Units for Specific Volume of Sea Water

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Considerable confusion has developed in oceanographic literature concerning the appropriate units to be used in reporting specific volume and its ancillary parameters, specific-volume anomaly and thermosteric anomaly (specific-volume anomaly at *in situ* temperature and salinity and atmospheric pressure). The problem revolves around the question, should specific volume and its anomalies be given in terms of liters or cubic centimeters as the unit of volume. The two systems have been used indiscriminately, despite the fact that one liter equals 1.000027 dm^3. Of course, any units are acceptable, provided they are dimensionally correct. Since oceanographic computations of this nature are based on Bjerknes and Sandström's (1910) tables or on others derived from them (*i. e.*, Sverdrup, 1933), the problem is narrowed down to a determination of the units used in these tables. This is precisely the source of the confusion. The Bjerknes and Sandström tables use the cubic centimeter as the unit of volume even though they are based on Knudsen's (1901) tables of density, without consideration of any change of units.

Actually Knudsen's density values are dimensionless, being defined as the ratio of density at atmospheric pressure to density of distilled water at 4°C. Since the liter was defined as the volume of one kilogram of distilled water at its temperature of maximum density, Knudsen's specific gravity and density in terms of grams and liters are numerically equal. Bjerknes and Sandström's use of cubic centimeters in place of liters appears justified in view of the intention of the founders of the c.g.s. system to equate the liter to one cubic decimeter. It was not until 1910, the publication date of the Bjerknes and Sandström tables, that results of an elaborate redetermination of the metric volume of the liter were published by the *Comite International de Poids et Mesures*. These results revealed a discrepancy of 27×10^{-6} between the two volume units. Unfortunately this redetermination of the liter and its implication regarding existing tables for density and specific volume has been ignored by a majority of oceanographers during the last 50 years.

[1] Except for minor emendations by the Editor, this note is published essentially without alteration from a handwritten draft completed just before the author's death on 5 June, 1960. Mr. Pollak was a Senior Scientist with the Inter-American Tropical Tuna Commission, La Jolla, California.

When density (usually in terms of σ_t) and specific-volume anomalies are reported in liter units, their values are numerically correct and there is no further problem. Use of the cubic centimeter, or its multiple, as the unit of volume affects σ_t differently than it does specific-volume anomaly or thermosteric anomaly. This difference stems from the definitions of the respective terms tabulated by Knudsen and by Bjerknes and Sandström. The former defined σ_t as a ratio minus the constant one, multiplied by 10^3. The value of σ_t in terms of cubic centimeters would be obtained by dividing the complete density value by 1.000027 and then reconverting to σ_t. Because of the limited range of densities encountered in the sea, this process is closely approximated by subtracting 0.027 from σ_t given in grams per liter. Only by redefining σ_t analogously to specific volume anomaly could present tables be made to represent σ_t correctly in grams per cubic decimeter. Specific volume anomaly, as its name implies, is the difference in specific volume between the water sample under consideration and water of standard temperature and salinity under the same pressure. Since transformation of volume units would be equally applicable to the sample and the standard, the affect on their difference would be entirely negligible in the last significant place to which the anomaly is reported. This implies that specific-volume anomaly is numerically the same in both systems of units. However, the specific volumes of standard water at various depths, as tabulated by Bjerknes and Sandström, must now be corrected by multiplying by 1.000027.

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