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THE INDEX OF REFRACTION OF SEAWATER

Roswell W. Austin and George Halikas

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A smoothly varying and internally self-consistent set of tables of the index of refraction of seawater with respect to air are presented. The dependence of the index on salinity (0 to 43‰), temperature (0 to 30°C), wavelength (400 to 700 nm) and pressure (0 to 1100 kg/cm² gage) has been fully covered. The relevant literature from prior to 1900 through the present has been extensively reviewed. Various comparisons between indices obtained from these sources and the

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tables presented have been performed suggesting an overall accuracy of the tabulated index values of about 3×10^{-5} at atmospheric pressure and 1×10^{-4} at higher pressures. The extreme values encountered were 1.32921 and 1.36844, while the average slopes of the index surface, over the range of the variables considered, are $\Delta n/\Delta s \approx 0.009/43‰$, $\Delta n/\Delta t \approx -0.002/30°C$, $\Delta n/\Delta\lambda \approx -0.013/300$ nm, $\Delta n/\Delta p \approx 0.015/1100$ kg/cm^2. Three dimensional diagrams provide complete views of the index of refraction surface.

The requirements necessary for obtaining salinity and specific gravity directly from measurements of the index of refraction, for oceanographic purposes have been examined.

PREFACE

Over the past several years the staff of the Visibility Laboratory has had increasingly frequent requirements for information on the index of refraction of seawater at wavelengths, salinities, temperatures, and pressures other than those tabulated in the usual reference sources. In some instances, it was possible by simple linear interpolation to obtain the desired value. In other instances, especially those involving the high pressures found at abyssal depths, the limited data available made such interpolation risky if, indeed, at all possible. Furthermore, it was often necessary to attempt interpolation between the values of different investigators, some of whom performed their measurements or presented their results in a manner which, at least superficially, was incompatible with those provided by others. A rather exhaustive search of the literature, however, failed to uncover any single work which would provide index values spanning the required ranges of the four parameters.

Neither the time nor the resources were available to us for the type of experimental program required to carefully measure the index of refraction of seawater over the range of oceanographic variables and with the type of equipment that is required to obtain accuracies of, say, one digit in the sixth or even fifth decimal place. It was decided instead to composite the necessary information by a careful and thorough analysis and then recombination of the data in the existing literature. Through this procedure it became possible to intercompare the work of various investigators, select the data we felt had the highest credibility and meld it into a single set of index values which would be internally consistent, thereby circumventing the difficulties we had encountered.

A basic premise throughout our analyses was the smoothness of the functional dependence of the index of refraction on the four variables, that is that the function and its derivatives are continuous and monotonic. There seems to be no physical reason to expect the contrary, at least over the range of interest of the variables, and certainly nowhere in the literature – either theoretical or experimental – is it suggested otherwise.

By careful examination of each original data source with respect to assumptions, experimental conditions, accuracy, etc., and by an overall intercomparison of all those works having overlapping parameter values, it was possible to decide to select or reject values to be included in our composite data base. Such decisions, while occasionally seemingly arbitrary, were certainly not capricious and were based on the requirement of obtaining a four-dimensional index surface with no discontinuity or inflections which conforms to our premise on the nature of the surface.

As a consequence of choosing to use only selected sets of an investigator's index values, we must assume full responsibility for any errors in our tabulations which result. Furthermore, because of this selective procedure, we felt compelled to check our final refractive index values against the values from other studies to demonstrate the degree of agreement. This we have done in Section 5. Considering the variety of sources and the span of years involved, we were indeed gratified that the agreement was as close as found. Even more important than the absolute agreement or disagreement of the index at particular values of the parameters is the fact that we now possess a single well-behaved body of data from which we may determine the shape of the index surface as a function of the four variables. In this regard the rather remarkable agreement between our values and Rusby's refractive index anomaly leads us to believe that the functional shape of our results, at least over the range of the variables presented by Rusby, is probably significantly better than is implied by the ±0.00003 we have stated as our absolute accuracy for the values of the index at atmospheric pressure.

I wish to acknowledge the very major contributions of co-author, George Halikas, a graduate student at the Scripps Institution of Oceanography, to all phases of this study. Because of his tenacity, capabilities with computer programming, facility with languages and meticulous attention to detail, we were able to turn what was initially to be a modest review of the literature and simple numerical analysis of the available index data into what we believe to be a rather complete and critical summary of all the known works on the subject and what we hope is the best consensus of the index values that can be drawn from these sources.

R. W. Austin, January 1976

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1. INTRODUCTION

Historically, much of the interest in the index of refraction of seawater has centered around its potential application of obtaining seawater density. This goal, which was almost obsessive with the earlier oceanographers, appears to have been surpassed by other methods of greater precision and easier application.

Following the rapid development of underwater optical and electro-optical systems, increasing attention has recently been given to the optical properties of the seawater medium, including both its propagative and refractive properties, as factors in the study, design, and evaluation of these systems, their underwater lenses and viewing ports. In the same context, there is an ancillary need to determine the index of refraction of seawater in order to design the submersible measuring instruments required to determine the optical properties of seawater.

The present study was originally undertaken to survey the past literature and determine the extent of the existing data base. Having established that although sparse, this base was probably adequate to our task, a comparative study was conducted to select those data which showed the greatest internal consistency and reliability, with due attention given to the experimental methods utilized. The selected body of data was subjected to careful interpolation over the parameters salinity, temperature, and pressure, and to interpolation and extrapolation over wavelength.

The result of this work is an internally consistent set of closely interpolated tables of the index of refraction of seawater as a function of wavelength, salinity, temperature, and pressure. There is a fundamental distinction between wavelength and the other three parameters, in that the latter inherently characterize the nature of seawater, whereas the former characterizes the radiation used in determining its properties.

In all that follows, wavelength will be expressed in nanometers (in air), salinity in per mille (‰) following the standard oceanographic usage, temperature in degrees Celsius (°C) and pressure in kilograms force per square centimeter, gage (kgf/cm^2), i.e., zero pressure gage is equal to one atmosphere absolute, or 1.0332 kgf/cm^2 absolute. In this report the more precise notation kilogram force (kgf) will be abbreviated as simply kilogram (kg). The index of refraction will be expressed with respect to air.

The ranges of interest of these parameters are as follows: wavelength 400 to 700 nm, salinity 0 to 43‰, temperature 0 to 30°C, and pressure 0 to 1100 kg/cm^2. At atmospheric pressure the complete ranges of the other three parameters have been covered, and the index of refraction has been determined to the fifth decimal place (3×10^{-5}). At higher pressures however, owing to the need to combine two different sets of data and to the difficulty of conducting high pressure index measurements the accuracy is generally lower, of the order of 1×10^{-4}. In our present work we have made and used the assumption that the dependence of index on salinity is linear for all combinations of the other three parameters, within the ranges specified above. This assumption is suggested by various investigators as will be shown later.

The present analysis will present the index of refraction to five decimal places. The extreme values encountered within the range of parameters considered are 1.32913 to 1.36844. All estimates of error will be expressed in terms of units in the fifth decimal place (10^{-5}) throughout, applicable to the least significant digit reported.

Considering the total range of each parameter given above, the index of refraction of seawater is least sensitive to changes in temperature, then salinity, then wavelength, and finally most sensitive to pressure, by the approximate amounts −0.002/30°C, +0.009/43‰, −0.013/300 nm, and +0.015/1100 kg/cm^2, respectively. These numbers indicate the relative importance of changes in the parameters. A collection of representative values of index and its derivatives is presented in Table 7-1.

The presentation of the material in this report has been organized as follows: In Section 2 a review of all the important studies on the index of refraction of pure water and seawater are presented in order to familiarize the reader with the relevant literature. Section 3 presents some background information on several physical properties of seawater as used in oceanography, and some useful relationships among the various quantities. In Section 4 the main body of our own work is analyzed, culminating in the choice of the data that are to serve as the basis of the composite tables describing the index of refraction of seawater surface as a function of salinity, temperature, wavelength, and pressure. The results of our work are compared with previous measurements in Section 5 in order to demonstrate the agreement or disagreement and propose explanations for any observed discrepancies. Section 6 is dedicated to the general problem of using the index of refraction as a measure of salinity or specific gravity, and examines the necessary conditions that must be fulfilled. The manner in which the composite tables that we have constructed are to be used, is described in Section 7 where examples are also given to facilitate their application. Finally, in Appendix A, the actual tables of the index of refraction are presented, together with some three-dimensional plots of the index surface, that provide a clear view of the functional behavior of the index surface on its four parameters. Appendix B simply presents a computer program which we have used in our work.

2. REVIEW OF PREVIOUS WORK

The optical index of refraction is usually expressed with respect to air and only rarely with respect to vacuum. In the case of seawater, however, the index has often been expressed as the difference between that of seawater and pure water or as the difference between that of seawater and 35‰ Copenhagen Standard Seawater (refractive index anomaly).

The index of refraction can be measured by a variety of methods whose accuracy varies over a wide range. Since the index varies over a small range, it is imperative to achieve high accuracy in expressing it to the fifth, sixth, or seventh decimal place. To achieve this, great demands are placed on the optical equipment, the measuring technique, and the experimental controls.

The two fundamental methods of measurement that can be employed consist of measuring either a refracting angle goniometrically, or the reduced velocity of light in a medium, interferometrically.

All the goniometric methods are based on Snell's law ($n_1 \sin\alpha_1 = n_2 \sin\alpha_2$) and one or another of its more fundamental realizations such as the critical angle of refraction. Of the earlier instruments, the Abbe and Pulfrich refractometers were the most successful, both using the critical angle of refraction and providing the value of the index of refraction with respect to air. The Abbe type experienced temperature uncertainities even though it employed a controlled-temperature water jacket, and it was also susceptible to the possibility of sample evaporation in the case of seawater. A different type of instrument is one employing a minimum deviation prism in which the glass-walled prism also serves as the container. Another method used in two of the studies to be mentioned later is that developed by Hallwachs (1893) which employs the same technique as the Pulfrich refractometer but in a two-container arrangement which can provide the index of a liquid relative to another liquid; in the present case the index of seawater relative to pure water. Except for one particular case, these methods are limited to measuring the index of refraction to a few units in the fifth decimal place; the one exception (Tilton and Taylor, 1938) provides it to the sixth decimal place.

All the interferometric methods employ the same technique of beating a reference beam traveling through air against a second beam traversing a liquid sample and counting the fringe shift resulting from introduction of the liquid. Carefully used, these methods are capable of providing the index to a greater accuracy than the goniometric methods. In a variation of the method, the reference beam is made to travel through a reference liquid (e.g., pure water or 35‰ Copenhagen Standard Seawater) and the index difference between the two liquids can be obtained even to the seventh decimal place (Rusby, 1967). The interferometric methods were first employed in the 1920's.

In this review of the historical data, we have made a conscious effort to locate all the original sources of index of refraction measurements in order to avoid difficulties arising from reprocessed information published by others at a later time. This also enabled us to examine the methods, the controls, the accuracies, and the omissions of the various investigations. We have, accordingly, omitted references to publications presenting the same data in different form (e.g., interpolated to standard values of the parameters, etc.) even though these were also examined.

The oldest published experimental measurements on the index of refraction of seawater date back to the end of the nineteenth century (Soret and Sarasin, 1889), and over the ensuing years the dependence of the index on temperature, salinity, and wavelength has been sporadically measured. Until 1971 (Stanley), however, no measurements were undertaken to establish its dependence on higher-than-atmospheric pressures, which for oceanographic purposes is an absolute necessity, in order to determine *in situ* value.

In the intervening years various investigators have performed laboratory measurements on seawater samples, but most have done so for only a few values of wavelength, salinity, and temperature. Moreover, many investigators lacked what is today considered to be adequate experimental control, and some even made their measurements on seawater samples which were characterized only by the geographical location where the sample was drawn, and not by the salinity of the sample itself.

Such measurements will be ignored here because of the lack of adequate sample characterization. A more subtle difficulty with the older measurements is that of refractometer-scale calibration. This problem, also ignored here, is difficult to identify and quantify, and would require judicious choice of the data to be incorporated into a study such as this.

Fortunately, none of the studies undertaken prior to 1934 are necessary for the present purpose, and only recent measurements (after 1968) have been used to construct our tables with the one exception that the values for pure water (salinity 0‰) were taken from Tilton and Taylor (1938) either directly or by our sources. The older data will be presented at the very end, for comparison purposes only, using our extensive tables as a reference.

It is, however, interesting to gather here and review the seawater index of refraction measurements if only to show the progress through time. This progress, in a very real sense, paralleled that of temperature measurement and control as well as that of salinity measurement (after overcoming the difficulties in its definition and international standardization). These difficulties do not apply to wavelength since the spectral lines were already well-known and utilized. The advent of the laser, however, greatly facilitated interferometric methods.

The refractive properties of seawater were first utilized by Hilgard (1877) as a means to determine seawater density. Krummel (1894) later devised an instrument for the same purpose, that was calibrated in arbitrary units against density. In both of the above works, the index of refraction was of no interest *per se,* much in the same way that the coefficient of thermal expansion of mercury is not of interest in calibrating a thermometer.

Soret and Sarasin (1889) were the first to measure the index of refraction of seawater – more perhaps out of curiosity than any real need. They used a seawater of unspecified salinity taken "in the Mediterranean, 4-km off Nice, in clear blue water. . . a little below the surface" whose index of refraction was measured to 10×10^{-5} at 10 and 20°C for the A, B, C, D, F, h, H solar spectrum lines (759.4, 686.7, 656.3, 589.3, 486.1, 410.2, 396.8 nm, respectively). These measurements are interesting but are of no practical use here, primarily because the sample salinities are unknown.

Subsequently, Tornoe (1900) investigated the possibility of determining salinity by using the index of refraction; interestingly he also examined the same possibility using electrical conductivity in 1893. He used three natural seawater samples and eight more diluted with pure water to obtain the index for Sodium D-light (589.3 nm) at a range of temperatures using the Halwachs method. Salinity* was determined using specific gravity (see Section 3). Since Tornoe was interested in the problem of determining salinity through optical means, he did not present values of the index of refraction *per se*. These values, however, may be computed using his data and a formula he has presented. Computations using his measurements are presented in Section 5 for comparison with our tables. Interestingly, Tornoe found a nonlinear dependence of index on salinity but as we will show later a linear relationship is equally efficient in describing the same data.

Shortly after Tornoe, Gifford (1906) made measurements of the index of refraction of seawater, on surface samples taken "in blue water, 5 miles south of the Royal Sovereign Lighthouse off the coast at Eastbourne." No salinity was provided, but the index is reported to seven decimal places even though the stated accuracy is only 10×10^{-5}. The omission of salinity determination is unfortunate because the measurements were made at 11 wavelengths from 768.2 to 226.5 nm, including two measurements in the ultraviolet (274.8, 226.5 nm) which have not been attempted since. No use can be made of these data in the present work.

In his Handbuch der Ozeanographie, Krummel (1907) presented a small table of index of refraction at 18°C for the Sodium D-lines (589.3 nm). The salinities range from 0 to 40‰ every 5‰, and the index is reported to the fifth decimal place. His method employed an Abbe refractometer, but no statement is made concerning the method used to measure salinity nor of the estimated accuracy. These measurements are compared to our tables in Section 5.

Vaurabourg (1921a, b) presented measurements of the index of refraction of diluted Mediterranean seawater samples over the temperature range 0° to 33°C for Sodium D-lines, using a Fery and a Zeiss immersion refractometer. His immediate interest was in obtaining a relationship between the index of refraction and specific gravity so he did not explicitly provide the corresponding sample salinities. They may, however, be obtained from the specific gravity σ_0 (see Section 3). The index measurements are stated to be accurate to 5×10^{-5}. A comparison of these values with our tables is given in Section 5 with the salinities computed using Knudsen's tables (1901).

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* The definition of salinity was formally established in 1902, Forch, Knudsen and Sorensen (see Section 3).

Pape (1922, 1924) presented a method of determining seawater salinity (up to 8‰) using an interferometer (the first time such an instrument was used for the purpose), but provided no index of refraction data. Instead he proceeded to exhaustively describe the calibration and use of a particular instrument of the Deutsche Seewarte (German Hydrographic Office). This work is, therefore, of no usefulness to this study.

In their monumental work on seawater Bein, Hirsekorn, and Moller (1935) performed elaborate measurements on the index of refraction of seawater, using both the Hallwachs method and an interferometric method. The first was exploratory, with the purpose of calibrating the second and using it to obtain seawater density directly. Their extensive report is a record of their meticulous and very complicated work, but contains only a small body of numerical data (to be found on their pages 127 and 162) since they developed an analytical expression relating the index to density. Much later, Saint-Guilly (1954) used these measurements to provide interpolated tables, but we disagree with his use of the data as will be shown in Section 5. Bein, *et al.,* characterized their samples through the parameter $\rho_{17.5}$ (see Section 3) rather than salinity, and we have made the conversion using Knudsen's tables. The remarkable fact about these data is that they are expressed to the sixth decimal place and the stated accuracy is assumed to be equally high. The same authors have also shown that density values obtained interferometrically and through chlorinity differ, suggesting that the two types of measurements are not equivalent. This point will be taken up later.

