263	536.15	23.01	4	338	611.15	5.99	2
189	462.15	40.19	4	264	537.15	22.77	4	339	612.15	5.80	2
190	463.15	39.98	4	265	538.15	22.54	4	340	613.15	5.60	2
191	464.15	39.69	4	266	539.15	22.30	4	341	614.15	5.40	2
192	465.15	39.47	4	267	540.15	22.06	4	342	615.15	5.21	2
193	466.15	39.25	4	268	541.15	21.83	4	343	616.15	5.01	2
194	467.15	39.02	4	269	542.15	21.59	4	344	617.15	4.82	2
195	468.15	38.80	4	270	543.15	21.35	4	345	618.15	4.63	2
196	469.15	38.57	4	271	544.15	21.08	4	346	619.15	4.43	1
197	470.15	38.34	4	272	545.15	20.87	4	347	620.15	4.24	1
198	471.15	38.12	4	273	546.15	20.64	4	348	621.15	4.05	1
199	472.15	37.89	4	274	547.15	20.42	4	349	622.15	3.85	1
200	473.15	37.67	4	275	548.15	20.19	4	350	623.15	3.67	2
201	474.15	37.41	4	276	549.15	19.95	4	351	624.15	3.49	1
202	475.15	37.20	4	277	550.15	19.71	4	352	625.15	3.30	1
203	476.15	36.98	4	278	551.15	19.49	4	353	626.15	3.11	1
204	477.15	36.75	4	279	552.15	19.22	4	354	627.15	2.93	1
205	478.15	36.52	4	280	553.15	19.00	4	355	628.15	2.75	1
206	479.15	36.29	4	281	554.15	18.78	4	356	629.15	2.58	1
207	480.15	36.06	4	282	555.15	18.52	5	357	630.15	2.40	1
208	481.15	35.83	4	283	556.15	18.28	5	358	631.15	2.23	1
209	482.15	35.60	4	284	557.15	18.05	5	359	632.15	2.05	1
210	483.15	35.39	4	285	558.15	17.81	5	360	633.15	1.90	1
211	484.15	35.15	4	286	559.15	17.57	4	361	634.15	1.73	1
212	485.15	34.95	4	287	560.15	17.33	4	362	635.15	1.57	1
213	486.15	34.75	3	288	561.15	17.10	4	363	636.15	1.42	1
214	487.15	34.54	4	289	562.15	16.85	4	364	637.15	1.25	2
215	488.15	34.31	4	290	563.15	16.64	4	365	638.15	1.10	2
216	489.15	34.08	4	291	564.15	16.41	4	366	639.15	0.95	2
217	490.15	33.85	4	292	565.15	16.13	4	367	640.15	0.81	2
218	491.15	33.62	4	293	566.15	15.95	3	368	641.15	0.67	2
219	492.15	33.39	4	294	567.15	15.71	3	369	642.15	0.54	2
220	493.15	33.17	4	295	568.15	15.48	3	370	643.15	0.41	2
221	494.15	32.95	5	296	569.15	15.25	3	371	644.15	0.31	2
222	495.15	32.71	5	297	570.15	15.02	3	372	645.15	0.20	2
223	496.15	32.47	5	298	571.15	14.80	3	373	646.15	0.11	2
224	497.15	32.24	5	299	572.15	14.59	3	374	647.15	0.03	2

