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**Fifth report of the Joint Panel on
Oceanographic Tables and Standards**

**Kiel,
10 - 12 December 1969
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Unesco, ICES, SCOR, IAPO**

Unesco

FIFTH REPORT OF THE JOINT PANEL
ON OCEANOGRAPHIC TABLES AND STANDARDS

Kiel, 10-12 December 1969

jointly sponsored by the
United Nations Educational, Scientific and Cultural Organization
International Council for the Exploration of the Sea
Scientific Committee on Oceanic Research
International Association of Physical Oceanography

The scientific views expressed here are those of experts participating in the work of the Panel and not necessarily those of Unesco or other sponsoring organizations.

The members of the Joint Panel of Experts on Oceanographic Tables and Standards (Annex III) were invited to attend a meeting in Kiel from 10 to 12 December 1969. The meeting was held at the Institute for Applied Physics of the University.

The members present were:

Mr. Frede Hermann (Chairman)	}	ICES
Mr. Odd Saelen		
Mr. Fred Culkin		
Dr. N.P. Fofenoff	}	IAPSCO
Prof. W. Kroebel		
Dr. K. Grasshoff	}	SCOR
Dr. Frederick H. Fisher		
Mr. M. Menaché	{	Unesco

The Soviet member, Mr. G.N. Ivanoff-Frantzkevich, was unable to attend the meeting.

The observers present were:

Prof. W. Wooster	}	SCOR
Dr. G. Giermann		Unesco
Dr. K. Kremling		I.f.M. Kiel

Prof. Kroebel welcomed the Panel to his institute, and the Chairman then opened the meeting. The agenda as proposed by the Chairman was adopted by the Panel as follows:

1. Adoption of the agenda.
2. Election of the Panel's Chairman.
3. Information on the progress of work:
 - (a) refraction index measurements;
 - (b) oxygen solubility tables;
 - (c) specific gravity of sea water;
 - (d) isotopic composition of distilled water;
 - (e) thermal expansion of sea water;
 - (f) conductivity of sea water under pressure;

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 - (f) conductivity of sea water under pressure;

- (g) measurements of sound velocity as function of pressure, temperature and salinity;
- (h) effect on conductivity of changes of composition of sea water.

4. Plans for further laboratory work.
5. Schedule of publishing new instalments to the International Tables.
6. Other matters

Item 2 of the agenda was postponed until 12 December.

Item 3 of the agenda

(a) Dr. Culkin referred to the work of Dr. J.S.M. Rusby. The measurements have been finished, the results published (Deep Sea Res. 1967, 14, 427 - 39) and the tables have been included in the Unesco Oceanographic Tables. The question of confirming these measurements was discussed but the Panel could not nominate anybody to perform the expensive measurements with the same precision as Dr. Rusby. With the publication of the tables, the task of the Panel with respect to the refractive index measurements is fulfilled.

(b) According to the resolution of the Panel's meeting in Bern the ICES Sub-Committee for Chemical Analysis of Sea Water was asked to recommend further steps with respect to the oxygen solubility tables. The ICES group recommended in 1967 the smoothing equation of E.J. Green as the basis for new oxygen saturation tables. In the meantime, new independent measurements of the oxygen solubility in sea water had been made by Carpenter and by J.P. Riley. The two new sets of measurements agreed excellently between each other but disagreed to a certain extent from Green's measurements.

In February 1969 a meeting of the recent originators of oxygen saturation values and others concerned with the question was held in Ft. Lauderdale, Florida. The meeting was sponsored by SCOR. The participants were Prof. D.E. Carritt, Prof. Bruce Benson, Dr. E.J. Green, Dr. J.L. Carpenter, Dr. Joris Gieskes, Prof. J.P. Riley, Dr. K. Grasshoff.

As a result of this meeting it was found that the raw data - after some necessary corrections had been applied to Green's measurements - agreed very well and that no significant differences could be found in spite of the fact that completely different techniques have been applied. It was decided that each originator should take all raw data and apply his technique of smoothing and interpolation. The exp. values which are obviously out of the range by more than ± 0.03 ml/l should be rejected and a new smoothing should be made on the basis of the remaining data.