A significant effort to determine the index of refraction of seawater as a function of temperature and chlorinity was undertaken by Utterback, Thompson, and Thomas (1934) who conducted measurements with an immersion refractometer at one wavelength only (589.3 nm, Sodium D-line pair) on samples of natural seawater diluted to cover a large chlorinity range, with the highest chlorinities apparently obtained from the Mediterranean. No reference to Copenhagen Standard Seawater was made. At each chlorinity, measurements were made at six temperatures (0 to 25°C every 5°C) effectively covering the temperature and chlorinity dependence of index of refraction at that particular and very popular wavelength, at atmospheric pressure. This body of data is of high quality. Even though criticism has been expressed on the use of the pair of Sodium D-lines that are 0.5 nm apart, resulting in decreased resolution, it can be shown that an error of 0.5 nm in wavelength would produce an index error of about 1.8×10^{-5} which is within their stated accuracy of 3×10^{-5}. For more precise measurements, however, the Sodium D-line doublet is not an optimal choice. These data of Utterback, *et al.* were the mainstay for over 30 years (up to 1968) and have been reproduced in various publications. For our purposes, the most significant result to come out of Utterback, *et al.* was the determination that the dependence of the index of refraction on chlorinity (and salinity) is linear, at least up to the typical concentrations (3.5 g/kg) found in the oceans. This is a very fortunate circumstance which has been corroborated by later investigators and which joins a number of similar linear relationships applicable to dilute aqueous solutions (Henry's Law; see Section 4.2 for comments). The slope of this linear dependence, however, is a function of temperature and also of pressure and wavelength. A comparison with our tables is presented in Section 5. Much later, Cox (1965) used the original data of the above investigators to compile a similar but slightly different table; however, we will not be concerned with it here.

A very significant development in index of refraction determinations was the publication by Tilton and Taylor (1938) of the U.S. National Bureau of Standards, of their monumental work on the index of refraction of pure water at a large number of wavelengths and temperatures at atmospheric pressure. Although not directly applicable to seawater, this study established the index of refraction of pure water to 1×10^{-6}, the highest accuracy ever attained up to the present time using the minimum deviation method, and afforded later experimenters a convenient way to calibrate refractometers. To achieve this accuracy Tilton and Taylor went to extreme pains to include changes in environmental temperature, pressure, humidity, degree of water purity, and even the dissolution of the prism-container. As an example of the progress in index determinations, their value at 589.3 nm and 20°C is 1.3329877, as compared to 1.33301 used by Utterback, *et al.* (1934) who did not have the benefit of Tilton and Taylor's pure water data. The Tilton and Taylor data have been used extensively and will be referred to again later.

Meanwhile, Miyake (1939) conducted a study of the index of refraction of seawater using a Pulfrich refractometer, with the main emphasis on the refractivities of its ionic constituents and managed to effectively explain the departure of the index of seawater from that of pure water as the sum of the departures of the individual major ionic constituents, Na, K, Mg, Ca, Cl, SO_4, etc. His values of the index of refraction of seawater, determined at the Sodium D-lines (589.3 nm) and at 25°C, do not appear to be as good as those of Utterback, *et al.* A comparison is presented in Section 5. The fact that simple additivity of refractivities can, however, account for the index of refraction of seawater corroborates the linear relationship between index and salinity. Miyake also established that 90 percent of the difference in index between pure water and seawater is due to the chloride ion, which is a significant statement with important implications on the differences between the chlorinity and the index methods of determining density, (see Section 3) since the chloride ion contributes only about 55 percent to density.

Saint-Guily (1952, 1954, 1955) examined again the possibility of determining seawater density from the index of refraction using the relations of Bein, *et al.*, and found that densities measured optically and chemically on the same samples showed differences that in all probability were attributable to the different sensitivity of the two methods with respect to composition (see Section 3). He also examined the potential of various interferometric methods in providing accurate measurements of index of refraction. In his 1954 paper, Saint-Guilly used the data of Bein, *et al.*, on the index difference between seawater and pure water for the Helium-yellow line (587.6 nm) and strangely (and erroneously) added them to the pure water data of Tilton and Taylor for the Sodium D-lines (589.3 nm) to obtain the index of seawater with respect to air at 589.3 nm. We strongly object to this misuse of the data, in arbitrarily switching wavelengths, and we have ignored the numerical values he has presented. Bein, *et al.*, never used the Sodium D-lines due to their doublet character.

Velmozhnaya (1960) and Sabinin and Gamutilov (1958) have presented an interferometric method of measuring seawater salinity using the index of refraction. However, as Pape had done almost 40 years earlier, they do not present index of refraction values *per se* but instead only a correspondence of salinity to the number of fringes counted, using a particular instrument (ITR-2). Thus, their study is of no interest for the present purpose.

A second study on the index of pure water, complimenting that of Tilton and Taylor, is that of Waxler, Weir, and Schamp (1964) who measured the index of refraction of pure water at high pressures and at several temperatures and wavelengths. Even though the accuracy is roughly 1×10^{-4} and some inconsistencies have been found in the data, this work has proven very useful in enabling us to compile the index of refraction tables at high pressures for various salinities, using the linear dependence on salinity. The examination of these data will be presented in Subsection 4.4.

Rusby (1967), in a very carefully designed experiment, undertook extremely precise interferometric measurements (0.04×10^{-5}) of the index of refraction difference between seawater and Copenhagen Standard Seawater (35‰), termed "refractive index anomaly," at the Hg wavelength 546.227 nm (in vacuo). The use of this wavelength is an improvement over the previously more popular Sodium D-line doublet (589.0 and 589.6 nm) for precise work of this type. Rusby's numerous samples were diluted from high-salinity Mediterranean seawater, covering a range 30 to 39‰, with salinity determined to a standard deviation of 0.0055‰. His results, even though relative to the 35‰ standard, are extremely useful and are reported to the seventh decimal place which is, for the inverse problem of determining salinity from the index, comparable to the accuracy of the conductivity method. Rusby determined the relationship between the salinity and the refractive index anomaly at 20°C on a very large number of samples and then proceeded to establish the temperature dependence by obtaining measurements at 17.3, 20.1, 25.3, and 30.1 °C on a smaller series of samples. These extensive measurements were fitted to a polynomial, giving the salinity when the refractive index anomaly at this wavelength and the temperature are known.

$$\begin{aligned} S = {} & 35.000 + 5.3302 \times 10^3 \Delta n + 2.274 \times 10^5 \Delta n^2 + 3.9 \times 10^6 \Delta n^3 \\ & + 10.59 \Delta n (T-20) + 2.5 \times 10^2 \Delta n^2 (T-20) \end{aligned} \tag{2.1}$$

valid within the ranges:

$$-8 \times 10^{-4} < \Delta n < 7 \times 10^{-4}$$

$$30.0‰ < S < 38.8‰$$

$$17°C < T < 30°C \, .$$

This relationship appears to contradict the linear dependence of index on salinity; but as will be shown later, it provides linear values to the 10^{-5} precision between salinities 33‰ to 38‰. These data will be compared with our tables in Section 5 even though the accuracy of Rusby's values far exceeds that of our own tables. For oceanographic purposes, Rusby's results are applicable at the ocean surface, and it would be desirable to have such extremely accurate determinations extended to lower temperatures and to higher-than-atmospheric pressures. Rusby's results have appeared in the UNESCO International Oceanographic Tables (1966a).

Within the past 7 years new and more extensive measurements have been obtained on the index of refraction of seawater – spurred, no doubt, by the recent development of optical equipment used in the oceans. The two works in question are by Mehu and Johannin-Gilles (1968) and by Stanley (1971).

The first of these determined the index at atmospheric pressure for 10 wavelengths, 5 chlorinities, and 6 temperatures and is the most extensive and internally consistent body of data available to date. The second determined the index at 35‰ salinity at 5 wavelengths, but over a large pressure and temperature range and is the only one ever to have included high-pressure index measurements on seawater.

These two bodies of data, together with that of Waxler, Weir, and Schamp mentioned earlier, form the basis for the extensive tables presented in this report and will, therefore, be reviewed and analyzed in greater detail. The Mehu and Johannin-Gilles study (hereinafter M-G) was undertaken through the recommendation of a UNESCO commission in 1962. All their measurements have been conducted at atmospheric pressure for:

Wavelengths:	404.7(Hg), 435.8(Hg), 467.8(Cd), 480.0(Cd), 508.5(Cd), 546.1(Hg), 577.0(Kr), 579.1(Hg), 589.3(Na), 643.8(Cd) nanometers,
Temperatures:	1, 5, 10, 15, 20, 25, 30 degrees Celsius, and
Chlorinities:	0, 4.887, 9.603, 14,589, 19.373 parts per thousand .

This forms a sufficiently dense body of data to permit a closely-spaced interpolation over the three parameters.

The samples used in the experiment were diluted from Copenhagen Standard Seawater of 19.373‰ chlorinity (or 34.998‰ salinity using the proportionality factor 1.80655) with the chlorinity for all the samples determined to five significant digits. Temperature control was within 0.025°C with a corresponding uncertainty in index of 0.5×10^{-5}. The index of refraction has been obtained with respect to air (not vacuum) and the experimental technique utilized the method of minimum deviation with readings taken goniometrically. The measurements actually obtained were of the difference in index of refraction between a seawater sample and one of twice-distilled pure water. This difference was then added to the index of refraction of pure water to obtain the desired result. Some of these pure water values (at 589.3, 577.0, 546.1, 435.8, and 404.7 nm) were taken directly from Tilton and Taylor, while at the other five wavelengths they were determined by the authors and are judged by us to be consistent. M-G also maintain that the index of refraction of seawater depends linearly on salinity, but their salinity dependence contains some systematic deviations at all wavelengths and has been dealt with as described in Subsection 4.2. Additional comments are to be found in Section 5.

The Stanley data provide the pressure dependence necessary for extending the tables to this fourth parameter. Stanley conducted interferometric measurements of the index of refraction of Copenhagen Standard Seawater of 35‰ salinity at four pressures (352, 703, 1055, and 1406 kg/cm^2 gage), three temperatures (0.03, 15.02, and 29.98°C), and five wavelengths (457.9, 488.0, 501.7, 514.5, and 632.8 nm). Unfortunately, he did not vary salinity, necessitating the use of the Waxler, *et al.* data for this purpose. He did, however, measure the index of pure water at the same pressures and temperatures, but only at 632.8 nm. Temperature control was maintained to within ±0.01°C, salinity to within +0.10‰ (only positive due to evaporation) and pressure to within ±1.4 kg/cm^2, with corresponding errors in the index of about $\pm 0.075 \times 10^{-5}$, $+2.0 \times 10^{-5}$, and $\pm 2.0 \times 10^{-5}$, respectively. The temperature dependent error is trivial, but the two other errors are significant. Stanley states a total experimental error of $\pm 6 \times 10^{-5}$. The method he employed involved an interferometer, so the actual quantity measured was the number of fringes, which was converted into an index of refraction difference at high pressures from that at atmospheric pressure.

This difference in index was added to the value at atmospheric pressure (after applying a small correction for vessel expansion) to obtain the index at high pressures. In our presentation of these results, we have used only the fringe counts (original data) and have completely ignored the actual absolute index of refraction that was computed. The reasons for this will be explained in Subsection 4.3. The Stanley data comprise the only set for higher than atmospheric pressures for seawater and cannot, therefore, be compared to any others for accuracy and quality.

In summary, the best available data of the index of refraction of **pure water** at atmospheric pressure are generally accepted to be those of Tilton and Taylor (1938), and at higher pressures, those of Waxler, Weir, and Schamp (1964). For **seawater**, the most comprehensive measurements are by Mehu and Johannin-Gilles (1968) at atmospheric pressure and by Stanley (1971) at higher pressures. These four data sets form the basis of our tables, but the data of Rusby (1966) and of Utterback, Thompson, and Thomas (1934) will be used for comparisons and determination of accuracy in Section 5.

3. SOME REMARKS ON THE CHLORINITY, SALINITY, DENSITY AND SPECIFIC GRAVITY AS RELATED TO THE INDEX OF REFRACTION

In the present study our immediate interest is in considering the relationship between chlorinity and salinity, since several studies of the index of refraction have characterized the seawater samples by either one or the other of these quantities. We are only interested in the density in a different sense; namely, in converting some of the older data from density to salinity for comparison with our values and, in a more general sense, in using the index of refraction to measure it. In oceanography the usual parameter characterizing density is not density itself but specific gravity, a dimensionless quantity which is the ratio of the density of a seawater sample at some temperature to the density of pure water at 4°C. If this density of pure water is taken by definition as equal to 1.0 g/cm^3, then the density (g/cm^3) and the specific gravity (dimensionless) are **numerically equal.** Originally, the gram was defined as the weight of 1 cubic centimeter of pure water at 4 degrees Celsius. The gram has since been redefined as being one-thousandth the mass of the standard kilogram kept at the Bureau International des Poids et Mesures. This latter definition constitutes an increment of 0.003 percent over the former, so present-day specific gravity differs numerically from density by this amount. The older literature used density and specific gravity interchangeably, with density being the preferred term.

The specific gravity is, perhaps, the most well studied property of seawater due to its direct applicability to the study of ocean currents. The literature concerning it is about as old as oceanography itself, dating perhaps to before the 1870's, and its study has been continued up to the present time. The reason for this is that, as is the case with so many other oceanographic measurements, it cannot be measured *in situ* nor can it be measured on shipboard, since the method to be employed requires very delicate weighing. In order to circumvent its direct measurement, one must conduct separate measurements of temperature, "salt content," and pressure and compute the specific gravity from empirical experimental relationships established in an on-shore laboratory. This is necessary because no satisfactory analytical expression deriving from theory has been developed for the equation of state of seawater. (See, however, Fisher, Williams, and Dial, 1970. With the progress of time, measurements of temperature and pressure have become increasingly more convenient, precise, and accurate. However, measurement of the "total salt" content is not as direct and has had an erratic history. Ever since Dittmar (1884) found that the composition of seawater is almost constant, implying that the ratios of dissolved ion concentrations are also almost constant (See Carritt and Carpenter, 1959), it has occurred to oceanographers that by measuring only one ionic constituent of seawater and knowing these almost-constant ratios, it would be possible to arrive at the other ionic constituents and, therefore, at the total salt content. Using this the density (specific gravity) could be obtained when the temperature and pressure are known. The chloride ion was chosen to be this single constituent since it can be very accurately titrated into AgCl. The other halides Br and I are also included in providing the chlorinity, from which the salinity is obtained.

The most accurate present-day measurements of the specific gravity of seawater (Cox, McCartney, and Culkin, 1970) necessitate knowledge of the salinity to five significant digits, e.g., 34.982‰ (34.982 g/kg). This means that any constituent contributing more than .0001 percent by weight should be accounted for, i.e., all constituents above the part-per-million range. The major ionic components of seawater are given below in Table 3-1, together with their partial contributions to the index of refraction (Miyake, 1939) and to the approximate specific gravity increments over the corresponding values for pure water. The contributions to specific gravity are only approximate, and the numbers actually represent the percentage contributions in g/kg to 35‰(g/kg) seawater. To obtain values on a volume basis the volume changes and the temperature must be taken into account.

Table 3-1. The percentage contribution of the major ionic constituents of 35‰ seawater, to the change in index of refraction Δn and specific gravity $\Delta \rho$ over the corresponding values of pure water.

	Δn %	$\Delta \rho$ (approx.) %
Cl	90.54	55.04
Na	1.71	30.61
SO_4	7.59	7.68
Mg	-1.60	3.69
Ca	1.37	1.16
K	0.39	1.10

NOTE: Δn taken from Miyake (1939). $\Delta \rho$ is approximate. It actually represents the increase by weight rather than volume. The negative contribution of Mg to Δn is noteworthy.

It is interesting to note that the ionic components do not contribute equally to specific gravity and index. Thus, one expects that a one-to-one correspondence could be established only if the seawater composition is truly constant. It was a consideration such as this that prompted Carritt and Carpenter (1959) to state that the measures of chlorinity, salinity, density (or specific gravity), conductivity, and index of refraction are not necessarily in a one-to-one relationship.

Historically, Forch, Knudsen, and Sorensen (1902) first presented a formal definition of salinity –

> "Salinity is defined as follows: The weight of dissolved solid material found in 1 kilo of seawater, after all the bromine has been replaced by an equivalent quantity of chlorine, all the carbonate converted to oxide, and all the organic matter destroyed," (from Carritt and Carpenter, 1959)

– with the implicit assumption that the composition of seawater is constant. They measured the specific gravity of seawater samples and related it to the salinity, temperature, and pressure. The results of this work led to the famous Knudsen Hydrographic Tables, (Knudsen, 1901), for obtaining the specific gravity of seawater. During this work, independent determinations of the salinity and the chlorinity (defined as "The total amount of chlorine, bromine, and iodine in grams contained in 1 kilogram of water, assuming that the bromine and iodine have been replaced by chlorine") were made and an empirical relationship was established between the two; i.e.,

$$S‰ = 0.030 + 1.8050\ Cl‰ \quad . \tag{3.1}$$

This relationship has been termed the *Knudsen relation* and has held for about 50 years almost without challenge. However, Carritt and Carpenter (1959) have shown that a better fit to the same data is:

$$S‰ = 0.0313 + 1.80488\ Cl‰ \tag{3.2}$$

which, however, would be modified to:

$$S‰ = 0.0078 + 1.8060\ Cl‰ \tag{3.3}$$

if the "atypical" Baltic and North Sea samples that were used in the original determinations were excluded. For a chlorinity of 19‰ the above three relations give S = 34.325‰, 34.324‰, and 34.322‰, while for Cl = 5‰ the salinities are S = 9.055‰, 9.056‰, and 9.038 ‰, respectively.

The above relations are essentially equivalent for normal oceanic salinities (~35‰), but they do differ at the lower salinities as shown in the above example, making evident the unwarranted weighting of the lower salinities by the North Sea and Baltic samples whose composition is certainly different. Such differences were not, however, important before the 1940's since the routine methods of measurement at that time could not achieve the necessary accuracy. It should be noted that the "total salt" content of seawater is about 0.45 percent greater than its salinity as defined by Knudsen (See Riley and Chester, 1971, p. 13).

It is important to note that the primary measure of salinity was at that time based on chlorinity and the Knudsen relation, and Standard Seawater was specified through its chlorinity.

In 1940, the definition of chlorinity was recast (Jacobsen and Knudsen, 1940) in order to divorce it from its dependence on the atomic weight values and was expressed in the following form:

> "The number giving the chlorinity in per mille of a seawater sample is by definition identical with the number giving the mass with unit gram of 'Atomgewicht silber' just necessary to precipitate the halogens in 0.3285234 kilogram of the seawater sample."