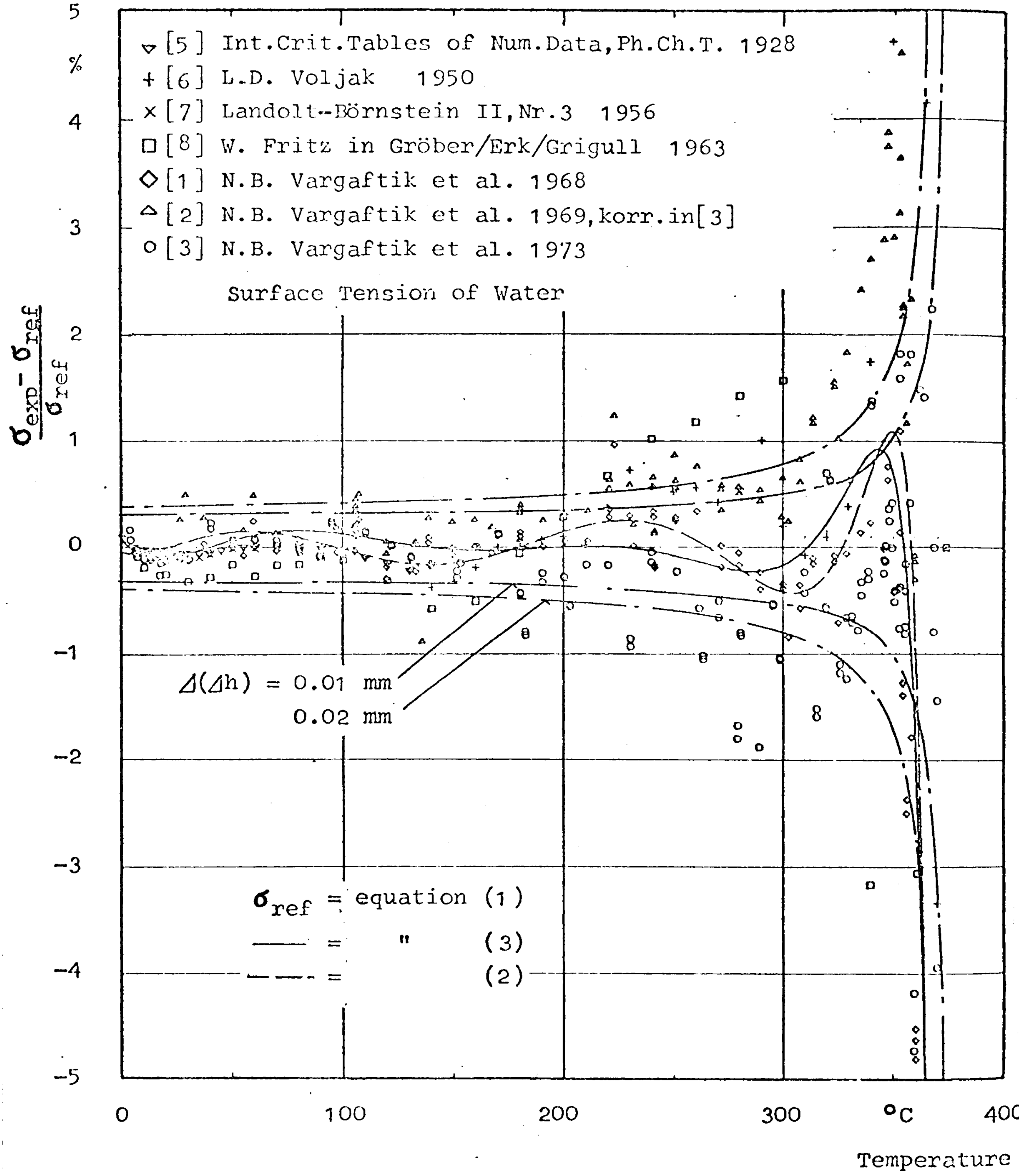

Figure 1 : Deviation of available measurements and estimated max. error f(t) —·—
$f(\Delta r_1, \Delta r_2, \Delta(\Delta h), \Delta\varrho = 0) = f(t)$