These calculations should be submitted to the Chairman of the meeting not later than fall 1969.

The participants did not feel that new measurements could improve the reliability of the existing data considerably.

Unfortunately the submission of the recalculated saturation values was delayed so that at the time of the meeting no comparison of the different treatments was possible.

In the meantime, R. Weiss from SCRIPPS Institute of Oceanography developed a simple equation for the smoothing of the experimental oxygen saturation data of Carpenter and Riley. This equation has a sound thermodynamical basis and is derivated from the Vant'Hoff equation for the dependence of the Bunsen solubility coefficient from the temperature and from the Setchenof equation for the salinity dependence.

This equation has the form:

$$\ln C = A_1 + A_2 \frac{100}{T} + A_3 \ln \left(\frac{T}{100} \right) + A_4 \frac{T}{100} + S \text{‰} (B_1 + B_2 \frac{T}{100} + B_3 \frac{T^2}{10^4})$$

and gives a mean standard deviation from the experimental data of ± 0.018 ml/l resu. ± 0.016 ml/l, depending on the source of the data used in the calculation.

The panel felt that this equation is the best available at present and should be used for the calculation of the new saturation tables.

It was decided that a copy of the preliminary paper of R. Weiss should be sent to the participants of the Ft. Lauderdale meeting for comments. Replies were expected by the end of January 1970. It would thus be possible to calculate the new tables before April 1970 and forward them to Unesco in May.

(c) Dr. Culkin gave a final report on the measurements of the specific gravity of sea water and the relationships to salinity and temperature. These measurements form the basis of the new tables to be published by Unesco as part of the Oceanographic Tables. The format of the tables was discussed. The Panel felt that the form of the U.S. Navy tables for the conversion of salinity and temperature into sigma-t is the most convenient. Moreover, it was discussed whether the basic determinations of the N.I.O should possibly be confirmed by an independent institution but it seemed unlikely that the Panel could nominate anybody able to do this with comparable accuracy. Dr. Kremling mentioned in this connexion that some comparisons which he performed with the new instrument for the determination of specific gravity gave equal results. This instrument allows determinations of the specific gravity with a precision of ± 3 in the third decimal of sigma-t. One determination takes only about 10 minutes. The principle is based on the measurement of the Eigenfrequency of a glass capillary filled with the sample. Before the final edition of the Unesco tables it was recommended to check the silicate content of the reference water. Attention should be paid to the results of the Soviet Institutes on the specific gravity - salinity - temperature relation. Mr. Crease - now head of the British Oceanographic Data Centre - should be approached by Dr. Culkin for calculation and interpolation of the new tables in co-operation with Dr. Fofonoff and Dr. Fisher.

According to a suggestion of Dr. Menaché the new Temperature Scale should be taken into consideration in this connexion. The Chairman expressed the gratitude of the Panel to Dr. Culkin and his colleagues for their excellent work.

The Panel discussed in this connexion the need for comparison of actual measurements of the specific gravity of random selected water samples from all parts of the world ocean and the sigma-t values as calculated from the temperature and the conductometrically determined salinity. Such measurements seemed to be feasible now with the new precision instrument available at the I.f.M. Kiel. The Panel recommended to give Dr. K. Kremling all necessary support to carry out such determinations. Dr. Kremling will approach certain institutes in order to arrange for the provision of samples. He was also asked by the Panel to perform some independent cross-checks on samples from the N.I.O.