'Atomgewicht silber' means atomic weight silver, a very pure form of silver. This definition ensured continuity of the pre-1940 measurements of chlorinity, and was established empirically by comparison of the new Standard Seawater "Urnormal 1937" with the 21 previously prepared batches of Standard Seawater over the period 1900–1937. Again the implication was that the composition of seawater was constant. The Knudsen relation between chlorinity and salinity continued to be used and the Knudsen tables provided the means of obtaining specific gravity.

In the 1950's, this well established state of affairs was reexamined and it was found, (Carritt and Carpenter 1959), that by specifying chlorinity exactly, the salinity could only be established to within $\pm 0.024‰$ at the 99 percent confidence level, using the data on which the Knudsen relationship was based. This led to some previously overlooked uncertainties concerning seawater composition which were actually pointed out by Dittmar (1889) himself. It was more recently found that deep waters have a proportionately higher calcium content than surface waters, a fact which had not been taken into account previously since the samples used did not include deep water. It was also found that the amount of dissolved gases and changes in isotopic composition of water that could not be detected by measuring chlorinity could contribute to small variations in density, leading to situations where two samples of the same chlorinity, but varying in the above quantities, have different salinities and densities. These latter differences, however, are only barely above the threshold of present-day measurement capabilities.

Discrepancies between chlorinity, specific gravity and index values were also found to occur by Bein, *et al.* (1935) who used a calibrated interferometer to obtain specific gravity and who also made independent determinations of chlorinity. Thompson and Wirth (1931) also found discrepancies of this type, implying that the Knudsen Hydrographic Tables were actually slightly low in specific gravity.

After Carritt and Carpenter generated new interest in this problem, Cox (1963) discussed the "salinity problem" and described the relatively new conductimetric methods used for its measurement. Cox, Culkin and Riley (1966) presented a much more refined chlorinity-to-electrical-conductivity relationship, using Copenhagen Standard Seawater. More recent work by Cox, McCartney and Culkin (1970) established a new relationship between specific gravity, salinity and temperature. From the above works of Cox and his colleagues at the National Institute of Oceanography, a new relationship between salinity and chlorinity was established,

$$S‰ = 1.80655\ Cl‰ \tag{3.4}$$

as described in UNESCO (1966b), which for Cl = 19‰ and 5‰ gives S = 34.325‰ and 9.033‰ respectively (Compare with relations 3.1, 3.2, 3.3).

This relationship we intend to use in the present study to obtain the correspondence of S and Cl, for the more recent experimental works on the index of refraction, and specifically the Mehu and Johannin-Gilles (1968) data.

A slight modification will be necessary to convert pre-1940 chlorinities to salinities due to the change in atomic weights as pointed out by Reeburgh (1966) and the relationship becomes

$$S‰ = \frac{1.80655}{1.00045}\ Cl‰ \qquad (3.5)$$

which will specifically be used to convert the Utterback, *et al.* data.

The difference between the last two formulae for a Cl of 19‰ would produce S = 34.324‰ and S = 34.309‰ which is not insignificant and has led to erroneous conclusions in the past.

Such differences become important when accuracies at and beyond the fifth decimal place in index of refraction are considered.

Recently, with the advances of conductimetric methods of measuring salinity, a new definition has been adopted for salinity which uses the conductivity ratio of a seawater sample to that of pure water, both at 15°C (UNESCO, 1966b). In addition, Copenhagen Standard Seawater is now labeled with both its chlorinity and its conductivity ratio.

A general observation applicable to almost all the experimental works that were reviewed in this study refers to the methods of obtaining the various seawater samples to cover a range of salinities. One very popular method is to begin with Copenhagen Standard Seawater (~35‰) and through dilution with multiply-distilled fresh water, to obtain samples at other salinities. This method is restricted, of course, to salinities below 35‰ and the ionic and isotopic composition of the fresh water used may be important. Some investigators have obtained higher salinities by permitting evaporation of their samples, which is a questionable practice. Another method is to begin with high-salinity seawater (e.g., from the Mediterranean) and follow the above procedure of dilution to obtain salinities above 35‰. A third and, in our opinion a more correct method, is to mix actual seawater samples of different salinities to obtain intermediate values. It is very probable that the above procedures encounter difficulties with respect to modification of the ionic composition, which are usually ignored. It is, nevertheless, an important point, when comparisons between different methods – e.g., conductimetric versus optical – are made in achieving the same goal, i.e., salinity determination. In relation to this, it is instructive to recall that investigators measuring pure water properties are chiefly concerned with its purity; whereas, in the case of seawater, this is an academic question.

In the present work the accuracy of the index of refraction provided in our tables is not sufficient to probe any such fine distinctions, but in Section 6 some thoughts on the subject and some estimates of the necessary accuracy will be offered.

In oceanographic usage, the density is expressed as specific gravity ρ(s,t,p) and is customarily used in an abreviated form expressed as $\sigma_{s,t,p}$ where

$$\sigma_{s,t,p} = [\rho(s,t,p)-1] \times 10^3 \ . \tag{3.6}$$

Thus for $\rho(s,t,p) = 1.02478$, we have $\sigma_{s,t,p} = 24.78$. It is also often useful to express this form of specific gravity, referred to atmospheric pressure, and call this term sigma–t (σ_t)

$$\sigma_t = [(\rho(s,t,o)-1] \times 10^3 \ . \tag{3.7}$$

When, in addition, a direct correspondence of specific gravity with salinity is desired, the temperature must be fixed, and 0°C has been chosen for this purpose, providing another variant, sigma–zero (σ_0)

$$\sigma_0 = [(\rho(s,0,0)-1] \times 10^3 \ . \tag{3.8}$$

In the older works, Knudsen (1901), Bein, *et al.* (1935), a parameter characterizing density was $\rho_{17.5}$, defined as

$$\rho_{17.5} = \left[\frac{S_{s,w(17.5)}}{S_{p,w(17.5)}}\right] - 1 \quad \times 10^3 \tag{3.9}$$

where $S_{s,w(17.5)}$ is the specific gravity of seawater at 17.5°C (referred to distilled water at 4°C), and $S_{p,w(17.5)}$ similarly for pure water. Specific gravity is not to be confused with specific weight which is the product of the density of seawater and the acceleration of gravity g. Since Bein, *et al.*, use this expression (Eq. 3.9), we have used Knudsen's Tables which provide the correspondence between Cl, S, σ_0, and $\rho_{17.5}$ to convert to salinity. The above relations should be kept in mind for some of the data we will consider later.

Most of the modern work on oceanographic standards and relationships between the various quantities can be found in a series of reports of the Joint Panel on Oceanographic Tables and Standards published by UNESCO, one of which is listed in the References at the end of this report.

4. THE INDEX OF REFRACTION OF SEAWATER

The index of refraction of seawater may generally be considered to be a function of the salinity S, temperature T, pressure P, and wavelength λ.

The natural ranges over which these variables extend are: $0<S<43‰$, $0<T<30°C$, $0<P<1100$ Kg/cm².* These are the relevant ranges of the parameters from the oceanographic point of view. The wavelength range of interest is $400<\lambda<700$ nm (i.e., the visible spectrum). In the oceans, however, not all combinations of these values are realized. As a matter of fact, most oceanic waters have very well defined characteristic temperature versus salinity correlations which are used to distinguish between different water masses. It also happens that the deep waters (high pressures) are always found to have low temperatures (except in the Mediterranean and the Red Sea), although the reverse is not true since there exist cold surface waters at high latitudes.

The coverage presented in our tables, however, is not restricted to oceanic conditions but includes the complete ranges given above. Our final results are gathered in Appendix A as Tables A-1 through A-6 where representative three-dimensional plots are also provided as Figures A-1 through A-6.

All index values are expressed with respect to air.

4.1 THE DATA BASE

As mentioned in the literature review, four bodies of data form the basis of our tables: the one by Mehu and Johannin-Gilles (1968), (hereinafter M-G), providing the dependence of index of refraction of seawater on temperature, chlorinity (salinity), and wavelength at atmospheric pressure, the one by Stanley (1971) providing the dependence on temperature, pressure and wavelength at 35‰ salinity, the one by Tilton and Taylor (1938) providing the index of pure water as a function of wavelength and temperature at atmospheric pressure, and the one by Waxler, Weir and Schamp (1964) providing the dependence on temperature, pressure and wavelength for pure water. In Section 5 the works of Utterback, Thompson and Thomas (1934) and of Rusby (1966) will be compared with our results within the restricted ranges of the parameters they provide, even though Rusby's refractive index anomaly data are numerically the most accurate.

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*Pressure is taken as gage pressure, i.e., atmospheric pressure is zero gage pressure.

4.2 THE DEPENDENCE OF INDEX ON TEMPERATURE, SALINITY, AND WAVELENGTH

The M-G data are presented in their original form in Table 4-1 and include 10 wavelengths, 5 chlorinities, and 7 well-spaced temperatures (the salinities have been computed, see Section 3). From such a table one may, by suitable interpolation and some extrapolation, obtain much more expanded tables of the index of refraction of seawater, provided the data are well behaved. The connotation here, for example, is that no systematic errors occur for some value of one parameter and that the random errors are smaller than the claimed accuracy, which is "within" 3×10^{-5}. As mentioned in the introduction, the intent is to examine the data using various objective tests and some judgement and to produce the most credible set of values covering all four parameters. With this in mind, the M-G data were examined, and several systematic discrepancies were noted. Figure 4-1 shows the plot for λ = 546.1 nm, which apart from the actual numerical values of index is an example identical to the plots for all the other wavelengths.

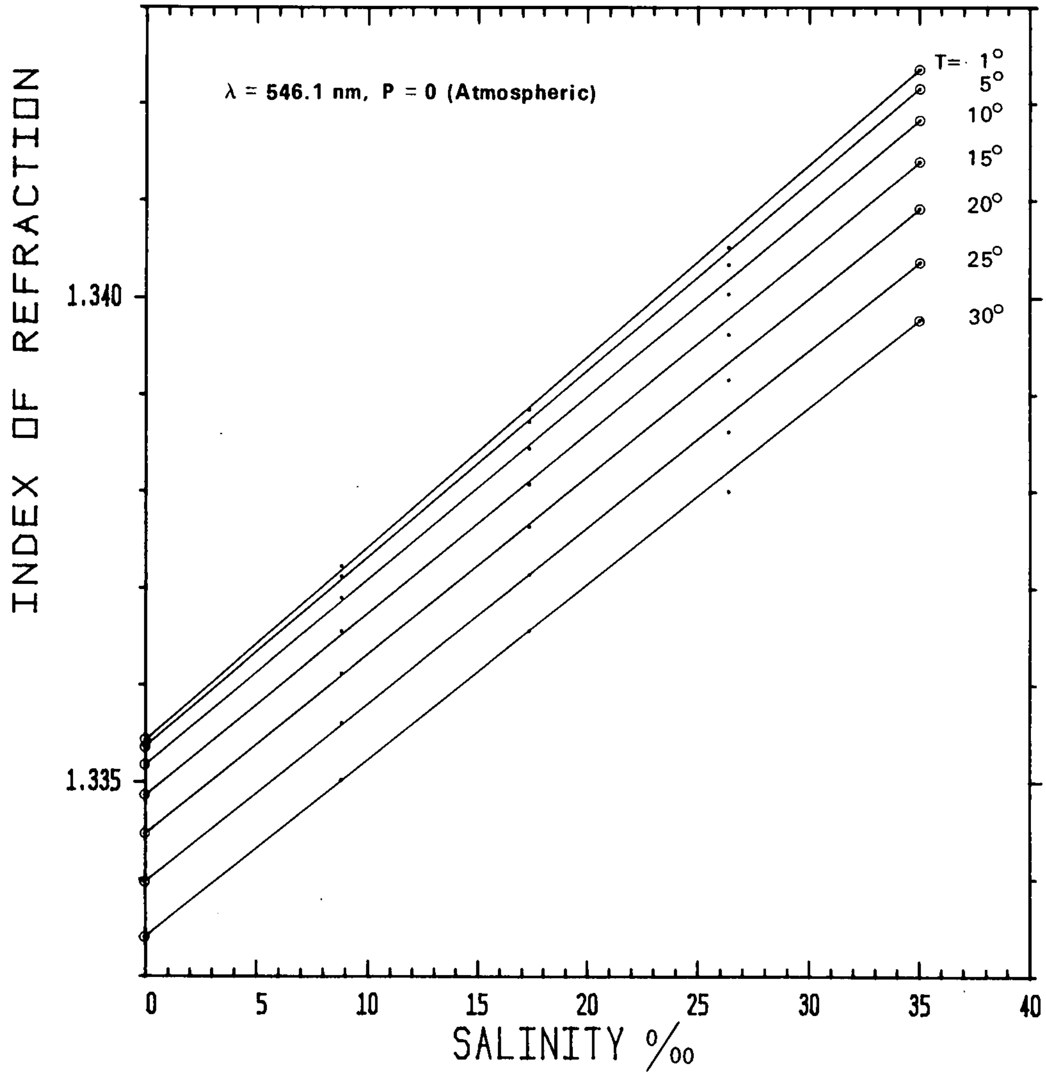


Fig. 4-1. Representative example of the Mehu and Johannin-Gilles data, demonstrating the departure from a linear dependence of the index on salinity.

Digressing briefly, it is recalled that except for Tornoe (1900) (see also Section 5), all investigators who determined the index of refraction dependence on salinity (to an accuracy of the order of 10^{-5}) have claimed it to be linear. M-G make the same claim and have fitted straight lines to their data using least squares. In the example in Figure 4-1, we have connected the lowest and highest salinities by straight lines, for reasons to be described later. It is observed that at the chlorinity value 14.588‰ (S = 26.354‰) the data fall below the line for all temperatures, while at 4.887‰ (S = 8.829‰) they fall slightly above it with smaller departures for the higher temperatures. At the middle chlorinity value of 9.603‰(S = 17.348‰), they appear to be on the line except at the lower temperatures. This behavior is identical at each of the 10 wavelengths, and the departures are of almost exactly the same magnitude ($< 20 \times 10^{-5}$). These discrepancies do not appear to be randomly produced (see Table 5-5), but instead indicate some systematic cause, which is almost impossible to trace since the authors' report is quite brief. Of all the possible causes of error – temperature, salinity, goniometer readings, handling of the samples, etc. – we may eliminate several as improbable. First, five of the pure water values (at 404.7, 435.8, 546.1, 577.0, and 589.3 nanometers) have been taken directly from Tilton and Taylor and their quality is unquestionable; the other five were determined by the authors themselves and appear to be consistent. Second, at 19.373‰ (S = 34.998‰), we have faith in the chlorinity values since they were very precisely determined during the standardization process in Copenhagen. Finally, we expect from previous studies that the dependence of index on chlorinity (and salinity) is linear. Observing that the authors claim a temperature control of 0.025°C, corresponding to the trivial uncertainty of about 0.15×10^{-5} in index, it appears that temperature errors can be excluded also. The remaining probable causes are either erroneous chlorinity determinations for the diluted samples or a systematic error in the goniometer and apparatus (whose limit of resolution was 3×10^{-5}, which is also the error the authors quote for their work). Surprisingly, no mention is made by the authors of their chlorinity measurements, the measurement method used, or the accuracy of the determinations, although they report them to five significant digits.

We did not contemplate locating these errors or correcting for them; instead, we have eliminated values which appeared to be inconsistent. Our principal objection lies in the lack of linearity of the data, beyond the stated 3×10^{-5} accuracy, and also in the sigmoid shape of the curves that would result which is inconsistent with the authors' claim that the functional dependence is linear. For further comments, see Section 5.

In view of the above objections, we have selected from the M-G data of Table 4-1 only those values that correspond to pure water (S = 0‰) and Copenhagen Standard Seawater (S = 34.998‰) in which we have more faith. The straight lines are drawn through these two salinities in Figure 4-1, and are circled for clarity. The abridged body of data upon which we base our Tables A-1 through A-4 in Appendix A, is given in Table 4-2. Chlorinity has been converted to salinity, using the proportionality factor 1.80655 (see Section 3).

Admittedly, in systematically eliminating some of the original data, we have relied heavily upon the assumption of linearity of index with salinity. We believe from previous studies (except Tornoe, see Section 5), that this linearity is accurate at least to the fifth decimal place. This almost arbitrary choice of the data to be retained is later justified through comparison with the data of Utterback, *et al.*, Section 5.

Table 4-1. Original Mehu and Johannin-Gilles (1968) data. The salinities have been computed.