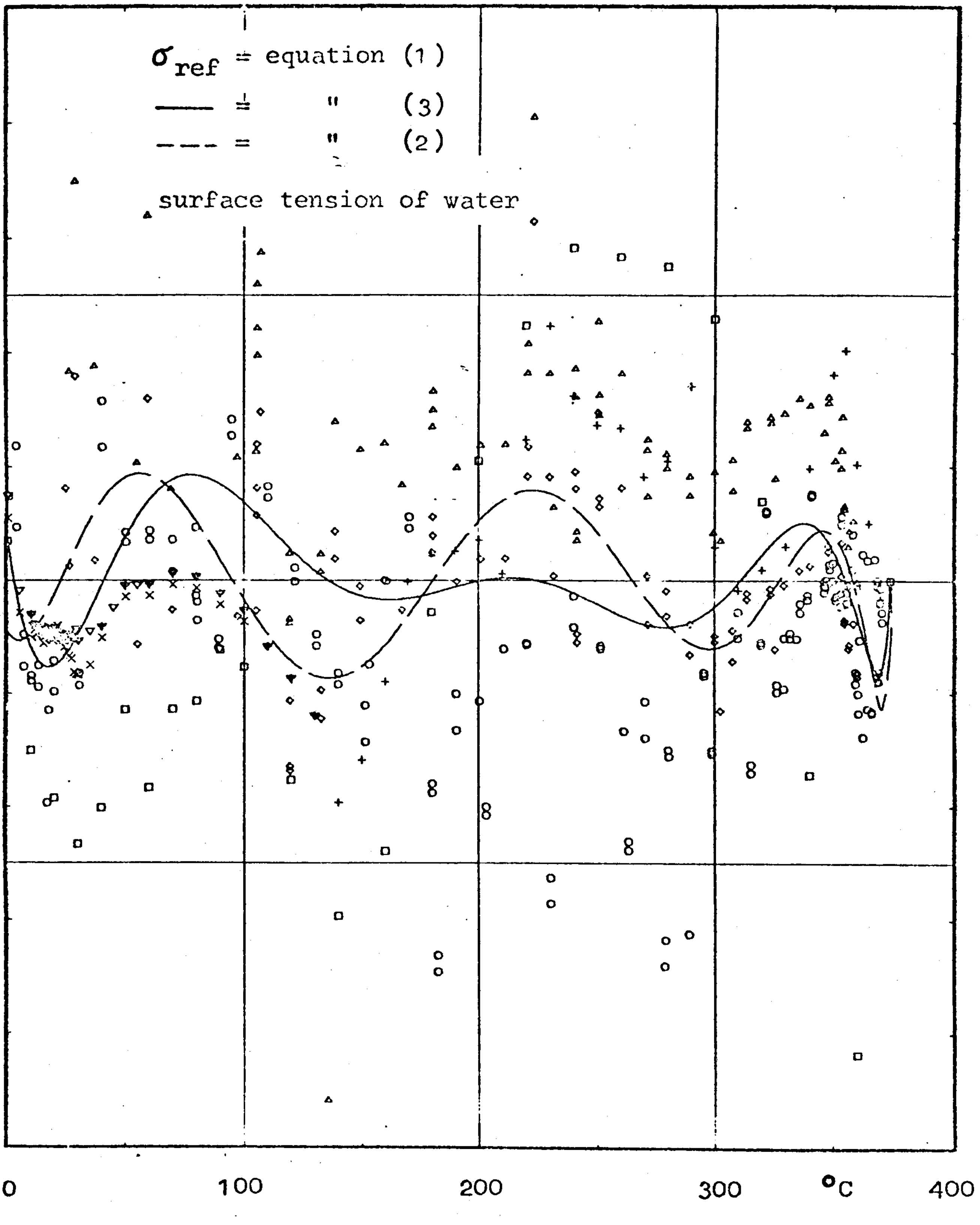

Figure 2 : Scattering of available measurements and comparison with equations. (Symbols see Fig.1)