(d) Dr. Menaché presented his report on the measurements of the isotopic composition of the reference water distilled according to the N.I.O. procedure from West Mediterranean water from about 2,000 m. The results of the measurements of the samples as supplied by the N.I.O. and by the I.f.M. show that there is no significant deviation of the isotopic composition of the original water and the distillate in either institute. The distillation procedure therefore can be recommended as a standard procedure for a reference water for the determination of the specific gravity. In this connexion the adoption of the new temperature scale was again brought to the attention of the Panel. The Panel asked the new Chairman to submit a short note on this matter to some of the major journals in marine science. The Panel recommends strongly that all calibration certificates etc. should state the use of the new temperature scale. The Chairman expressed to Dr. Menaché the sincere thanks of the Panel for his work. In this connexion the question of the determination of the absolute density of water was raised again. The discussions resulted in a resolution which was adopted by the Panel (Annex I).

(e) The members of the Panel reported on measurements of the thermal expansion of sea water. The Chairman read a letter from Dr. Ivanoff-Frantzkevich giving a progress report on the Soviet measurements of thermal expansion. The measurements will be completed by the middle of 1970. Dr. Fofonoff reported on work being carried out at the Woods Hole Oceanographic Institution by Bradshaw and Schleicher at 30.5, 35.0, 39.5 ‰ S at pressures between 1 and 1,000 bars.

The design of further experiments was discussed, especially in connexion with the measurements of the absolute density of pure water.

(f) The Panel discussed the need for new independent measurements of the pressure dependence of conductivity. The number of in situ pressure - conductivity - temperature - instruments is rapidly increasing. Apart from the experiments started at the Institute of Applied Physics in Kiel no laboratory could be nominated by the members of the Panel which is at present engaged in conductivity pressure measurements. The Chairman recommended that the members of the Panel should investigate whether and where such experiments are being performed or planned. In this connexion, it was discussed that there is also an urgent demand for the extension of the temperature correction values of the relative conductivity below the range as published in the International Oceanographic Tables. Especially the low range (below 12 degrees centigrade) is of special interest because of the fact that most of the in situ conductivity measurements are made at low temperatures. At present, it is impossible to convert the conductivity values measured at low temperatures into conductivities at 15°C, as printed

in the tables. Dr. Fofonoff developed a system of ratios replacing the ratio $R(t,p,S)/R(15,0,35)$. In situ conductivity instruments measure the ratio $\frac{\lambda(T,S,P)}{\lambda(15,35,0)}$.

T,S,P indicate electrical conductivity, temperature, salinity and pressure respectively. In order to convert these measurements to salinities it is necessary to know the function $f(T,S,P) = \frac{\lambda(T,S,P)}{\lambda(15,35,0)}$.

This ratio can be split into a number of ratios as follows:

$$\frac{\lambda(T,S,P)}{\lambda(15,35,0)} = \frac{\lambda(T,S,P)}{\lambda(T,S,0)} \cdot \frac{\lambda(T,S,0)}{\lambda(15,S,0)} \cdot \frac{\lambda(15,S,0)}{\lambda(15,35,0)}$$

In this equation the last ratio is R_{15} , which is tabulated against salinity in the Unesco International Tables, but measurements of the second ratio have not been made.

In order to calculate salinities from the measured ratio $\frac{\lambda(T,S,P)}{\lambda(15,35,0)}$ and measured temperature and pressure it is necessary to measure the ratio $\frac{\lambda(T,S,0)}{\lambda(T,35,0)}$ at temperature below 12°C or to measure the ratio $\frac{\lambda(T,S,0)}{\lambda(15,S,0)}$. The intense discussion resulted in a second recommendation (Annex I).

(g) Prof. Kroebel presented a progress report on the measurements of sound velocity in sea water as a function of salinity, temperature and pressure. A new instrument for precision determination is being developed at his institute which permits a level of precision in sound velocity measurement not known hitherto. Once the fundamental relationships are known, the sound velocity could be used for the determination of, e.g. pressure or density. The Panel had the opportunity to visit Prof. Kroebel's institute and his outstanding instrumentation and experimental set-ups for the determination of the fundamental relationships as mentioned above. The Panel is convinced of the usefulness of Prof. Kroebel's efforts and was very impressed by this demonstration. It was decided by the panel to give Prof. Kroebel all possible support. The Chairman will express the feelings of the Panel in a letter to Prof. Kroebel.