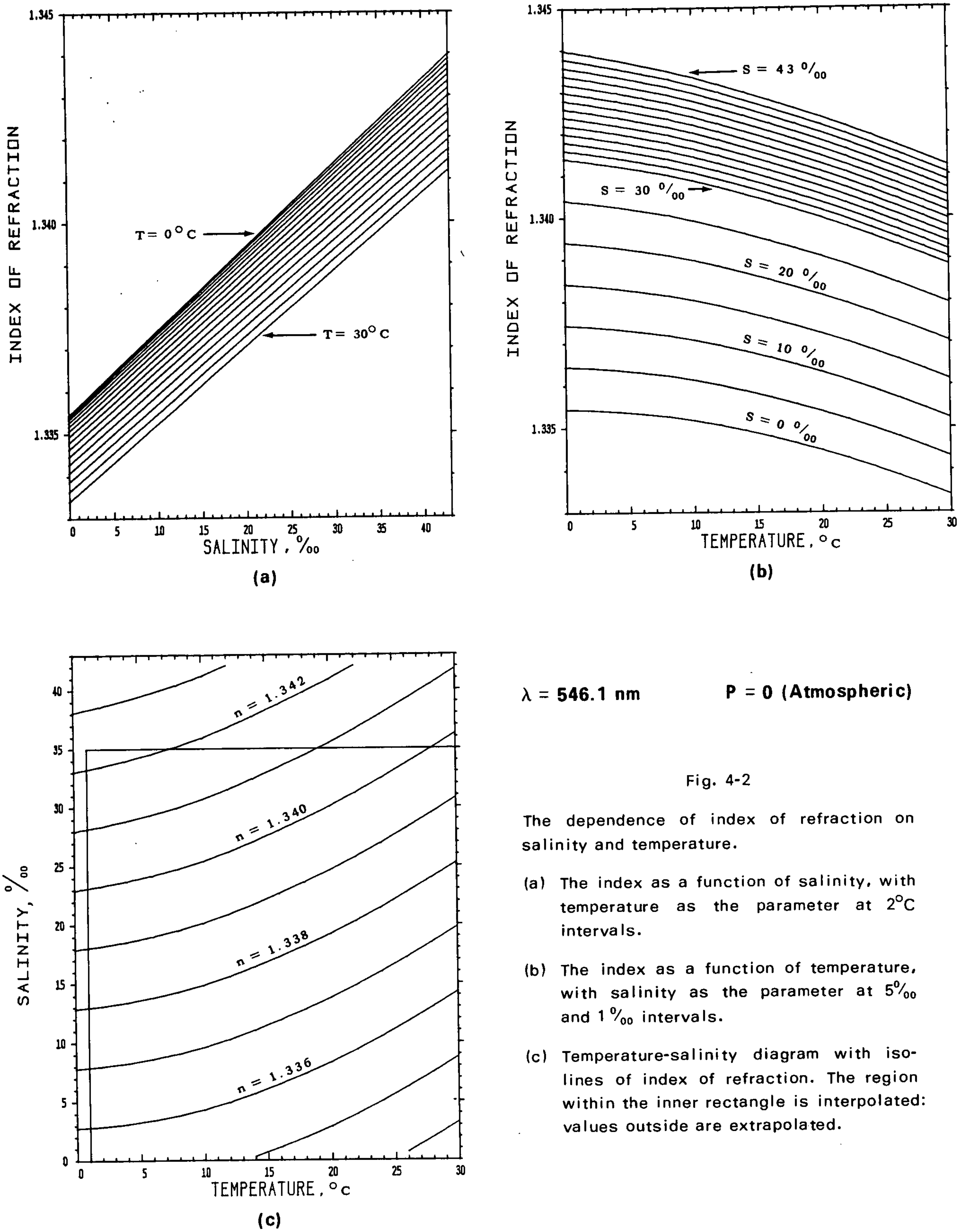
λ (nm)	S (‰)	Chlor. (‰)	TEMPERATURE °C						
			1.0	5.0	10.0	15.0	20.0	25.0	30.0
404.7	0.0	0.0	1.34375	1.34368	1.34348	1.34316	1.34274	1.34224	1.34166
	8.829	4.887	1.34563	1.34552	1.34528	1.34493	1.34448	1.34395	1.34335
	17.348	9.603	1.34722	1.34710	1.34685	1.34650	1.34607	1.34556	1.34497
	26.354	14.588	1.34903	1.34887	1.34856	1.34814	1.34763	1.34706	1.34643
	34.998	19.373	1.35093	1.35072	1.35040	1.34999	1.34950	1.34894	1.34831
435.8	0.0	0.0	1.34121	1.34114	1.34094	1.34062	1.34021	1.33971	1.33913
	8.829	4.887	1.34306	1.34295	1.34271	1.34236	1.34192	1.34139	1.34078
	17.348	9.603	1.34465	1.34454	1.34428	1.34392	1.34349	1.34298	1.34239
	26.354	14.588	1.34643	1.34626	1.34595	1.34553	1.34504	1.34447	1.34385
	34.998	19.373	1.34831	1.34811	1.34778	1.34736	1.34688	1.34632	1.34569
467.8	0.0	0.0	1.33913	1.33906	1.33886	1.33854	1.33813	1.33764	1.33706
	8.829	4.887	1.34096	1.34085	1.34061	1.34026	1.33982	1.33930	1.33869
	17.348	9.603	1.34254	1.34244	1.34217	1.34180	1.34136	1.34085	1.34027
	26.354	14.588	1.34429	1.34412	1.34381	1.34339	1.34291	1.34235	1.34173
	34.998	19.373	1.34615	1.34596	1.34563	1.34520	1.34471	1.34416	1.34355
480.0	0.0	0.0	1.33844	1.33837	1.33817	1.33786	1.33745	1.33695	1.33638
	8.829	4.887	1.34026	1.34015	1.33991	1.33957	1.33913	1.33860	1.33800
	17.348	9.603	1.34185	1.34173	1.34147	1.34111	1.34067	1.34016	1.33958
	26.354	14.588	1.34359	1.34341	1.34310	1.34270	1.34221	1.34165	1.34104
	34.998	19.373	1.34544	1.34525	1.34492	1.34450	1.34401	1.34345	1.34284
508.5	0.0	0.0	1.33701	1.33694	1.33674	1.33644	1.33603	1.33554	1.33497
	8.829	4.887	1.33881	1.33871	1.33847	1.33814	1.33770	1.33718	1.33659
	17.348	9.603	1.34041	1.34029	1.34002	1.33966	1.33922	1.33872	1.33814
	26.354	14.588	1.34212	1.34195	1.34163	1.34124	1.34075	1.34020	1.33959
	34.998	19.373	1.34397	1.34378	1.34344	1.34302	1.34253	1.34199	1.34138
546.1	0.0	0.0	1.33544	1.33537	1.33518	1.33487	1.33447	1.33398	1.33341
	8.829	4.887	1.33723	1.33712	1.33690	1.33655	1.33612	1.33561	1.33502
	17.348	9.603	1.33884	1.33871	1.33844	1.33807	1.33764	1.33714	1.33656
	26.354	14.588	1.34052	1.34034	1.34004	1.33962	1.33915	1.33861	1.33800
	34.998	19.373	1.34235	1.34215	1.34183	1.34140	1.34092	1.34037	1.33977
577.0	0.0	0.0	1.33434	1.33428	1.33408	1.33378	1.33338	1.33289	1.33233
	8.829	4.887	1.33612	1.33603	1.33579	1.33545	1.33502	1.33451	1.33393
	17.348	9.603	1.33773	1.33762	1.33734	1.33698	1.33653	1.33602	1.33547
	26.354	14.588	1.33939	1.33922	1.33891	1.33850	1.33803	1.33749	1.33689
	34.998	19.373	1.34122	1.34104	1.34070	1.34028	1.33979	1.33924	1.33865
579.1	0.0	0.0	1.33427	1.33421	1.33402	1.33371	1.33331	1.33282	1.33226
	8.829	4.887	1.33605	1.33596	1.33573	1.33538	1.33495	1.33444	1.33386
	17.348	9.603	1.33766	1.33755	1.33728	1.33691	1.33646	1.33595	1.33540
	26.354	14.588	1.33932	1.33915	1.33885	1.33843	1.33796	1.33742	1.33682
	34.998	19.373	1.34115	1.34097	1.34064	1.34021	1.33972	1.33917	1.33858
589.3	0.0	0.0	1.33395	1.33388	1.33369	1.33339	1.33299	1.33250	1.33194
	8.829	4.887	1.33573	1.33563	1.33540	1.33506	1.33463	1.33412	1.33354
	17.348	9.603	1.33734	1.33722	1.33695	1.33658	1.33614	1.33563	1.33507
	26.354	14.588	1.33899	1.33881	1.33851	1.33810	1.33763	1.33709	1.33649
	34.998	19.373	1.34081	1.34063	1.34030	1.33987	1.33938	1.33883	1.33824
643.8	0.0	0.0	1.33241	1.33234	1.33215	1.33186	1.33146	1.33098	1.33042
	8.829	4.887	1.33419	1.33408	1.33385	1.33352	1.33309	1.33259	1.33201
	17.348	9.603	1.33580	1.33566	1.33540	1.33504	1.33459	1.33409	1.33352
	26.354	14.588	1.33742	1.33724	1.33693	1.33654	1.33607	1.33554	1.33494
	34.998	19.373	1.33924	1.33905	1.33872	1.33830	1.33781	1.33726	1.33666

Table 4-2. Selected data of the index of refraction, as a function of wavelength, salinity and temperature at atmospheric pressure, used in constructing the index tables. Additional values at λ = 700 nm and S = 34.998 ‰ have been estimated.

λ (nm)	S (‰)	Chlor. (‰)	TEMPERATURE °C						
			1.0	5.0	10.0	15.0	20.0	25.0	30.0
404.7	0.0	0.0	1.34375	1.34368	1.34348	1.34316	1.34274	1.34224	1.34166
	34.998	19.373	1.35093	1.35072	1.35040	1.34999	1.34950	1.34894	1.34831
435.8	0.0	0.0	1.34121	1.34114	1.34094	1.34062	1.34021	1.33971	1.33913
	34.998	19.373	1.34831	1.34811	1.34778	1.34736	1.34688	1.34632	1.34569
467.8	0.0	0.0	1.33913	1.33906	1.33886	1.33854	1.33813	1.33764	1.33706
	34.998	19.373	1.34615	1.34596	1.34563	1.34520	1.34471	1.34416	1.34355
480.0	0.0	0.0	1.33844	1.33837	1.33817	1.33786	1.33745	1.33695	1.33638
	34.998	19.373	1.34544	1.34525	1.34492	1.34450	1.34401	1.34345	1.34284
508.5	0.0	0.0	1.33701	1.33694	1.33674	1.33644	1.33603	1.33554	1.33497
	34.998	19.373	1.34397	1.34378	1.34344	1.34302	1.34253	1.34199	1.34138
546.1	0.0	0.0	1.33544	1.33537	1.33518	1.33487	1.33447	1.33398	1.33341
	34.998	19.373	1.34235	1.34215	1.34183	1.34140	1.34092	1.34037	1.33977
577.0	0.0	0.0	1.33434	1.33428	1.33408	1.33378	1.33338	1.33289	1.33233
	34.998	19.373	1.34122	1.34104	1.34070	1.34028	1.33979	1.33924	1.33865
579.1	0.0	0.0	1.33427	1.33421	1.33402	1.33371	1.33331	1.33282	1.33226
	34.998	19.373	1.34115	1.34097	1.34064	1.34021	1.33972	1.33917	1.33858
589.3	0.0	0.0	1.33395	1.33388	1.33369	1.33339	1.33299	1.33250	1.33194
	34.998	19.373	1.34081	1.34063	1.34030	1.33987	1.33938	1.33883	1.33824
643.8	0.0	0.0	1.33241	1.33234	1.33215	1.33186	1.33146	1.33098	1.33042
	34.998	19.373	1.33924	1.33905	1.33872	1.33830	1.33781	1.33726	1.33666
700.0	0.0	0.0	1.33109	1.33103	1.33084	1.33055	1.33016	1.32968	1.32913
	34.998	19.373	1.33788	1.33771	1.33738	1.33695	1.33644	1.33591	1.33532

NOTE: For the data at 700 nm see text.

We have plotted in Figure 4-2 an example of the result obtained by using Table 4-2 to construct our greatly expanded tables, included in Appendix A. This figure is for the wavelength 546.1 nm and demonstrates the behavior of index of refraction with salinity (4-2a) and temperature (4-2b). These curves are monotonic and have smooth derivatives. The method used to derive them through interpolation from the data, is included in detail in Appendix B. A particularly interesting situation arises in Figure 4-2b near 0°C; the temperature gradient for pure water (S = 0‰) appears to vanish, while for higher salinities it does not. Since these pure water data were taken from Tilton and Taylor (1938), we have reverted to their work for clarification. Close examination indicated that they found (their p. 463) a maximum of the index of refraction of pure water, located between 0 and 0.5°C depending on wavelength which is reminiscent



λ = 546.1 nm **P = 0 (Atmospheric)**

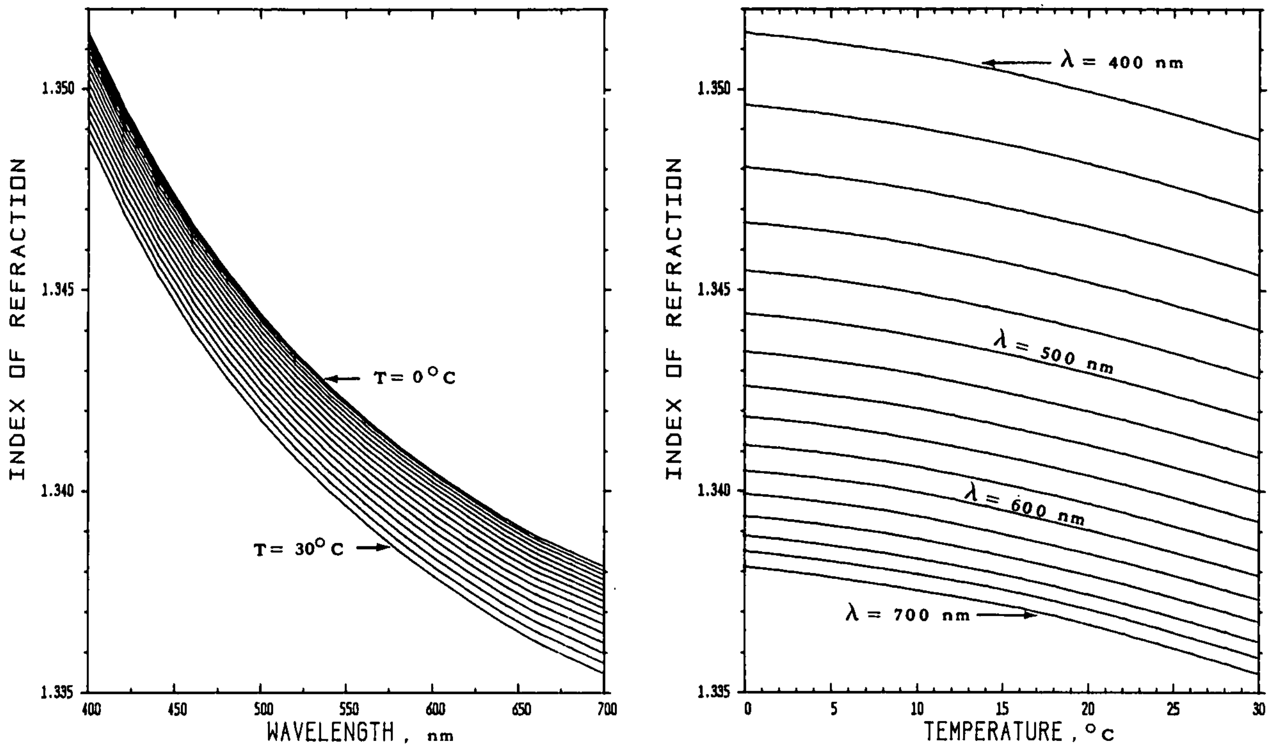
Fig. 4-2

The dependence of index of refraction on salinity and temperature.

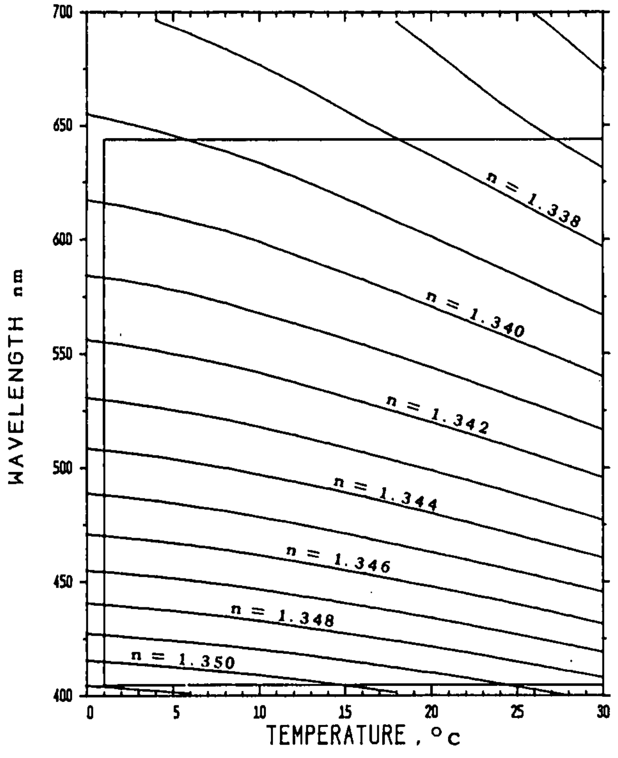
(a) The index as a function of salinity, with temperature as the parameter at 2°C intervals.

(b) The index as a function of temperature, with salinity as the parameter at 5‰ and 1‰ intervals.

(c) Temperature-salinity diagram with iso-lines of index of refraction. The region within the inner rectangle is interpolated: values outside are extrapolated.



(a) (b)



(c)

S = 35 ‰ **P = 0 (Atmospheric)**

Fig. 4-3

The dependence of index of refraction on wavelength and temperature.

(a) The index as a function of wavelength, with temperature as the parameter at 2°C intervals.

(b) The index as a function of temperature, with wavelength as the parameter every 20 nanometers.

(c) Temperature-wavelength diagram with isolines of index of refraction. The region within the inner rectangle is interpolated; values outside are extrapolated.

of the density maximum of pure water near 4°C. They, however, appear to disagree with some previous workers on whether the index maximum occurs above or below 0°C. In any case, it is too slight to be observed in our tables since it involves a few units in the seventh decimal place in going from 0.5 to 0°C, and the values at 1 and 0°C differ by about one unit in the sixth in index.

In using the data in Table 4-2 to derive our Tables A-1 through A-4 given in Appendix A, we have proceeded in the following manner.

We first proceeded to extend the wavelength coverage out to 700 nm, using the difference in index, Δn, between pure water and 34.998‰ salinity seawater in the interval 404.7 to 643.8 nm at seven temperatures as given in Table 4-2. By extrapolating these Δn curves out to 700 nm and knowing the index of pure water at this wavelength, we computed the corresponding values at $S = 34.998$‰, which are shown at the bottom of Table 4-2. The pure water values are directly from Tilton and Taylor, while the others were estimated as indicated above.