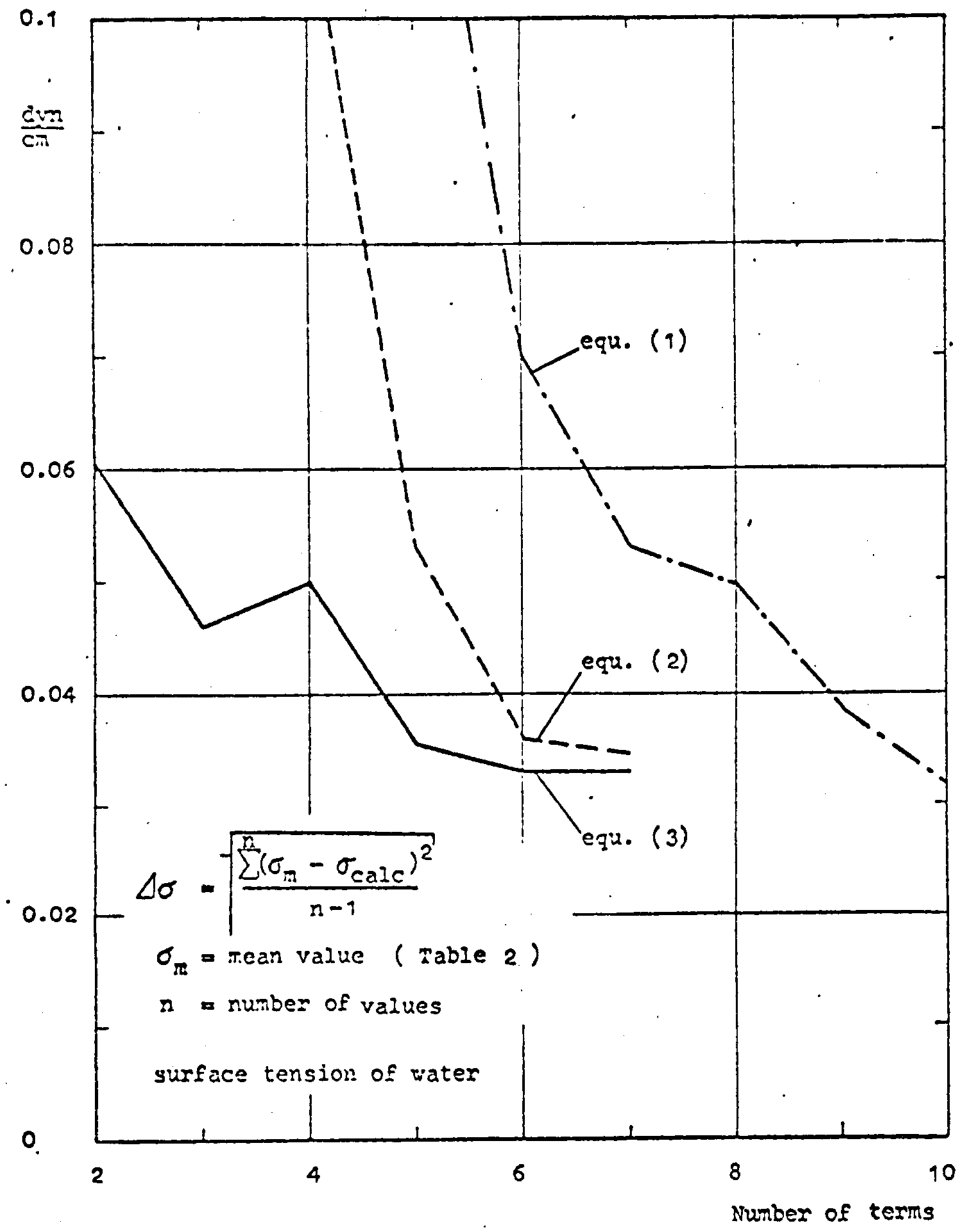

Figure 3: Comparison of the equations (1)-(3).