(h) Dr. Fisher presented a summary of the progress of work with respect to the equation of state of sea water. His evaluations were followed by a lively discussion.*

Dr. Kremling presented his investigations on the influence of changes of the ionic composition of sea water of lower salinities and the impact on conductivity. Previous papers of Park and Grasshoff deal especially with the effect of the state of the carbonate system on conductivity. The presentation was followed by an intense discussion. It is the feeling of the Panel that such changes should not be neglected. A verification of the combined effects of sampling, storage and changes in the ionic composition is needed. The laboratory experiments show clearly that the third decimal of the salinity is influenced and that the accuracy of the third decimal of the salinity as obtained by means

(*) Dr. Fisher's presentation is reproduced in Annex II.

of conductivity measurements is doubtful. The difference between accuracy and precision ought to be clearly understood by all users of a conductivity instrument. The best way of checking the accuracy would be to measure the density of samples taken on a routine basis with the new densitometer. Only by such measurements could the value of the third decimal be stated.

In order to check how changes in the carbon dioxide system affect the routine determination of salinity the Panel proposed that institutions which have the opportunity should make replicate determinations on a number of samples of conductivity ratio, density, C1‰ and pH at different time intervals after collection of the sample.

(i) Plans for further laboratory work had already been discussed in connexion with the sub-items of Point 3 of the agenda. The discussions led to the two recommendations of the Panel.

(j) The calculations of the new sigma-t tables should be made as soon as independent checks have been made by Dr. Kremling. The tables and nomographs should be ready for submission to Unesco by the end of 1970. The oxygen saturation tables should be ready for submission in May 1970. It was decided after a thorough discussion that the tables should have the arguments cm^3/dm^3 , Salinity, Temperature. The spacing should be in full units of salinity, and two-tenths of a degree in temperature. To allow a computation of tables in other units, e.g. ml (S,T,P) per kilogramme of water, or micromoles or microgramatoms per litre, the complete set of coefficients and the form of the equations will be published in the preface of the tables.

As it is confirmed by the redeterminations of the specific gravity that the new values do not deviate significantly from the values as published in the Knudsen Hydrographic Tables corresponding to the second decimal in chlorinity, the Panel felt that the density values from the Knudsen Hydrographic Tables are sufficient for the computation of a conversion table salinity into chlorosity at 20°C. Dr. Grasshoff was asked to compile such a conversion table with suitable spacing of the arguments. This conversion table should then be published as an annex to the Unesco Hydrographic Tables, as decided already at the Bern Meeting of the Panel.

Item 2 of the agenda:

The Panel elected Dr. Grasshoff as the new Chairman.

It was decided that the Panel should meet again when new investigations and measurements of relationship as mentioned under items (e), (f), (h) are performed and further additions to the Unesco Hydrographic Tables could be provided.

The Chairman closed the meeting at noon on 12 December 1969, with thanks to the host, Prof. Kroebel.

ANNEX I

RECOMMENDATION 1969, NO. 1

The Joint Panel on Oceanographic Tables and Standards determined that knowledge of the absolute density of sea water as a function of temperature and salinity is necessary to an accuracy of one part per million. Such precision cannot be obtained without acknowledgement of density of pure water to at least the same accuracy in order to use pure water as a reference for the sea water measurements. With the adoption of the new International Practical Temperature Scale in 1968 (Metrologia, 1969, V (2), pp. 35-44), in which the triple point of pure water is taken to be of water having the isotopic composition of ocean water. It is recommended that measurements of the following properties be made at a pressure of one normal atmosphere of degassed water of known isotopic composition, preferably as close as possible to that specified above.

1. Absolute density at 4°C and preferably at at least two other temperatures 0° and 20°C.
2. Thermal expansion to an accuracy sufficient to calculate density to the required accuracy from 0° to 40°C.

The Panel recommends that the measurements be made at least at two different laboratories, such as Bureau International des Poids et Mesures, National Bureau of Standards, National Physical Laboratory.