Having established the complete data set to be used, we proceeded to interpolate over wavelength, salinity, and temperature, using the computer routine of Appendix B to obtain a much more closely spaced body of data which is presented as Tables A-1 through A-4 in Appendix A. Tables A-1(a) to (p) are for equispaced wavelengths, Tables A-2(a) to (j) are for selected laser wavelengths, Tables A-3(a) to (i) are for the wavelengths used by M-G, while Tables A-4(a) to (t) hold for specified salinities. Note that Tables A-1 and A-4 contain essentially the same data in a different form of presentation. Figure 4-2 is a representative plot of Tables A-1, A-2, and A-3 while Figure 4-3 is representative of Table A-4.

The accuracy of the original values is "within" 3×10^{-5}; and since our interpolation routine produces values passing through the original data points, we claim our tables to have the same accuracy, except for the extrapolated wavelengths (643.8 to 700 nm) where the accuracy may be slightly reduced.

All of the above are applicable at atmospheric pressure, and the following sections will involve their extension to higher pressures.

4.3 THE DEPENDENCE OF INDEX ON TEMPERATURE, PRESSURE AND WAVELENGTH

As mentioned at the end of Section 2, the only measurements of the dependence of the index of refraction of seawater on pressure were conducted by Stanley (1971). These measurements are of a lower accuracy ($\pm 6 \times 10^{-5}$) than are the previously described M-G data for atmospheric pressure and hold only for 35‰ Copenhagen Standard Seawater. In the interferometric method used, the number of fringes passing a reference mark were counted as a sample was depressurized to atmospheric pressure. The relationship between the index of refraction n and the number of fringes m is

$$n = \frac{m\lambda}{2t} \qquad (4.1)$$

where λ is the wavelength and t the length of the sample traversed by the beam. By differentiating the above:

$$dn = \frac{\lambda}{2t}\, dm - \frac{n}{t}\, dt \tag{4.2}$$

or in finite difference form

$$\Delta n = n - n_0 = \frac{\lambda}{2t_0}\, \Delta m - \frac{n_0 \Delta t}{t_0} \tag{4.3}$$

where the subscript zero denotes atmospheric pressure. Here Δm denotes the number of fringes passing a reference mark as the sample was depressurized and Δt denotes the theoretically computed expansion of the vessel due to pressure.

The above equation provides only the change in index Δn, so the index of refraction at atmospheric pressure n_0 must be determined in order to obtain the index at higher pressures. Stanley proceeded to measure n_0 at two wavelengths (501.7 and 632.8 nm), using an Abbe refractometer calibrated for the D-lines (589.3 nm) from data for pure water of Tilton and Taylor and for seawater of Utterback, *et al.* These indices of refraction in air were referred to vacuum (by multiplication with 1.00029) and are shown in Table 4-3 as taken directly from Stanley (1971). They cover the pressure range 0 to 1406 kg/cm^2 at seven temperatures. The same author, however, also measured the change in index with pressure at three additional wavelengths (457.9, 488.0, and 514.5 nm), but was unable to obtain the corresponding values of n_0 at atmospheric pressure, upon which to base a determination of the absolute indices. These measurements are in the form of fringe counts Δm over the same pressure range but, unfortunately, only at three temperatures (0.03, 15.02, and 29.98°C) and are presented in Table 4-4. The coefficients $\lambda/2t_0$ and $\Delta t/t_0$ necessary for applying the above formula for Δn (Eq. 4-3) are also provided, together with Table 4-4, where the multiple entries represent replicate measurements.

Tables 4-3 and 4-4 have been reproduced here in their complete form for comparison with the atmospheric pressure values of the M-G measurements, at the two wavelengths where this is possible. Using the M-G data and our interpolation routine (see Appendix B), we have obtained index of refraction values at these wavelengths and at the corresponding temperatures, for $35^{\circ}/_{00}$ salinity. A comparison is shown below, where the Stanley data have been divided by 1.00029, to be re-expressed with respect to air.

		0.03° C	5.03° C	10.03° C	15.02° C	20.00° C	24.99° C	29.98° C
λ = 501.7 nm	Stanley	1.34443	1.34416	1.34373	1.34340	1.34288	1.34233	1.34176
	Mehu *et al.*	1.34433	1.34411	1.34377	1.34335	1.34286	1.34232	1.34171
	$\Delta n \times 10^5$	10	5	−4	5	2	1	5
λ = 632.8 nm	Stanley	1.33976	1.33938	1.33896	1.33860	1.33811	1.33756	1.33698
	Mehu *et al.*	1.33957	1.33934	1.33902	1.33859	1.33810	1.33756	1.33696
	$\Delta n \times 10^5$	19	4	−6	1	1	0	2

Table 4-3. Absolute index of refraction, with respect to vacuum, taken from the original (Stanley, 1971). With permission of Pergamon Press.

Absolute refractive index of 35·00‰ *seawater as a function of temperature, pressure and wavelength.*

Pressure			*Temperature*				
	0·03°C	5·03°C	10·03°C	15·02°C	20·00°C	24·99°C	29·98°C
			6328 Ångstroms				
Atmospheric	1·34015	1·33977	1·33935	1·33899	1·33850	1·33795	1·33737
352 kg/cm²	1·34539	1·34487	1·34431	1·34387	1·34329	1·34270	1·34209
	1·34539	1·34486	1·34431	1·34389	1·34333	1·34271	1·34205
							1·34206
703 kg/cm²	1·35025	1·34962	1·34896	1·34844	1·34779	1·34713	1·34649
	1·35025	1·34963	1·34897	1·34845	1·34781	1·34713	1·34646
1055 kg/cm²	1·35482	1·35403	1·35329	1·35267	1·35200	1·35129	1·35060
	1·35480	1·35404	1·35332	1·35272	1·35200	1·35130	1·35057
				1·35267			
1406 kg/cm²	—	1·35813	1·35743	1·35666	1·35591	1·35517	1·35446
	—	1·35815	1·35738	1·35672	1·35593	1·35522	1·35441
	—		1·35733	1·35666			1·35444
			5017 Ångstroms				
Atmospheric	1·34482	1·34455	1·34422	1·34379	1·34327	1·34272	1·34215
352 kg/cm²	1·35008	1·34969	1·34924	1·34873	1·34812	1·34759	1·34694
	1·35008	1·34969	1·34925	1·34873	1·34814	1·34754	1·34693
						1·34757	1·34695
703 kg/cm²	1·35507	1·35450	1·35394	1·35333	1·35269	1·35207	1·35136
	1·35507	1·35449	1·35393	1·35332	1·35268	1·35207	1·35138
						1·35211	1·35138
1055 kg/cm²	1·35953	1·35891	1·35835	1·35763	1·35695	1·35631	1·35560
	1·35952	1·35892	1·35832	1·35765	1·35696	1·35633	1·35561
	1·35953					1·35632	1·35561
1406 kg/cm²	—	1·36315	1·36241	1·36166	1·36094	1·36019	1·35945
	—	1·36312	1·36240	1·36165	1·36096	1·36018	1·35946
	—			1·36166		1·36021	1·35946

Table 4-4. Interferometer fringe counts, representing the index of refraction, as a function of pressure and temperature, taken from the original (Stanley, 1971). With permission of Pergamon Press.

Number of fringes counted, dm, *for* 35·00% *seawater as a function of temperature, pressure and wavelength.*

Pressure		*Wavelength* (Ångstroms)			
	4579	4880	5017	5145	6328
		Temperature,	0·03°C		
352 kg/cm²	67·1	62·4	60·4	58·8	47·7
	67·1	62·5	60·4	59·1	47·7
703 kg/cm²	129·3	120·4	117·6	113·6	91·7
	129·1	120·3	117·5	114·2	91·8
				114·0	
1055 kg/cm²	186·2	173·8	168·5	164·4	133·1
	186·4	173·9	168·4	164·5	132·9
			168·5		
		Temperature, 15·02°C			
352 kg/cm²	62·6	58·1	56·5	54·8	44·3
	63·0	58·5	56·5	55·3	44·5
				55·2	
703 kg/cm²	120·5	113·0	109·2	106·4	85·7
	120·9	112·8	109·1	106·8	85·8
		113·0			
1055 kg/cm²	175·0	163·4	158·2	154·2	123·9
	175·2	163·5	158·4	154·7	124·4
1406 kg/cm²	226·2	211·1	204·1	199·2	123·8
					159·8
	226·0	221·2	204·0	199·3	160·3
			204·1		159·8
		Temperature, 29·98°C			
352 kg/cm²	59·8	56·1	54·7	53·7	42·9
	60·2	56·2	54·8	53·4	42·4
	60·0		54·9		42·5
703 kg/cm²	116·3	108·6	106·6	102·7	82·6
	116·6	109·0	105·5	103·2	82·6
			105·5		
1055 kg/cm²	169·7	157·5	153·6	149·4	119·7
	169·4	158·0	153·7	149·5	119·4
			153·7		
1406 kg/cm²	217·6	204·0	197·3	193·0	154·5
	217·7	204·1	197·5	192·9	153·9
		204·3	197·5		154·2

NOTE: The values of $\lambda/2t$ and dt/t apply to Equation 4-3 for computing the rise in index of refraction from atmospheric to some higher pressure.

$\lambda/2t=0{\cdot}0001071$ for 6328 Å
$=0{\cdot}0000870$ for 5145 Å
$=0{\cdot}0000848$ for 5017 Å
$=0{\cdot}0000825$ for 4880 Å
$=0{\cdot}0000774$ for 4579 Å
$dt/t=0$ for atmospheric pressure
$=-0{\cdot}0001042$ for 352 kg/cm²
$=-0{\cdot}0002083$ for 703 kg/cm²
$=-0{\cdot}0003125$ for 1055 kg/cm²
$=-0{\cdot}0004166$ for 1406 kg/cm²

The above comparison indicates that the values agree fairly well at all temperatures, except 0.03°C where the difference exceeds the authors' combined specified errors; i.e., 3×10^{-5} for M-G, and $\pm 6 \times 10^{-5}$ for Stanley. The negative sign at 10.03°C is noteworthy.

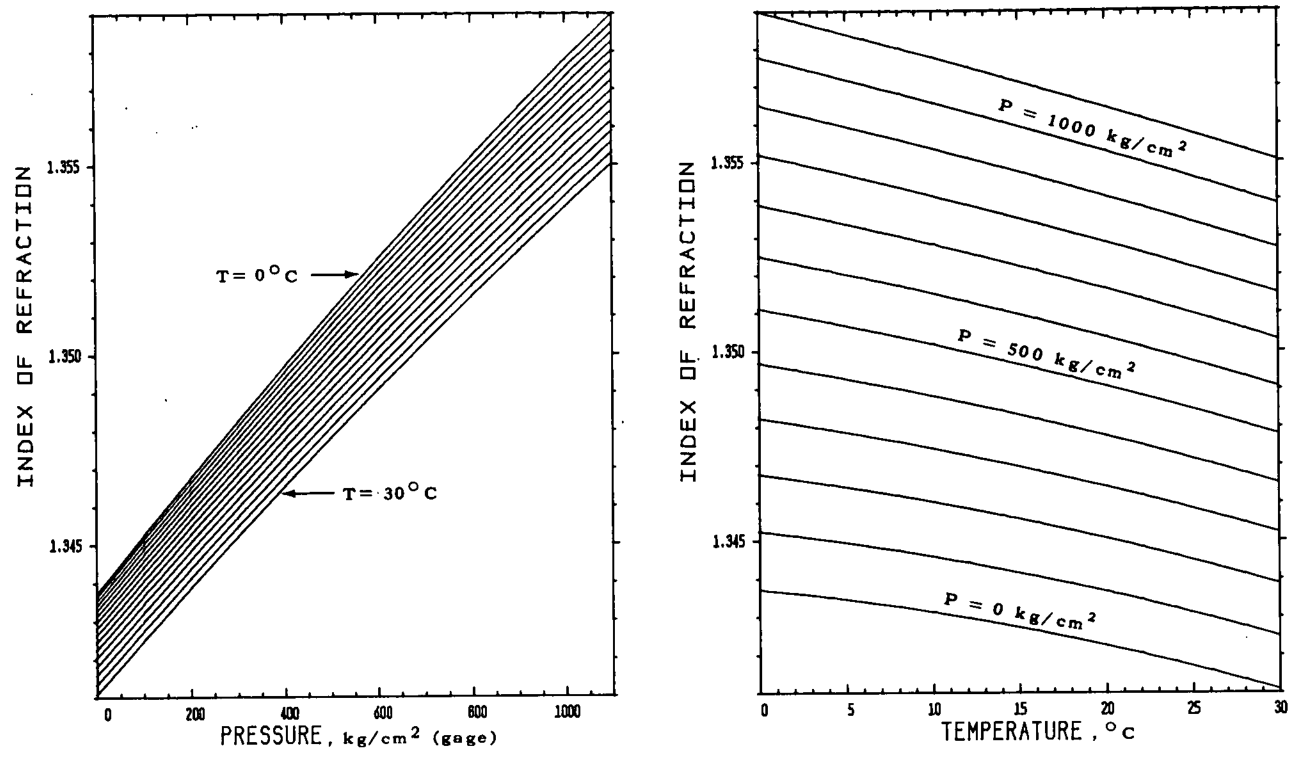
It became necessary, therefore, to take some corrective measures if our complete tables of the index of refraction were to be internally consistent.

Taking into consideration that the M-G data shown in Figure 4-3 agree well with Utterback, *et al.*, at 35‰, 0°C and 589.3 nm and are consistent at the other wavelengths as well (the comparison will be presented in Section 5), we have taken exception to Stanley's absolute values of n_0 and place our trust with Mehu and Johannin-Gilles. We thus choose to ignore Stanley's computed absolute indices of refraction shown in Table 4-3 and use instead his original data given in Table 4-4 in combination with the M-G data at atmospheric pressure, which can also be applied to the other three wavelengths. This led to greater consistency in the data.

In short, we decided to use, at atmospheric pressure, the index of refraction n_0 derived from the M-G data and to employ Stanley's equation for Δn (above) and his **mean** fringe counts from Table 4-4 to derive new values of the index of refraction. Following this we computed the new index of refraction (relative to air) for the five wavelengths, three temperatures and five pressures in the same way, as done by Stanley to construct Table 4-3 with the intention of developing complete tables of the index of refraction of 35‰ Copenhagen Standard Seawater for a range of temperatures, wavelengths, and pressures. A representative example is shown in Figure 4-4 for one of Stanley's wavelengths, interpolated using our technique. The behavior of the index of refraction curves appears quite smooth as far as can be judged from this plot. Unfortunately, when the same data were subsequently examined against wavelength, it was found that they presented some inconsistencies in their functional behavior which, in our opinion, derive from experimental errors and not from the actual physical behavior of water. They are shown in Figure 4-5 in the form of the difference Δn of the index at high pressures from that at atmospheric pressure. The latter have been taken from the M-G data, as mentioned above, and can be seen in Figure 4-3a. These inconsistencies of the wavelength dependence led to a reconsideration of Stanley's data and to an attempt to extract from his measurements the most likely physical behavior of the index of refraction of seawater. The following subsection describes in detail the procedure followed to improve on the dependence of the index on wavelength at the same pressures and temperatures as given by Stanley and to obtain a set of smoothly varying index values.

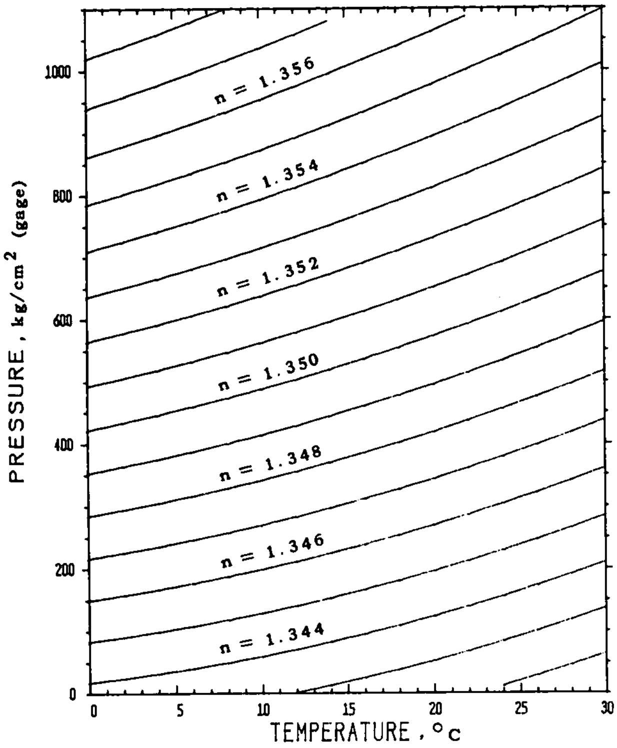
SPECIAL CONSIDERATION OF STANLEY'S HIGH-PRESSURE DATA VERSUS WAVELENGTH

The primary use of Stanley's fringe-count data was to obtain a "smooth" variation of the index function with the three parameters – wavelength, pressure, and temperature. The condition of "smoothness" was translated mathematically to mean the continuity and monotonicity of the function and its derivatives. We note in support of our smoothness assumption that Waxler, Weir and Schamp (1964) found this behavior in their study of the index of **pure** water at high pressures (See Section 4.4 below).



(a)

(b)



(c)

λ = **514.5 nm**

S = 35 ‰

Fig. 4-4

The dependence of index of refraction on pressure and temperature.

(a) The index as a function of pressure, with temperature as the parameter at 2°C intervals.

(b) The index as a function of temperature, with pressure as the parameter every 100 kg/cm².

(c) Temperature-pressure diagram with isolines of index of refraction.