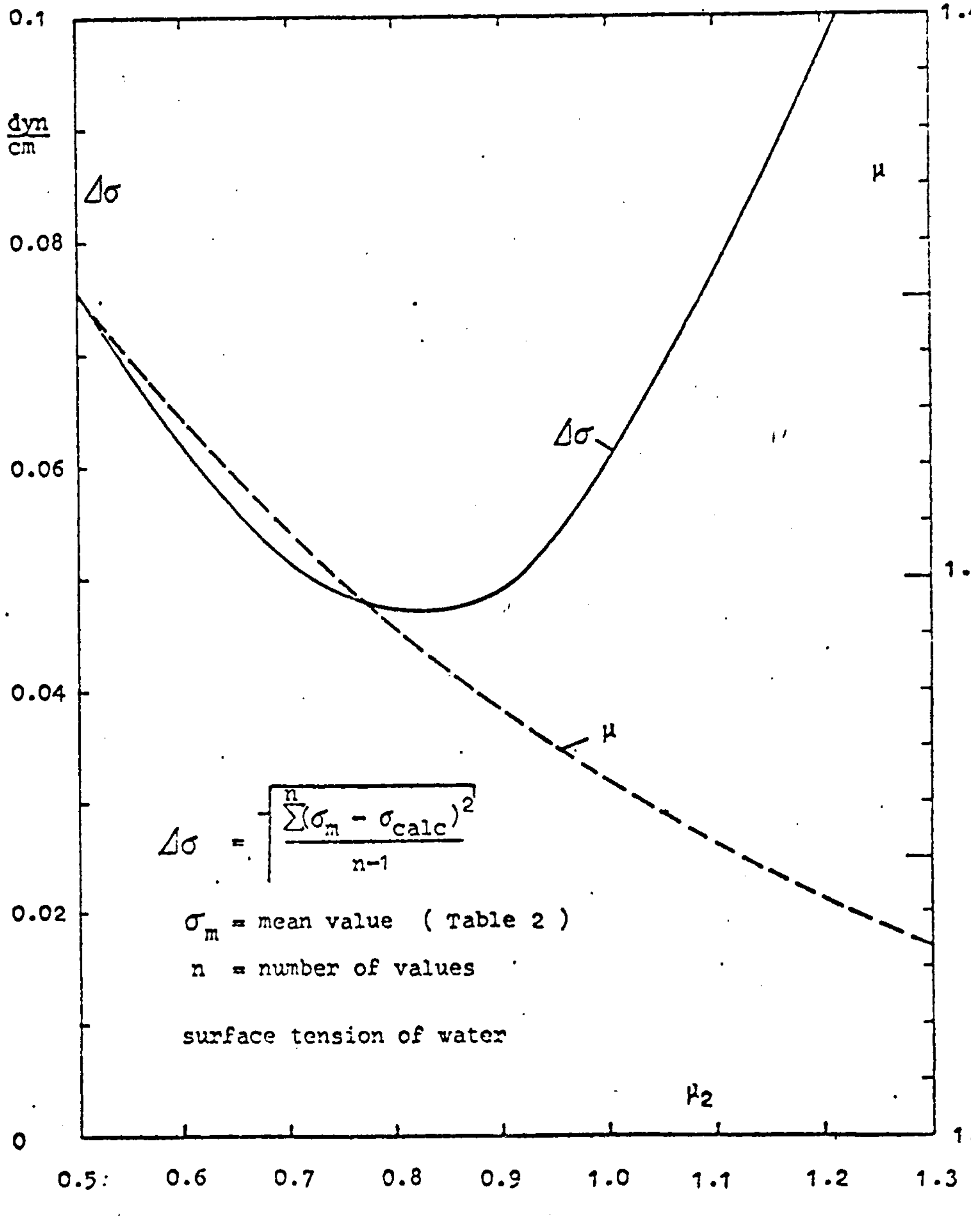

Figure 4: Variation of μ_2 in equation (3a).