Considering that, at temperatures superior to 16°C, the density of pure water is now known only with an insufficient precision, it is recommended that, at the time of future determinations of density of sea water, the calibration with pure water is made at 4 or 0°C solely, the thermic dilatation of the sinker (or pycnometer), if it is not known, being able to be determined on a sample of same material, interferometrically.

The Panel hopes that, if necessary, funds can be obtained to ensure that this work can be accomplished.

The Panel asks all great international oceanographic organisms to endorse this Recommendation.

ANNEX II

Analytic Equation of State for Water and Sea Water

F.H. Fisher,
Robert Bruce Williams and O.E. Dial, Jr.

University of California, San Diego
Marine Physical Laboratory
of the
Scripps Institution of Oceanography

The following is a brief summary of the results of work reported at the meeting of the Joint Panel on Tables and Oceanographic Standards in Kiel, December 1970. This work will be presented for publication in more detail at a later date, probably in the Journal of Geophysical Research.

The equation used is the Tumlirz equation used by Eckart ^{1/} in his paper on this subject

$$V = V_{\infty} + \frac{\lambda}{P_0 + P} \quad (1)$$

where V is the specific volume (cc/gm), P the pressure (bars) and V_{∞} , λ , and P_0 are temperature dependent parameters. This equation fits the pure water PV data of Kell and Whalley ^{2/} (K&W) to a precision with the standard deviation of approximately 10 PPM over the temperature range of 0 to 100°. A total of 20 terms appear in the three parameters V_{∞} , λ and P (Table I).

In attempting to fit Eq. (1) to the sea water data of Wilson and Bradley ^{3/}, (W&B), the most extensive set of experimental data from a single laboratory, we found that P_0 , λ and V_{∞} displayed an erratic

dependence on salinity. When λ was constrained to be the value derived from the pure water data of Kell and Whalley, it was found that P_0 and V_∞ displayed a linear dependence on salinity. Finally, the equation used to fit the sea-water data is that shown in Equation (2)

$$V = V_\infty - K_1 S + \frac{\lambda}{P_0 + K_2 S + P} \quad (2)$$

where λ , V_∞ and P_0 are those values used to fit the pure water data. K_1 displays a quadratic temperature dependence and K_2 a linear one (Table I).

Use of Bradshaw and Schleiher's ^{4/} (B&S) data on thermal expansion has been incorporated in our results in the coefficient K_1 . It appears from the B&S data that the W&B data is less reliable at low temperatures.

It should be noted that the pure water equation has a density maximum at 4.00°C. Use has been made of the atmospheric pressure data discussed by Kell ^{5/} in addition to the PV data of K&W.

The density maximum for sea water shows a greater salinity dependence; that is, the cross-over of the freezing point and the density maximum occurs at a lower salinity than stated in the text books, in this case at ~22‰ instead of ~25‰.

This equation, FWD for Fisher, Williams and Dial, then requires 20 terms for the 0-150° pure water data and only five additional terms for sea water. A truncated equation for pure water will be examined to see if the number of parameters for pure water can be reduced in order

to represent only the data between 0° and 40°.

Table II shows the fit of the FWD equation to the W&B data.

Table III summarizes results of various investigators for the thermal expansion coefficient of sea water shown in the W&B technical report along with our results.

Table IV in an analogous manner summarizes the specific volume results along with ours and those calculated by us from Li's results.

Similarly, Table V summarizes the compressibility results.

In Table VI we compare our results for thermal expansion ($\partial V/\partial T$) against those of B&S as a function of temperature, salinity and pressure. At 0° we find the greatest disagreement with their results.

In Table VII we do see, however, that changes in specific volumes from -2° to +2° calculated by the FWD equation compare very favorably with the results of B&S. In this case we are comparing our values from our equation against their raw data.

Values of the adiabatic gradient calculated from the FWD equation for $S=35\%$ were slightly lower than those reported by Fofonoff 6/, for example, 4% at 2° and 400 bars and 7% at 2° and 1,000 bars.