Initially, mean values for the number of fringes in Table 4-4 were obtained (there are from one to four readings for each data point) and by using equation (4.3) for Δn (and the $\lambda/2t_0$ and dt/t_0 values – also in Table 4-4), the change of index of refraction with pressure at each of the three temperatures 0.03, 15.02, 29.98°C was computed, as shown in the first five columns of Table 4-5 below. We have omitted the pressure 1406 kg/cm^2 since no values are given at 0.03°C and this pressure is, moreover, beyond the oceanographic range. From preliminary considerations, it was found that the data for 501.7 nm contained much larger random errors than were found at the other wavelengths; thus it was decided to exclude this wavelength from the analysis so as not to weight the final result disproportionately. This wavelength is, however, included in Table 4-5 for comparison. It should be noted that there is a small, but more or less regular, decrease of about 20×10^{-5} in Δn with increasing wavelength which, however, is not quite monotonic (see Figure 4-5). This wavelength dependence is over and above that shown in Figure 4-3a and is a result of the effect of the increase in pressure on the index of refraction.

In order to introduce monotonicity with wavelength, the data were analyzed as described below.

The particular method used to systematize the data was adopted through the gradual development of our procedure. To judge the smoothness of the data, the behavior of the pressure derivative dn/dp was first examined for all wavelengths at each temperature, which necessitated an interpolation to obtain a closer spacing of pressures. These derivatives indicated a general drop with pressure but were somewhat erratic around a linear trend. Noting that there appeared only a small wavelength dependence, we combined all wavelengths to obtain linear least squares fits of Δn versus $d(\Delta n)/dp$ at each of the three temperatures. By integrating these linear gradients, we recovered the index of refraction dependence on pressure, at each of the three temperatures, as shown in Column 6, Table 4-5. This result was applicable to a "mean" wavelength of about 530 nm (see later) and differs from any one of the first five columns by only 20×10^{-5} at most. Figure 4-5 shows a plot of these values where the horizontal lines are for the "mean" wavelength 530 nm (Column 6), and the circled points show the index increment computed from the original Stanley fringe counts (Columns 1 through 5). The departures of Column 6 from Columns 1 through 5, therefore, contain the residual wavelength dependence due to the rise in pressure and are numerically given in Columns 1 through 4 of Table 4-6 (excluding 501.7 nm which showed greater discrepancies). The small distance of the points from the lines in Figure 4-5 is exactly this residual wavelength dependence. We have treated this wavelength dependence separately, as described in the following paragraph.

Plotting the values for each temperature and pressure against wavelength (Figure 4-6) it can be seen that they do demonstrate trends that are not, however, monotonic in all cases. Using the method of least squares, straight lines were fitted which exhibited quite satisfactory behavior with wavelength, shown as dashed lines in the figure. The difference exhibited among the linear fits at the three temperatures did not appear to be significant. We therefore, combined the three temperatures to obtain one single plot of this type, shown as Figure 4-7, with the numerical values shown in Columns 5 through 8 of Table 4-6. In performing the fits, there was a remanent residual error which we have ignored, since it is well within Stanley's $\pm 6 \times 10^{-5}$ accuracy. However, it is shown in the last four columns of Table 4-7 for reference purposes. Higher-order polynomial fits tried at all steps in this procedure did not appear to provide any decided advantages and have thus been ignored in favor of simplicity.

Table 4-5. The increase in index of refraction ($\Delta n \times 10^5$) produced by the rise in pressure. The final column represents an "average-wavelength" behavior obtained using least squares fits.

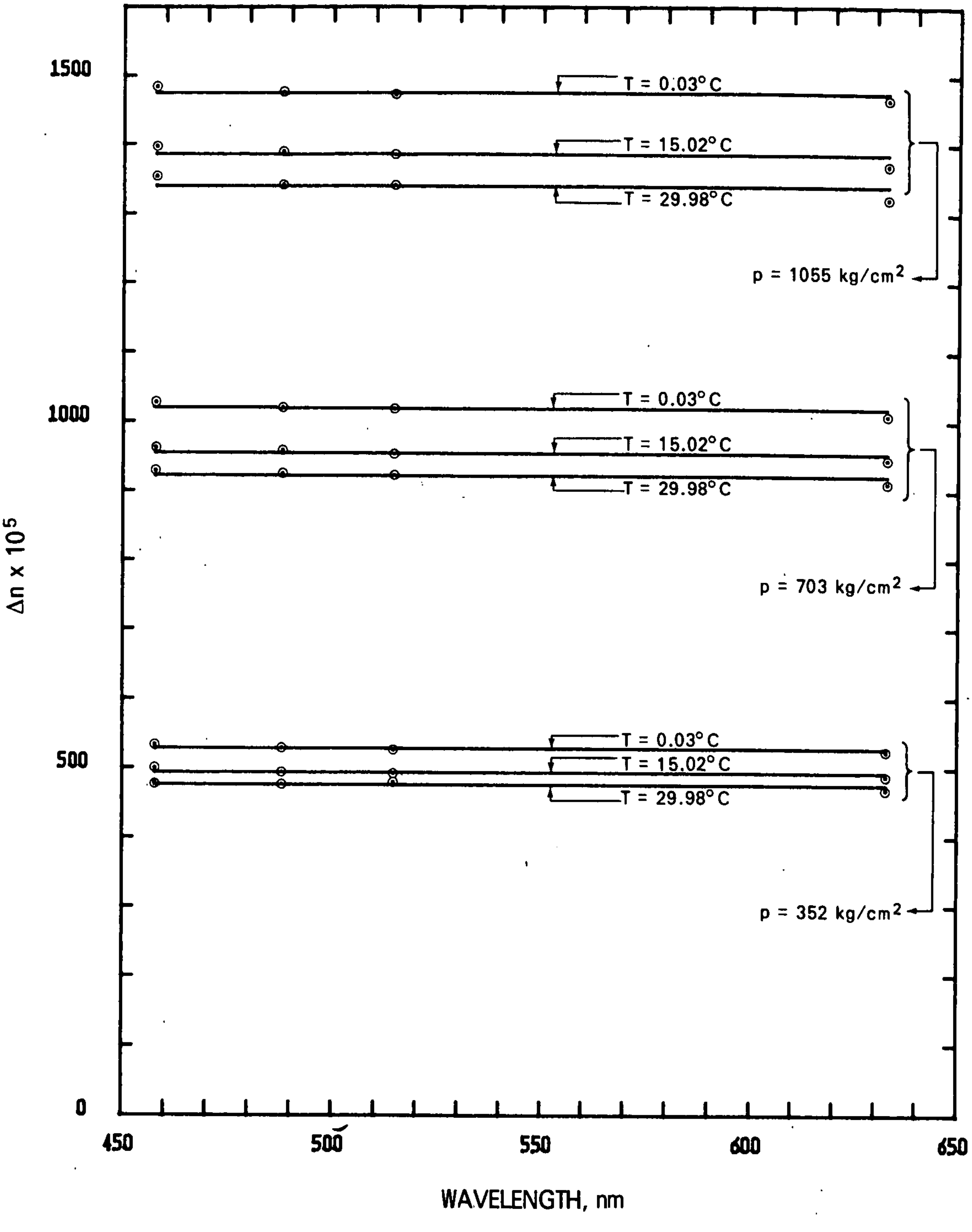
T °C	p kg/cm^2	Computed Stanley Data					Fit vs. Pressure at 530 nm
		457.9 nm	488.0 nm	501.7 nm	514.5 nm	632.8 nm	530 nm
0.03	0	0.0	0.0	0.0	0.0	0.0	0.0
	352	533.2	529.1	526.0	526.7	524.7	528.1
	703	1027.9	1020.7	1024.7	1019.0	1010.4	1018.7
	1055	1483.8	1476.1	1470.4	1472.5	1466.1	1474.5
15.02	0	0.0	0.0	0.0	0.0	0.0	0.0
	352	499.9	494.9	493.0	493.2	489.2	494.0
	703	962.1	959.6	953.4	955.2	946.0	955.0
	1055	1397.1	1390.3	1384.2	1385.5	1370.0	1385.6
29.98	0	0.0	0.0	0.0	0.0	0.0	0.0
	352	478.3	477.1	478.6	479.7	470.0	476.0
	703	929.2	925.4	925.4	923.4	912.4	921.9
	1055	1354.1	1343.2	1344.8	1341.9	1322.0	1340.2

Table 4-6. The residual wavelength dependence ($\Delta(\Delta n) \times 10^5$) of the index of refraction due to rise in pressure, and the same systematized to apply at all temperatures.

T °C	p kg/cm^2	Difference of fit at 530 nm from computed Stanley data $\Delta(\Delta n) \times 10^5$				Fit combining all temperatures $\Delta(\Delta n) \times 10^5$			
		457.9 nm	488.0 nm	514.5 nm	632.8 nm	457.9 nm	488.0 nm	514.5 nm	632.8 nm
0.03	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	352	5.1	1.0	-1.4	-3.4	3.4	2.0	0.7	-5.0
	703	9.2	2.0	0.3	-8.3	6.8	4.0	1.6	-9.3
	1055	9.3	1.6	-2.0	-8.4	9.1	5.0	1.3	-14.8
15.02	0	0.0	0.0	0.0	0.0	SAME			
	352	5.9	0.9	-0.8	-4.8				
	703	7.1	4.6	0.2	-9.0				
	1055	11.5	4.7	-0.1	-15.6				
29.98	0	0.0	0.0	0.0	0.0	SAME			
	352	2.3	1.1	3.7	-6.0				
	703	7.3	3.5	1.5	-9.5				
	1055	13.9	3.0	1.7	-18.2				

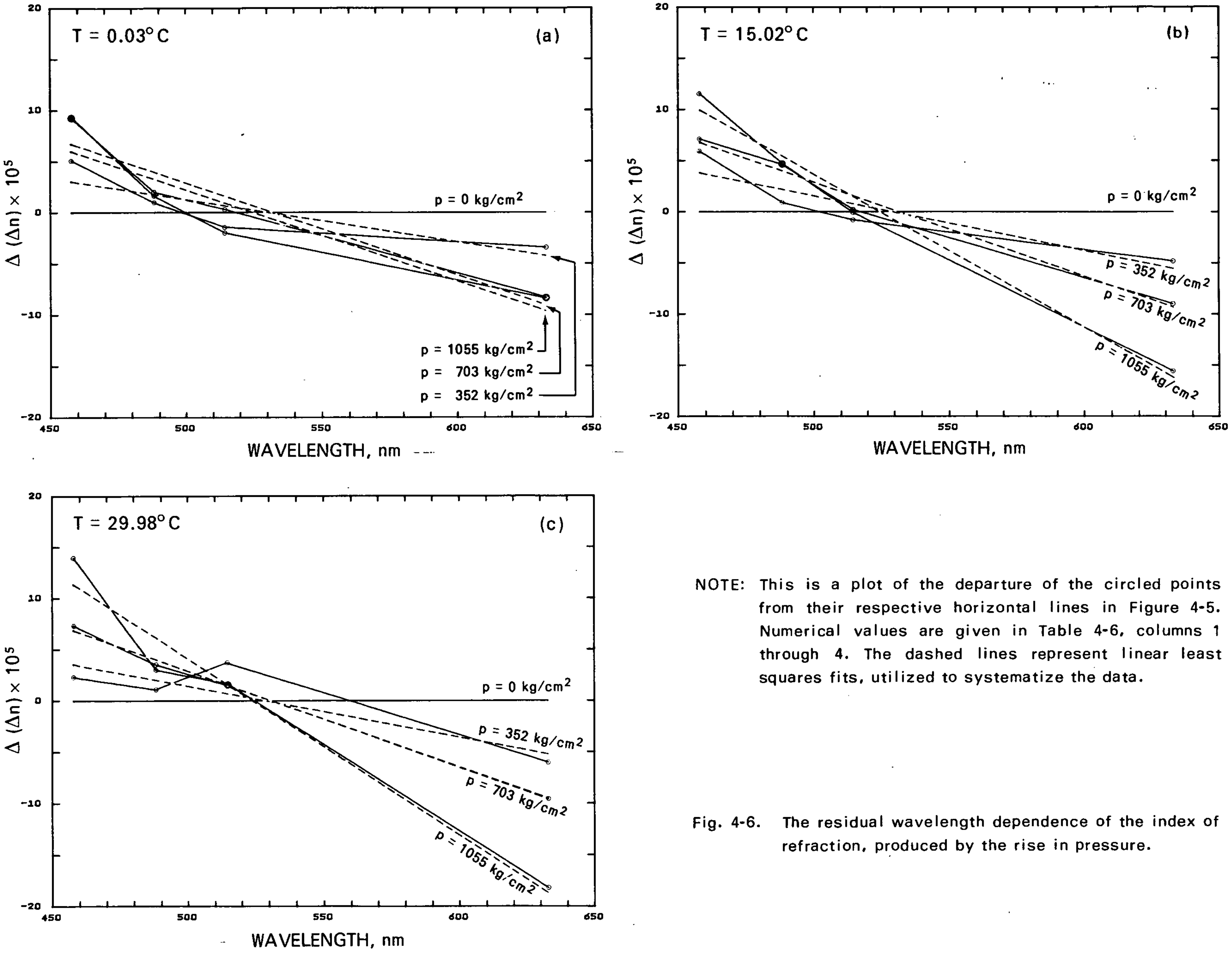
Table 4-7. Comparison of index data ($\Delta n \times 10^5$) computed from Stanley's fringe counts with the systematized values adopted to construct the index of refraction tables. Also shown are the residual differences that remain unaccounted.

T °C	p kg/cm^2	Computed Stanley data, $\Delta n \times 10^5$				Present study $\Delta n \times 10^5$				Residual differences of $\Delta n \times 10^5$			
		457.9 nm	488.0 nm	514.5 nm	632.8 nm	457.9 nm	488.0 nm	514.5 nm	632.8 nm	457.9 nm	488.0 nm	514.5 nm	632.8 nm
0.03	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	352	533.2	529.1	526.7	524.7	531.6	530.1	528.8	523.1	1.6	-1.0	-2.1	1.6
	703	1027.9	1020.7	1019.0	1010.4	1025.5	1022.7	1020.3	1009.4	2.4	-2.0	-1.3	1.0
	1055	1483.8	1476.1	1472.5	1466.1	1483.6	1479.4	1475.8	1459.6	0.2	-3.3	-3.3	6.5
15.02	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	352	499.9	494.9	493.2	489.2	497.4	496.0	494.7	489.0	2.5	-1.1	-1.5	0.2
	703	962.1	959.6	955.2	946.0	961.7	959.0	956.5	945.7	0.4	0.6	-1.3	0.3
	1055	1397.1	1390.3	1385.5	1370.0	1394.6	1390.5	1386.9	1370.7	2.5	-0.2	-1.4	-0.7
29.98	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	352	478.3	477.1	479.7	470.0	479.4	478.0	476.7	471.0	-1.1	-0.9	3.0	-1.0
	703	929.2	925.4	923.4	912.4	928.7	925.9	923.5	912.6	0.5	-0.5	-0.1	-0.2
	1055	1354.1	1343.2	1341.9	1322.0	1349.3	1345.2	1341.5	1325.4	4.8	-2.0	0.4	-3.4



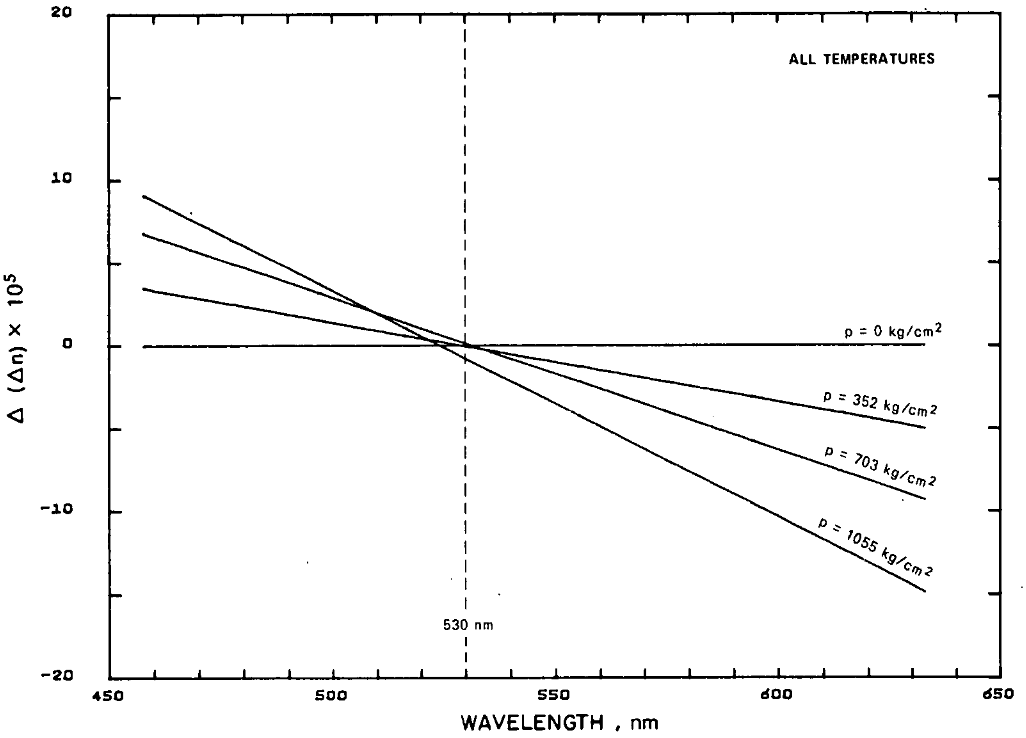
NOTE: The data are taken from Table 4-5. The circled points are for the five wavelengths, while the horizontal lines represent the values in Column 6.

Fig. 4-5. The increase in index of refraction, due to elevated pressure, over the corresponding values at atmospheric pressure. The slight non-monotonicity of Stanley's data is evident.



NOTE: This is a plot of the departure of the circled points from their respective horizontal lines in Figure 4-5. Numerical values are given in Table 4-6, columns 1 through 4. The dashed lines represent linear least squares fits, utilized to systematize the data.