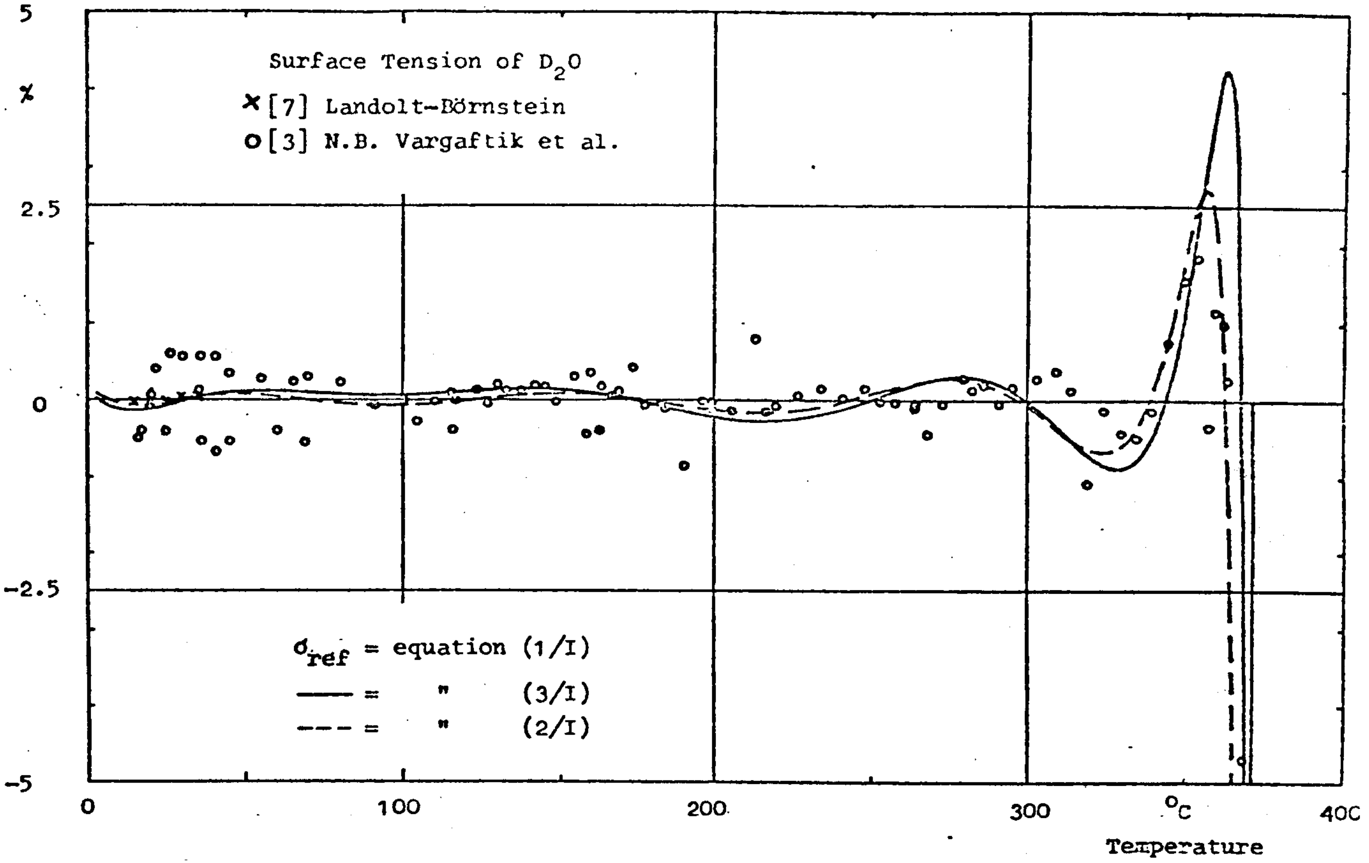

Figure 5: Percentage deviations of measurements and equations of D_2O

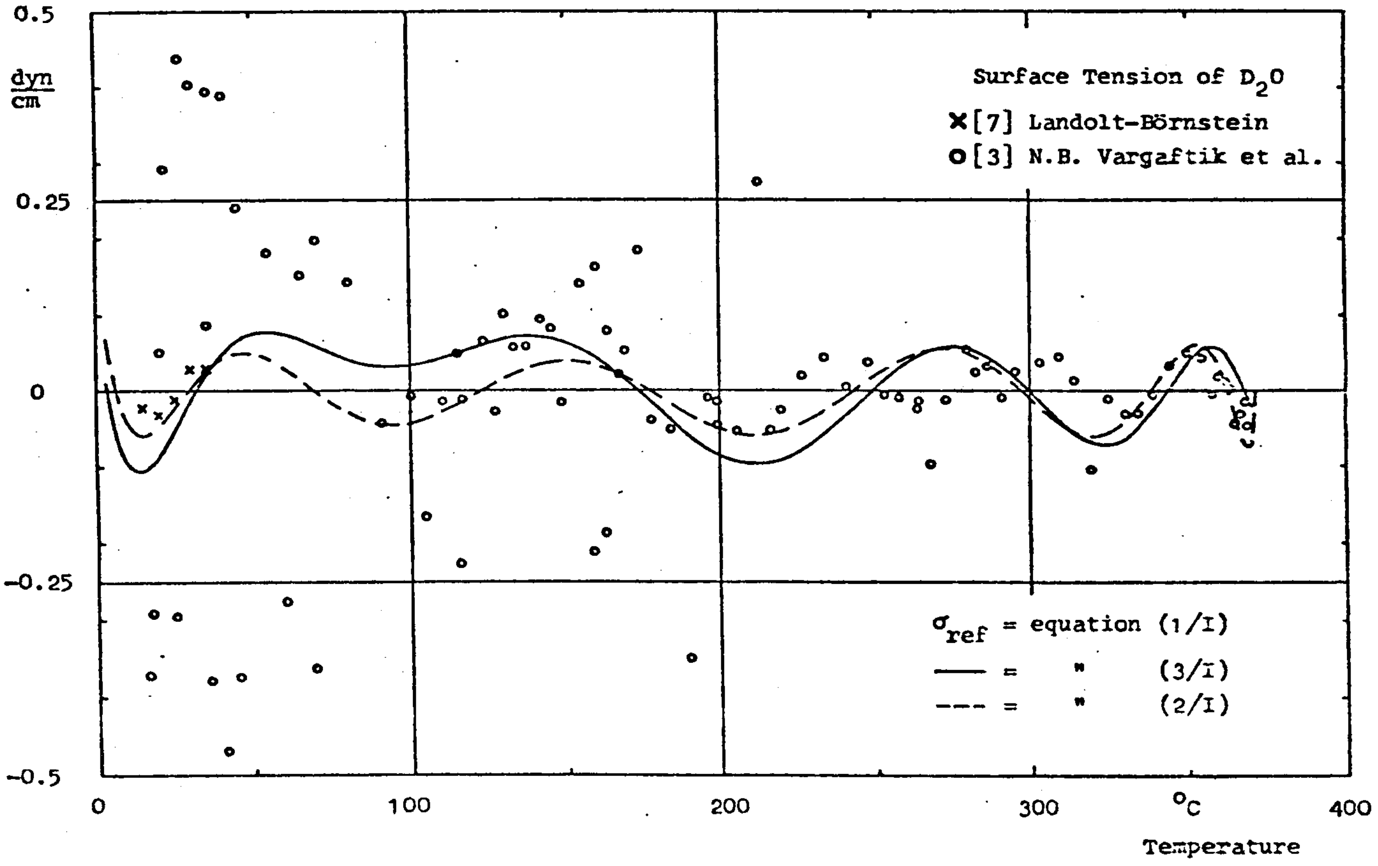

Figure 6: Scattering of measurements of D_2O

Discussion

G.S. KELL : What about the solubility of the capillaries at temperatures near critical?

J. STRAUB : The same question I asked during a working group meeting in Moscow in May 1974 the authors of paper X/2, which made the measurements on surface tension for water. Their reply was, that the measurements at temperatures above 350°C are made in short time, so that the solubility of quartz in water didn't influence the measurements.