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3. W. Wilson and D. Bradley, NOLTR 66-103, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland (1966).
4. A. Bardshaw and K.E. Schleicher, "Direct Measurement of Thermal Expansion of Sea Water under Pressure", submitted for publication to Deep Sea Research.
5. G.S. Kell, J. Chem. Engr. Data, 12, 66 (1967).
6. N.P. Fofonoff, The Sea, Vol. 1, 3-30 (1962), N.M. Hill, editor, Interscience Publishers, New York.

TABLE I

TUMLIRZ EQUATION FOR PURE WATER AND SEA WATER

$$V = V_{\infty} - K_1 S + \frac{\lambda}{P_0 + K_2 S + P}$$

$$\lambda = 1788.316 + 21.55053 * T - 0.4695911 * T^2 + 3.096363 \times 10^{-3} T^3 - .7341182 \times 10^{-5} * T^4$$

$$P_0 = 5918.499 + 58.05267 * T - 1.1253317 * T^2 + 6.6123869 \times 10^{-3} * T^3 - 1.4661625 \times 10^{-5} * T^4$$

$$V_{\infty} = .6980547 - .7435626 * 10^{-3} * T + .3704258 \times 10^{-4} * T^2 - .6315724 \times 10^{-6} * T$$

$$+ .9829576 \times 10^{-8} * T^4 - .1197269 \times 10^{-9} * T^5 + .1005461 \times 10^{-11} * T^6$$

$$- .5437898 \times 10^{-14} * T^7 + .169946 \times 10^{-16} * T^8 - .2295063 \times 10^{-19} * T^9$$

$$K_1 = 2.679 \times 10^{-4} + 2.02 \times 10^{-6} * T - 6.0 \times 10^{-9} * T^2$$

$$K_2 = 10.874 - 4.1384 * 10^{-2} * T$$

λ bars cc/gm

P, P_0 bars

K_2 bar/o/oo

V_{∞} cc/gm

K_1 cc/gm/o/oo

TABLE II

Standard deviations in parts per million of the fit of the FWD equation to raw specific volume data of Wilson and Bradley vs. temperature and salinity. (Temperature cited is nominal since data were taken at varying temperatures near cited one.) The average of the standard deviations is 107 ppm for all the data.

T S ‰	10.221	20.720	30.881	35.568	40.370
~ 0°	208	175	230	264	156
~ 5°	173	129	212	187	236
~10°	128	51	167	172	45
~15°	102	38	94	134	55
~20°	42	76	44	140	37
~25°	17	60	85	95	62
~30°	17	106	93	47	104
~35°	22	117	55	43	98
~40°	19	154	34	100	161

TABLE III

THERMAL EXPANSION OF SEA WATER (S = 35°/00)
COMPARISON TABLES

T°C	P Bars	Hydrographic Tables x 10 ⁻⁵	Eckart x 10 ⁻⁵	Crease x 10 ⁻⁵	NOL x 10 ⁻⁵	FWD x 10 ⁻⁵
0°	1	5.2	8.0	5.6	7.8	5.76
	200	10.5	13.4	10.6	13.2	10.9
	400	15.4	18.2	15.0	18.0	15.4
	600	19.8	22.5	17.1	22.2	19.3
	800	23.2	26.6	22.6	26.1	22.6
	1000	26.5	29.5	25.6	29.5	25.5
10°	1	16.7	16.2	16.7	16.3	16.6
	200	20.2	19.9	20.1	20.0	20.1
	400	23.3	23.1	23.2	23.3	23.2
	600	26.1	26.0	26.1	26.3	25.9
	800	28.6	28.8	28.6	29.0	28.3
	1000	30.9	30.7	30.8	31.3	30.5
20°	1	25.7	23.8	25.7	24.1	25.6
	200	27.8	26.2	27.7	26.5	27.8
	400	29.8	28.2	29.7	28.6	29.7
	600	31.7	30.0		30.6	31.5
	800	33.5	31.7		32.3	33.1
	1000	35.5	32.9		33.8	34.6
30°	1	33.5	31.3	33.4	31.7	33.4
	200	34.7	32.5	34.6	33.0	34.5
	400	36.1	33.6	35.7	34.2	35.6
	600	37.6	34.4		35.2	36.5
	800	39.3	35.2		36.1	37.5
	1000	41.4	35.8		36.9	38.3
40°	1	41.0	39.4		39.6	40.5
	200	41.8	39.5		40.0	40.7
	400	43.0	39.5		40.2	41.1
	600	44.6	39.5		40.5	41.4
	800	46.9	39.5		40.6	41.7
	1000	49.6	39.5		40.7	42.1