Fig. 4-6. The residual wavelength dependence of the index of refraction, produced by the rise in pressure.



NOTE: This figure combines the three cases in Figure 4-6. Numerical values are given in the last 4 columns of Table 4-6. The plot demonstrates that no wavelength correction is necessary at 530 nm.

Fig. 4-7. Systematized behavior of the residual wavelength dependence of the index of refraction, produced by the rise in pressure, applicable at all temperatures.

As a result of the above work, we have constructed a new set of data to replace Stanley's, with the advantage of "smooth" functional behavior and with residual errors that are within his $\pm 6 \times 10^{-5}$ accuracy. This new data set is presented, adjacent to the corresponding Stanley data, as the center panel of Table 4-7. It contains the maximum information yielded by Stanley's original data and forms the basis of our smoothly-behaved interpolated and extrapolated index values at high pressures which are presented in Tables A-5(a) and A-5(b) of Appendix A. The linear least squares fit technique used in generating the new data set has the additional advantage of permitting linear extrapolation beyond the range of 457 to 632 nm to obtain the index of refraction values at other wavelengths with the same accuracy as that of the interpolated data.

Tables A-5(a), (b) in Appendix A were obtained using the same interpolation routine (described in Appendix B). Table A-5(a) is exact for the wavelength of 530 nm (see Figure 4-7), and only approximate for the other wavelengths, while Table A-5(b) provides corrections for the other wavelengths. Both are sequentially additive to Tables A-1 through A-4 of Appendix A to provide the temperature and wavelength dependence of the index of refraction, with respect to air, of 35‰ Copenhagen Standard Seawater at higher-than-atmospheric pressures. In order to provide the reader with a feeling of the actual values of the index of refraction of seawater at higher-than-atmospheric pressure, we have compiled Table 4-8 in which the value at atmospheric pressure has been taken from our tables, and the values at higher pressures are obtained by adding the central panel of Table 4-7.

Unfortunately no comparison with other results can be made since no other measurements for high pressures exist. Because our residual errors (Table 4-7) are below Stanley's stated accuracy, we feel confident that our Table A-5(a) and A-5(b) are at least as accurate as his $\pm 6 \times 10^{-5}$ uncertainty.

In order to extend these high-pressure data to other salinities, and permit the computation of the index of refraction of any seawater sample, we have considered some additional data as described in the following subsection.

Table 4-8. The index of refraction, as a function of wavelength, pressure, and temperature, obtained by combining data at atmospheric pressure with data representing index increments due to pressure. Salinity is 35‰.

T °C	p kg/cm²	457.9 nm	488.0 nm	514.5 nm	632.8 nm
0.03	0	1.34681	1.34504	1.34372	1.33957
	352	1.35214	1.35034	1.34901	1.34480
	703	1.35708	1.35527	1.35392	1.34966
	1055	1.36164	1.35984	1.35848	1.35416
15.02	0	1.34582	1.34407	1.34273	1.33859
	352	1.35082	1.34903	1.34768	1.34348
	703	1.35544	1.35366	1.35230	1.34805
	1055	1.35979	1.35797	1.35660	1.35230
29.98	0	1.34417	1.34240	1.34110	1.33695
	352	1.34896	1.34719	1.34587	1.34167
	703	1.35346	1.35167	1.35034	1.34608
	1055	1.35771	1.35586	1.35452	1.35021

4.4 EXTENSION OF THE HIGH PRESSURE INDEX TO OTHER SALINITIES

The preceding analysis has provided a measure of the index of refraction dependence on temperature, salinity and wavelength at atmospheric pressure only (Subsection 4.2) and of its dependence on temperature and wavelength at higher pressures, but only at 35‰ salinity (Subsection 4.3).

In order to extend this latter dependence to other salinities, we have had to assume that the dependence on salinity at high pressures is linear, a hypothesis which we already employed for the atmospheric pressure data. By linear interpolation, we may take pure water data at higher pressures along with the 35‰ high pressure data of Subsection 4.3 and obtain the index at any desired salinity under pressure.

We are aware of only three studies in which measurements of the index of refraction of pure water have been made at high pressures. Two of these studies, Rosen (1947) and Stanley (1970), have presented only limited coverage of temperature and wavelength, respectively, and cannot serve as a basis for extended tables. The third study, Waxler, Weir and Schamp (1964), has by far the best coverage of temperature, wavelength and pressure, and is the only one that will concern us here.

The ranges of the parameters are quite adequate for our purpose; namely, 8 wavelengths, 5 temperatures and 5 pressures covering 467.8 to 667.8 nm, 1.56 to 54.34°C, and 1 to 1127 bars (absolute), respectively. The two difficulties that appeared were that the pressures at which measurements were made are different for the different temperatures and that the values of the index of refraction are absolute. A reproduction of the original data is shown as Table 4-9. In order to use the data, it became necessary to preprocess them as follows. First the pressure in bars (absolute) was converted to kg/cm^2 (gage) using the relationship

$$p(\text{kg/cm}^2\text{, gage}) = [p(\text{bars abs.}) - 1] \times 1.019716 \ .$$

Table 4-9. Original data of the index of refraction of pure water as a function of pressure, temperature, and wavelength; from Waxler, Weir and Schamp (1964). Pressure in bars (absolute) and wavelength in Angstroms.

Temperature °C	Wavelength Å Pressure bars	6678.149	6438.4696	5875.618	5085.82	5015.675	4921.929	4799.92	4678.16
1.56	1	1.33220	1.33279	1.33438	1.33739	1.33772	1.33832	1.33882	1.33951
	269.5	1.33635	1.33697	1.33857	1.34161	1.34197	1.34254	1.34305	1.34374
	507.4	1.33989	1.34047	1.34212	1.34517	1.34552	1.34615	1.34663	1.34734
	768.5	1.34350	1.34415	1.34579	1.34887	1.34923	1.34985	1.35034	1.35106
	1049.7	1.34721	1.34785	1.34947	1.35255	1.35296	1.35359	1.35408	1.35479
7.64	1	1.33204	1.33263	1.33422	1.33724	1.33757	1.33803	1.33867	1.33935
	256.1	1.33586	1.33645	1.33804	1.34108	1.34139	1.34186	1.34252	1.34325
	497.8	1.33940	1.34002	1.34160	1.34466	1.34502	1.34544	1.34614	1.34688
	730.7	1.34267	1.34324	1.34494	1.34801	1.34828	1.34877	1.34944	1.35073
	1088.9	1.34698	1.34764	1.34928	1.35243	1.35273	1.35318	1.35391	1.35462
24.80	1	1.33077	1.33136	1.33293	1.33591	1.33624	1.33670	1.33734	1.33802
	259.6	1.33438	1.33490	1.33653	1.33953	1.33987	1.34030	1.34096	1.34167
	463.6	1.33714	1.33780	1.33943	1.34240	1.34278	1.34324	1.34389	1.34458
	762.8	1.34106	1.34163	1.34322	1.34630	1.34660	1.34710	1.34778	1.34846
	1108.6	1.34521	1.34581	1.34748	1.35053	1.35085	1.35133	1.35201	1.35271
34.50	1	1.32963	1.33020	1.33177	1.33474	1.33506	1.33552	1.33615	1.33683
	259.3	1.33319	1.33375	1.33531	1.33830	1.33865	1.33908	1.33974	1.34043
	480.9	1.33614	1.33679	1.33832	1.34132	1.34163	1.34213	1.34274	1.34344
	799.2	1.34007	1.34069	1.34228	1.34537	1.34567	1.34613	1.34676	1.34747
	1110.0	1.34367	1.34429	1.34589	1.34897	1.34928	1.34974	1.35042	1.35116
54.34	1	1.32655	1.32712	1.32866	1.33159	1.33191	1.33236	1.33299	1.33366
	241.6	1.32985	1.33043	1.33192	1.33490	1.33523	1.33567	1.33633	1.33698
	489.7	1.33307	1.33361	1.33518	1.33813	1.33849	1.33893	1.33960	1.34028
	785.1	1.33667	1.33725	1.33883	1.34184	1.34216	1.34258	1.34327	1.34396
	1127.7	1.34053	1.34116	1.34274	1.34577	1.34608	1.34656	1.34718	1.34791

It then became necessary to express all the data at the same values of pressure for all temperatures. This was accomplished using the interpolation technique of Appendix B, and the pressures were chosen to be close to the original, namely, 0, 250, 500, 750, 1100 kg/cm^2. Having expressed all the data on the same basis, we next converted the index data from absolute to relative-to-air by dividing with 1.000282. This factor was obtained by dividing the atmospheric pressure data with those of Tilton and Taylor (1938), since the authors did not explicitly state how they arrived at the absolute index. It may be recalled that Stanley (1971) used the factor 1.00029 for this purpose.

Since the final presentation was decided to be in the form of tables of index increments at higher pressures over the atmospheric pressure values (as also done in Subsection 4.3), we subtracted the atmospheric pressure values to obtain only increments, Δn, with pressure, temperature and wavelength, as shown in Table 4-10 where the upper panel for $P = 0$ represents the actual index of refraction values (with respect to air), and the lower panel provides the increments of index, Δn, with increasing pressure for $P = 250$, 500, 750, 1100 kg/cm^2. We subsequently proceeded to separate the effects of wavelength and temperature in order to permit a more concise final presentation.

The first step in this latter procedure was to average the Δn increments over all 8 wavelengths, as shown in the right hand column of Table 4-10, then subtract these averages from the table itself to obtain a table of "first order" residuals. These residuals were subsequently averaged over temperature, Table 4-11a, and these averages were fitted versus wavelength using linear least squares, Table 4-11b. Thus we managed to separate the data into a pressure-temperature component (last column, Table 4-10) and into a pressure-wavelength component (Table 4-11b), in exactly the same way that the Stanley data were presented in Subsection 4.3. In order to check this relatively simple procedure, which was dictated by our previous experience with the Stanley data, we used these results to reconstruct the index increments, as given in Table 4-12 and compare with Table 4-10. The difference of the two, presented in Table 4-13, obviously shows that the unaccounted-for residuals are quite small and in almost all cases are smaller than 5 units in the fifth decimal place. This compares very favorably with the authors' statement that "the standard deviation of the index values is 0.00005 which corresponds to a limit of reproducibility of ± 0.0001," and also has the advantage of smooth and monotonic behavior of the function and its first derivative, i.e., it is quite free of the random fluctuations in the fifth decimal place due to observational errors.

During the above procedure it was found necessary to modify two data values of the index of refraction, the first of which was in disagreement with Tilton and Taylor (1938) and the second modification was indicated by the general trend of the rest of the data. These values are: at $P = 0$, $\lambda = 492.2$ nm, $T = 1.56°C$ changed from 1.33832 to 1.33818 and the second at $P = 750$ kg/cm^2, $\lambda = 467.8$ nm, $T = 7.64°C$ changed from 1.35082 to 1.35002.

The results of the high pressure behavior of the index of refraction of pure water, shown as a function of temperature in the last column of Table 4-10 and as a function of wavelength in Table 4-11(b) were interpolated (and extrapolated over wavelength) using the technique in Appendix B, to generate the extended Tables A-6(a),(b) given in Appendix A. The form of these tables is similar to that of Tables A-5(a), (b), i.e., they are incremental to the atmospheric pressure values given in Tables A-1 through A-4.

Table 4-10. The pure water index of refraction at atmospheric pressure, together with the index increments produced by rising pressure.

p kg/cm^2	T °C	467.8 nm	480.0 nm	492.2 nm	501.6 nm	508.6 nm	587.6 nm	643.8 nm	667.8 nm	
P= 0.0	1.56	1.33913	1.33844	1.33780	1.33734	1.33701	1.33400	1.33241	1.33182	
	7.64	1.33897	1.33829	1.33765	1.33719	1.33686	1.33384	1.33225	1.33167	
	24.80	1.33764	1.33696	1.33632	1.33586	1.33553	1.33255	1.33099	1.33039	
	34.50	1.33645	1.33577	1.33514	1.33468	1.33436	1.33140	1.32982	1.32926	
	54.34	1.33328	1.33261	1.33198	1.33153	1.33121	1.32828	1.32675	1.32618	
P= 250.0	1.56	386.5	386.7	387.9	388.9	385.9	383.1	382.7	379.3	385.1
	7.64	374.6	369.8	367.9	367.2	369.2	367.1	367.2	367.0	368.7
	24.80	345.8	343.0	341.1	343.9	342.9	341.1	344.1	342.3	343.0
	34.50	341.7	340.8	337.8	340.9	337.8	335.9	336.9	338.0	338.7
	54.34	338.3	340.0	337.2	338.3	337.0	332.2	336.7	335.9	336.9
P= 500.0	1.56	758.8	756.9	755.8	756.2	754.1	750.4	744.6	745.6	752.8
	7.64	743.2	737.1	731.2	735.1	732.2	728.1	729.4	726.3	732.8
	24.80	694.3	693.1	691.7	691.5	687.1	686.9	680.8	673.8	687.4
	34.50	674.5	672.5	675.0	670.5	671.6	668.5	672.8	664.0	671.2
	54.34	664.0	662.9	658.9	660.0	655.9	653.9	650.8	653.9	657.6
P= 750.0	1.56	1110.4	1107.3	1106.7	1106.3	1103.6	1097.1	1091.8	1086.5	1101.2
	7.64	1075.1	1084.5	1081.6	1078.5	1084.7	1079.6	1068.4	1070.5	1077.9
	24.80	1010.8	1010.7	1007.0	1003.0	1005.5	996.2	994.1	994.9	1002.8
	34.50	986.8	984.0	985.1	983.5	985.7	975.6	975.1	968.6	980.5
	54.34	971.0	969.1	963.2	966.1	964.9	958.4	953.9	954.2	962.6
P=1100.0	1.56	1565.6	1563.8	1562.5	1561.5	1552.9	1546.2	1543.5	1539.1	1554.4
	7.64	1515.0	1512.7	1503.9	1504.9	1508.1	1495.3	1489.9	1483.2	1501.6
	24.80	1434.1	1432.3	1428.3	1425.6	1427.2	1419.5	1410.6	1410.4	1423.5
	34.50	1397.7	1392.3	1387.6	1388.0	1389.0	1377.4	1374.4	1369.4	1384.5
	54.34	1371.4	1365.9	1365.5	1364.5	1364.9	1354.9	1350.7	1345.4	1360.4

NOTE: At p = 0 the index of refraction *per se* is shown. At higher pressures, only the increase in index over that of atmospheric pressure is given. (Compare with Table 4-5.) The column on the right represents the "average" dependence of the index on temperature and pressure, i.e., for an "average wavelength" which turned out to be 540 nm. Values in body of table for pressures 250 kg/cm^2 and above are $\Delta n \times 10^5$.

Table 4-11. The residual wavelength dependence of the pure water index of refraction due to rise in pressure alone. The temperature effect has been removed. (a) Shows the values of the means of the residuals obtained from Table 4-10. (b) Shows the linear least squares fit on the values of (a) at left. Compare to Table 4-6.

(a)

	Pressure kg/cm^2				
λ nm	0.0	250.0	500.0	750.0	1100.0
467.8	0.0	2.9	6.6	5.8	11.9
480.0	0.0	1.6	4.2	6.1	8.5
492.2	0.0	-0.1	2.2	3.7	4.7
501.6	0.0	1.3	2.3	2.5	4.0
508.6	0.0	0.0	-0.2	3.9	3.5
587.6	0.0	-2.6	-2.8	-3.6	-6.2
643.8	0.0	-1.0	-4.7	-8.3	-11.0
667.8	0.0	-2.0	-7.6	-10.1	-15.4

(b)

	Pressure kg/cm^2				
λ nm	0.0	250.0	500.0	750.0	1100.0
467.8	0.0	1.5	4.4	6.2	9.3
480.0	0.0	1.2	3.7	5.2	7.8
492.2	0.0	1.0	3.0	4.2	6.3
501.6	0.0	0.8	2.5	3.4	5.2
508.6	0.0	0.7	2.1	2.9	4.3
587.6	0.0	-0.9	-2.6	-3.6	-5.4
643.8	0.0	-2.0	-5.9	-8.2	-12.3
667.8	0.0	-2.4	-7.3	-10.2	-15.3

Table 4-12. The computed smoothly varying increments of index over the corresponding values at atmospheric pressure, as a function of pressure, temperature, and wavelength.

p kg/cm^2	T °C	467.8 nm	480.0 nm	492.2 nm	501.6 nm	508.6 nm	587.6 nm	643.8 nm	667.8 nm
P= 250.0	1.56	386.6	386.4	386.1	385.9	385.8	384.3	383.2	382.7
	7.64	370.2	370.0	369.7	369.6	369.4	367.9	366.8	366.3
	24.80	344.5	344.3	344.0	343.9	343.7	342.2	341.1	340.6
	34.50	340.2	340.0	339.7	339.6	339.4	337.9	336.8	336.3
	54.34	338.4	338.2	337.9	337.8	337.6	336.1	335.0	334.5
P= 500.0	1.56	757.2	756.5	755.8	755.3	754.8	750.2	746.9	745.5
	7.64	737.3	736.6	735.8	735.3	734.9	730.3	727.0	725.6
	24.80	691.8	691.1	690.4	689.9	689.5	684.8	681.5	680.1
	34.50	675.6	674.9	674.2	673.7	673.2	668.6	665.3	663.9
	54.34	662.0	661.3	660.6	660.0	659.6	655.0	651.7	650.3
P= 750.0	1.56	1107.4	1106.4	1105.4	1104.7	1104.1	1097.6	1093.0	1091.0
	7.64	1084.1	1083.1	1082.1	1081.3	1080.7	1074.3	1069.7	1067.7
	24.80	1009.0	1008.0	1007.0	1006.2	1005.6	999.2	994.6	992.6
	34.50	986.8	985.8	984.8	984.0	983.4	976.9	972.3	970.4
	54.34	968.8	967.8	966.8	966.0	965.5	959.0	954.4	952.4
P=1100.0	1.56	1563.7	1562.2	1560.7	1559.6	1558.7	1549.0	1542.1	1539.1
	7.64	1511.0	1509.5	1508.0	1506.8	1505.9	1496.2	1489.3	1486.4
	24.80	1432.8	1431.3	1429.8	1428.7	1427.8	1418.1	1411.2	1408.2
	34.50	1393.8	1392.3	1390.8	1389.6	1388.8	1379.1	1372.2	1369.2
	54.34	1369.7	1368.2	1366.7	1365.6	1364.7	1355.0	1348.1	1345.1

NOTE: This is the end result, in the analysis of the Waxler, *et al.* data. The values are directly comparable to Table 4-10. See also Table 4-7. Values in body of table are $\Delta n \times 10^5$.