TABLE IV

SPECIFIC VOLUME OF SEA WATER, (S = 35°/00)
COMPARISON TABLES (cm³/gm)

T°C	P Bars	Hydrographic Tables	Eckart	Crease	NOL	FWD
0°	1	.9726	.9726	.9727	.9726	.9725
	200	.9639	.9640	.9640	.9638	.9638
	400	.9557	.9557	.9558	.9556	.9556
	600	.9479	.9480	.9480	.9479	.9479
	800	.9406	.9407	.9407	.9406	.9406
	1000	.9337	.9338	.9338	.9337	.9337
10°	1	.9737	.9736	.9737	.9738	.9736
	200	.9654	.9654	.9654	.9654	.9653
	400	.9575	.9575	.9576	.9576	.9575
	600	.9501	.9502	.9502	.9502	.9500
	800	.9430	.9432	.9432	.9432	.9430
	1000	.9364	.9366	.9365	.9366	.9363
20°	1	.9758	.9757	.9758	.9757	.9757
	200	.9677	.9678	.9678	.9677	.9677
	400	.9601	.9601	.9602	.9601	.9600
	600	.9528	.9530	.9529	.9529	.9528
	800	.9460	.9462	.9461	.9461	.9459
	1000	.9395	.9397	.9394	.9396	.9394
30°	1	.9787	.9784	.9789	.9784	.9786
	200	.9708	.9706	.9709	.9706	.9707
	400	.9632	.9631	.9632	.9631	.9632
	600	.9561	.9560	.9560	.9560	.9560
	800	.9494	.9493	.9491	.9493	.9492
	1000	.9431	.9430	.9424	.9429	.9428
40°	1	.9823	.9819		.9819	.9722
	200	.9745	.9741		.9741	.9744
	400	.9760	.9666		.9667	.9669
	600	.9601	.9596		.9596	.9598
	800	.9535	.9529		.9529	.9530
	1000	.9473	.9466		.9466	.9466

TABLE V

COMPRESSIBILITY OF SEA WATER, S = 35°/00 (Bars⁻¹)
COMPARISON TABLES

T°C	P Bars	Hydrographic Tables x 10 ⁻⁶	Eckart x 10 ⁻⁶	Crease x 10 ⁻⁶	NOL x 10 ⁻⁶	FWD x 10 ⁻⁶
0°	1	46.2	46.5	46.4	46.7	46.3
	200	44.0	44.0	44.0	44.1	43.9
	400	41.7	41.7	41.7	41.7	41.7
	600	39.7	39.5	39.6	39.5	39.6
	800	37.8	37.5	37.7	37.5	37.7
	1000	36.2	35.7	35.9	35.7	36.0
10°	1	44.1	44.1	44.1	44.3	44.0
	200	42.0	41.8	41.9	42.0	41.9
	400	39.9	39.7	39.9	39.8	39.9
	600	38.0	37.8	38.1	37.8	38.1
	800	36.4	36.0	36.3	36.0	36.4
	1000	34.9	34.3	34.6	34.3	34.8
20°	1	42.6	42.5	42.7	42.7	42.6
	200	40.6	40.5	40.6	40.5	40.6
	400	38.7	38.5	38.7	38.5	38.8
	600	36.9	36.7		36.7	37.0
	800	35.3	35.0		35.0	35.4
	1000	33.9	33.4		33.4	33.9
30°	1	41.8	41.6	41.9	41.7	41.7
	200	39.8	39.6	39.8	39.7	39.8
	400	37.9	37.8	38.0	37.8	38.1
	600	36.1	36.1		36.0	36.4
	800	34.4	34.4		34.4	34.8
	1000	32.9	32.9		32.8	33.4
40°	1	41.4	41.3		41.2	41.4
	200	39.3	39.3		39.3	39.5
	400	37.2	37.5		37.4	37.7
	600	35.3	35.8		35.7	36.1
	800	33.4	34.3		34.1	34.5
	1000	31.6	32.8		32.6	33.1

TABLE VI

Comparison of values of $\frac{\partial v^w}{\partial T}_{T,P,S}$ in parentheses calculated from FWD equation with those of Bradshaw and Schleicher computed from their comprehensive formula.

$$\text{Unit of } \frac{\partial v^w}{\partial T}_{T,P,S} = 10^{-6} \frac{\text{cm}^3}{\text{g}^\circ\text{C}}$$

S = 30.50°/oo

T°C	0		10		20		30	
P, bars								
1	(43)	39	(154)	154	(246)	246	(325)	324
500	(159)	158	(230)	229	(291)	290	(345)	346
1000	(235)	240	(284)	284	(324)	323	(362)	362

S = 35.00°/oo

T°C	0		10		20		30	
P, bars								
1	(56)	52	(162)	162	(250)	251	(327)	327
500	(166)	166	(234)	234	(293)	293	(346)	347
1000	(238)	244	(285)	286	(325)	325	(361)	363

S = 39.50°/oo

T°C	0		10		20		30	
P, bars								
1	(68)	65	(169)	170	(254)	256	(329)	329
500	(172)	174	(238)	239	(295)	296	(347)	348
1000	(241)	248	(287)	289	(325)	326	(361)	363

TABLE VII

Calculated values from FWD equation vs. B&S observed values for the change in the specific volume of sea water from -2° to $+2^{\circ}$. FWD values are listed in parentheses: Units are in 10^{-6} cc/gm.

P bars	201.3	401.2	601.0	800.9	1000.8
Salinity o/oo	35.004	35.005	35.004	35.002	35.006
T°C					
-2		(-269) -277.1	(-352) -356.9	(-415) -424.3	(-467) -480.5
-1	(-101) -97.5				
0	(0) 0	(0) 0	(0) 0	(0) 0	(0) 0
+2	(230) 225	(310) 310	(379) 383	(437) 445	(486) 498

ANNEX III

Members of the Joint Panel on Oceanographic Tables and Standards
(as at 1 December 1969)

		<u>Appointed by</u>
Mr. F. Hermann (Chairman)	Danmarks Fiskeri-og Havundersøgelser Charlottenlund Slot, Charlottenlund, Denmark	ICES
Prof. O. Saelen	Universitet i Oslo Oceanografisk Institut Blindern, Oslo Norway	ICES
Dr. G.N. Ivanov-Frantzkevich	Institute of Oceanology Academy of Sciences of the USSR 1 Sadovaya Street Lublino, Moscow Zh-387 USSR	Unesco
Dr. N.P. Fofonoff	Woods Hole Oceanographic Institution Woods Hole, Massachusetts U.S.A.	IAPSO
Prof. Dr. W. Kroebel	Institut für Angewandte Physik Neue Universität, Haus 34 Kiel 23 Federal Republic of Germany	IAPSO
Dr. F.H. Fisher	Scripps Institution of Oceanography San Diego, California 92152 U.S.A.	SCOR
Dr. F. Culkin	National Institute of Oceanography Wormley, Godalming Surrey, England	ICES
Dr. K. Grasshoff (new Chairman from the end of the 5th meeting on)	Institut für Meereskunde der Universität Kiel Niemannsweg 11 23 Kiel Federal Republic of Germany	SCOR
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