Table 4-13. The final unaccounted for residuals of the index of refraction of pure water. The distribution of the numerical values essentially demonstrates the scatter of errors in the data. See also Table 4-7.

p km/cm^2	T °C	467.8	480.0	492.2	501.6	508.6	587.6	643.8	667.8
P= 250.0	1.56	0.1	-0.4	-1.7	-3.0	-0.1	1.2	0.5	3.4
	7.64	-4.4	0.1	1.8	2.4	0.3	0.8	-0.4	-0.7
	24.80	-1.3	1.2	2.9	-0.0	0.8	1.1	-3.0	-1.7
	34.50	-1.5	-0.9	1.9	-1.4	1.6	2.0	-0.2	-1.7
	54.34	0.2	-1.8	0.7	-0.5	0.6	3.9	-1.8	-1.4
P= 500.0	1.56	-1.6	-0.4	0.0	-0.9	0.8	-0.1	2.3	-0.1
	7.64	-5.9	-0.5	4.7	0.2	2.6	2.1	-2.4	-0.8
	24.80	-2.4	-2.0	-1.3	-1.6	2.3	-2.1	0.7	6.4
	34.50	1.1	2.4	-0.8	3.1	1.7	0.1	-7.5	-0.1
	54.34	-2.0	-1.6	1.7	-0.0	3.7	1.1	0.9	-3.6
P= 750.0	1.56	-2.9	-0.9	-1.3	-1.6	0.5	0.5	1.2	4.5
	7.64	9.0	-1.4	0.5	2.8	-4.0	-5.3	1.3	-2.8
	24.80	-1.8	-2.7	-0.0	3.2	0.2	3.0	0.5	-2.3
	34.50	-0.0	1.8	-0.3	0.5	-2.3	1.3	-2.8	1.8
	54.34	-2.2	-1.3	3.6	-0.0	0.5	0.6	0.5	-1.7
P=1100.0	1.56	-1.8	-1.6	-1.8	-2.0	5.8	2.8	-1.4	-0.0
	7.64	-4.0	-3.3	4.0	1.9	-2.2	1.0	-0.6	3.2
	24.80	-1.3	-1.0	1.5	3.1	0.6	-1.4	0.6	-2.2
	34.50	-3.9	0.0	3.2	1.7	-0.2	1.7	-2.3	-0.2
	54.34	-1.6	2.3	1.3	1.1	-0.2	0.1	-2.6	-0.3

The manner that Tables A-6(a),(b) are to be used, is to first find the index of pure water at atmospheric pressure from Tables A-1 through A-4, then add the appropriate value given in A-6(a) and then add algebraically the one in Table A-6(b).

Their use, in conjunction with Table A-5(a),(b), is to provide, by linear interpolation, the index of refraction at any desired salinity, any high pressure, and for any given temperature and wavelength, since the appropriate information exists for S = 35‰ and S = 0‰.

As a check on the accuracy of our pure water high-pressure data we may also briefly compare with Rosen (1947) and Stanley (1970). We have computed from our tables the index appropriate to the values of the parameters that these authors employed and the comparisons are shown in Table 4-14. It was necessary to convert the pressures of Rosen from absolute atmospheres to kg/cm^2 gage using p(kg/cm^2, gage) = p (atm., abs) − 1)/ 0.967842 and also to convert the Stanley data to index referred to air rather than vacuum vacuum by dividing by 1.000292, before performing the comparisons.

Due to the generally lower accuracies of the higher-pressure data the comparison is only valid to one or two units in the fourth decimal place. More specifically Waxler *et al.* whose data we used to construct our tables, state an uncertainty of ± 0.0001, while Stanley states a total experimental error of ±0.00006. In the case of Rosen no specific mention of error was made but there is a statement implying

Table 4-14. Comparison of Rosen (1947) and Stanley (1970) data, for pure water, with interpolated values of present study.

(a) Comparison with Rosen (1947). Pure water at T = 25°C. Discrepancies Δn x 10^4 show no trend.

	λ = 406 nm			λ = 436 nm			λ = 546 nm			λ = 579 nm		
p kg/cm^2	Rosen	Present Study	Δn	Rosen	Present Study	Δn	Rosen	Present Study	Δn	Rosen	Present Study	Δn
0.0	1.3422	1.34212	0.8	1.3398	1.33969	1.1	1.3340	1.33398	0.2	1.3330	1.33282	1.8
515.6	1.3496	1.34928	3.2	1.3472	1.34683	3.7	1.3413	1.34106	2.4	1.3401	1.33988	1.3
1032.2	1.3558	1.35571	0.9	1.3531	1.35324	-1.4	1.3474	1.34741	-0.1	1.3462	1.34621	-0.1

(b) Comparison with Stanley (1970). Pure water for λ = 632.8 nm. Discrepancies Δn x 10^4 increase with increasing pressure.

	T = 1.03°C			T = 5.03°C			T = 10.02°C			T = 15.01°C		
p kg/cm^2	Stanley	Present Study	Δ n	Stanley	Present Study	Δn	Stanley	Present Study	Δn	Stanley	Present Study	Δn
0	1.33270	1.33270	0.0	1.33263	1.33263	0.0	1.33244	1.33244	0.0	1.33213	1.33215	-0.2
352	1.33829	1.33806	1.3	1.33805	1.33785	2.0	1.33772	1.33753	1.9	1.33723	1.33712	1.1
703	1.34341	1.34302	3.9	1.34294	1.34281	1.3	1.34260	1.34243	1.7	1.34201	1.34193	0.8
1055	1.34811	1.34763	4.8	1.34772	1.34721	5.1	1.34716	1.34672	4.4	1.34655	1.34619	3.6

	T = 20.01°C			T = 24.98°C			T = 29.98°C		
p kg/cm^2	Stanley	Present Study	Δn	Stanley	Present Study	Δn	Stanley	Present Study	Δn
0	1.33173	1.33175	-0.2	1.33126	1.33127	-0.1	1.33070	1.33071	-0.1
352	1.33680	1.33663	1.7	1.33625	1.33607	1.8	1.33564	1.33546	1.8
703	1.34151	1.34132	1.9	1.34085	1.34065	2.0	1.34021	1.33996	2.5
1055	1.34590	1.34619	3.4	1.34516	1.34487	2.9	1.34447	1.34411	3.6

that the errors are approximately 0.0001. Thus agreement within two units in the fourth place, i.e., the combined error ranges, may be considered good. In Table 4-14 the comparisons of our tables with Stanley and Rosen are shown, to the fourth decimal place, following the authors' level of accuracy. From Table 4-14(b) it is evident that the discrepancies with Stanley's data grow with increasing pressure, whereas they essentially vanish at atmospheric pressure since in both studies the Tilton and Taylor data were used. Thus Stanley's data suggest that the index of refraction may be greater than we have taken it to be. In Table 4-14(a) a comparison with Rosen's data is presented. Here again there is disagreement, but no trend in the discrepancies is evident.

Whatever the case may be, the above comparisons only serve to illustrate what was stated previously, namely, that the pure water high-pressure index data are of a lesser quality than the data examined in Subsections 4.2 and 4.3. For the sake of offering a numerical error estimate, we suggest that the Tables A-6(a),(b) we have constructed in Appendix A have errors of ± 0.0001 up to mid-pressures and perhaps ± 0.0002 at the highest pressures.

Of course the purpose of this subsection was not so much to offer accurate values of the pure water index of refraction *per se,* as to make possible the computation at various salinities through linear interpolation, in conjunction with Stanley's data for $S = 35‰$ presented in Subsection 4.3. For this purpose, it is felt that the data presented here should be satisfactory to the engineering user. The main advantage of our numerical values lies in the smooth functional behavior, which we have secured through our method of analysis.

4.5 COMMENTS

As a summary to our work, it is now possible, using the material presented in Subsections 4.2, 4.3, and 4.4, to completely traverse the index of refraction of seawater surface, even at high pressures. The accuracy with which this can be done is at the mercy of the assumption of linear dependence on salinity at all pressures. This linearity is quite well supported at atmospheric pressure by several authors although some questions still remain as will be mentioned in Section 5 when the data of Rusby and of Mehu and Johannin-Gilles are discussed. We have chosen to carry this linearity further and apply it to higher pressures although we cannot support this with any experimental evidence; this portion of our work therefore must be viewed as an approximation awaiting confirmation. It was only undertaken to provide the final link in completely covering the index of refraction dependence on its four parameters and we feel that this is preferable to not presenting it at all.

The general method that is to be employed in finding the index of refraction at any given wavelength, temperature, pressure, and salinity is to first use Tables A-1 through A-4 in Appendix A to determine the index at atmospheric pressure for salinities $S = 0‰$ and $S = 35‰$. Then proceed to Tables A-5(a),(b), and A-6(a),(b) to include the pressure effect at these two salinities and finally interpolate linearly between the values at the two salinities to arrive at the desired index of refraction.

5. COMPARISONS WITH PREVIOUSLY PUBLISHED DATA

In this section we will use our interpolation procedure to produce values of the index of refraction of seawater for the particular values of the independent variables – salinity, temperature, and wavelength – at which other investigators have made their measurements. This affords the possibility of comparison with their results and an additional indication of the accuracy of the index values we are presenting. It is also an opportunity to compile the results of these investigators work within a single publication.

At the outset, it may be recalled that very little work has been done on the dependence of the index of refraction on pressure. The works of Stanley (1971) and Waxler, Weir and Schamp (1964) have adequately fulfilled this need and have been exhaustively dealt with in Subsections 4.3 and 4.4. All the comparisons that will be presented here, will therefore be restricted to measurements at atmospheric pressure only, but for the various values of temperature, salinity and wavelength as indicated in each case.

Most investigators have made measurements only over restricted ranges of the variables, thus each comparison will be valid only for those ranges. We hope to show, however, that our results as presented in Appendix A appear to be accurate to a few units in the fifth decimal place and have the advantage of providing complete coverage of the ranges of the variables, as opposed to what may be obtained from the results of any single investigator.

It is quite difficult, if not impossible, to compare our results with the old studies conducted before about 1930, because the seawater samples that were measured were often characterized by their specific gravity and temperature, rather than salinity and temperature. In principle, it is possible to derive the salinity from the specific gravity and then compare with our results; but due to the problems of changes in the definition of salinity and of its relationship to specific gravity, as mentioned in Section 3, it is not obvious that such comparisons are actually valid. Among the older investigators, only Tornoe (1900) and Krummel (1907) gave values of the salinity of their samples, but it is believed that their "salinity," measured gravimetrically, differs somewhat (see Section 3) from the salinity as now used. Thus, comparisons with the older measurements must be viewed with caution.

We will first present comparisons with those index measurements which are specified by the actual salinity (or chlorinity) and temperature of the samples. Following this, we will provide comparisons with data from those studies that provide the specific gravity and temperature of the seawater samples from which we will derive the salinity at which the measurements were made.

To facilitate comparison of data, we have presented the index values of each investigator, then our own values, and next to these the difference between the two, in the fifth decimal place. Positive differences indicate that the particular investigator's values are high, and negative differences indicate that they are low. With our values used as a reference this systematic presentation permits the direct comparison of the values of one investigator with those of another.

As explained in the literature review in Section 2, there exists only a small number of investigations of the index of refraction which can be used here. We will discuss these at this time, not necessarily in chronological order. We will specifically compare our interpolated results with those of Tornoe (1900), Krummel (1907), Utterback, Thompson and Thomas (1934), Miyake (1939), Rusby (1967), Mehu and Johannin-Gilles (1968), Bein, Hirsekorn and Moller (1935), and Vaurabourg (1921a). All of these studies present the value of the index of refraction (with respect to air), except for Rusby who presented the difference in index from 35‰ Copenhagen Standard Seawater (refractive index anomaly), also with respect to air.

The data of Utterback, *et al.*, (see Section 2), were originally in terms of chlorinity and have been converted to salinity using the relation given in Section 3. These are shown in parentheses in Table 5-1, together with values interpolated from our tables at Utterback's salinities and temperatures for the wavelength $\lambda = 589.3$ nm. The numbers to the right of the index values show their difference in the fifth decimal place. The only observable trend is in that larger differences occur at 0°C. If it is recalled that at each temperature our values are *a priori* linear (see Figure 4-1), then Utterback's data either suggest very slight deviations from linearity or are contaminated by errors. Whichever the case may be, it is encouraging to observe that the maximum difference of 6×10^{-5} in index is within the combined error margins, which are 3×10^{-5} for both our results and for Utterback's.

Comparison with Miyake's results (see Section 2) is shown in Table 5-2, where we have used the same relation for the chlorinity to salinity conversion, as with the data of Utterback. These measurements were made at 25°C with Sodium D-light (589.3 nm). The column showing the differences suggests that Miyake's data are quite erratic considering that our data are exactly linear. In our view, Miyake's real contribution was in demonstrating the additivity of refractivities of the major ionic constituents of seawater in producing the rise in index over that of pure water (see Table 3-1).

Table 5-1. Comparison of Utterback, *et al.* (1934) data with interpolated values of present study.

		0 °C		5 °C		10 °C		15 °C		20 °C		25 °C	
Cℓ (‰)	S (‰)	n	Δn x 10^5	n	Δn x 10^5	n	Δn x 10^5	n	Δn x 10^5	n	Δn x 10^5	n	Δn x 10^5
1.477	2.667	1.33448 (1.33453)	5.	1.33439 (1.33442)	3.	1.33419 (1.33422)	3.	1.33388 (1.33388)	0.	1.33347 (1.33350)	3.	1.33298 (1.33299)	1.
3.084	5.569	1.33505 (1.33509)	4.	1.33495 (1.33499)	4.	1.33474 (1.33477)	3.	1.33442 (1.33441)	-1.	1.33400 (1.33404)	4.	1.33351 (1.33350)	-1.
5.147	9.294	1.33578 (1.33584)	6.	1.33567 (1.33570)	3.	1.33544 (1.33547)	3.	1.33511 (1.33514)	3.	1.33468 (1.33470)	2.	1.33418 (1.33421)	3.
7.559	13.650	1.33664 (1.33670)	6.	1.33651 (1.33654)	3.	1.33626 (1.33628)	2.	1.33591 (1.33595)	4.	1.33548 (1.33554)	6.	1.33497 (1.33500)	3.
9.075	16.387	1.33718 (1.33723)	5.	1.33704 (1.33706)	2.	1.33678 (1.33681)	3.	1.33642 (1.33643)	1.	1.33598 (1.33601)	3.	1.33546 (1.33546)	-0.
10.476	18.917	1.33768 (1.33774)	6.	1.33752 (1.33754)	2.	1.33726 (1.33729)	3.	1.33689 (1.33692)	3.	1.33644 (1.33647)	3.	1.33592 (1.33595)	3.
12.063	21.783	1.33824 (1.33829)	5.	1.33808 (1.33809)	1.	1.33780 (1.33782)	2.	1.33742 (1.33745)	3.	1.33696 (1.33700)	4.	1.33644 (1.33648)	4.
14.006	25.291	1.33893 (1.33897)	4.	1.33875 (1.33877)	2.	1.33846 (1.33849)	3.	1.33807 (1.33810)	3.	1.33760 (1.33763)	3.	1.33707 (1.33711)	4.
15.226	27.494	1.33936 (1.33941)	5.	1.33918 (1.33918)	0.	1.33888 (1.33888)	0.	1.33848 (1.33847)	-1.	1.33801 (1.33803)	2.	1.33747 (1.33750)	3.
16.750	30.246	1.33990 (1.33994)	4.	1.33971 (1.33971)	0.	1.33940 (1.33940)	0.	1.33899 (1.33901)	2.	1.33851 (1.33855)	4.	1.33797 (1.33801)	4.
18.998	34.305	1.34070 (1.34075)	5.	1.34049 (1.34047)	-2.	1.34017 (1.34017)	0.	1.33974 (1.33977)	3.	1.33925 (1.33927)	2.	1.33870 (1.33874)	4.
19.227	34.719	1.34078 (1.34082)	4.	1.34057 (1.34056)	-1.	1.34025 (1.34025)	0.	1.33982 (1.33985)	3.	1.33933 (1.33935)	2.	1.33878 (1.33881)	3.
21.381	38.608	1.34155 (1.34158)	3.	1.34132 (1.34131)	-1.	1.34098 (1.34098)	0.	1.34054 (1.34055)	1.	1.34004 (1.34006)	2.	1.33948 (1.33949)	1.

NOTE: Utterback, *et al.* data in parentheses. Column under Δn shows the difference Δn × 10^5.
λ = 589.3 nm, p = 0 (atmospheric).

Table 5-2. Comparison of Miyake (1939) data with interpolated values of present study.

		T = 25 °C	
Cℓ (‰)	S (‰)	n	Δn x 10^5
0.0	0.0	1.33250 (1.33250)	0.
1.900	3.431	1.33312 (1.33303)	-9.
3.790	6.844	1.33374 (1.33369)	-5.
5.660	10.220	1.33435 (1.33437)	2.
7.530	13.597	1.33496 (1.33498)	2.
9.370	16.920	1.33556 (1.33559)	3.
11.230	20.278	1.33617 (1.33629)	12.
13.070	23.601	1.33677 (1.33681)	4.
14.800	26.725	1.33733 (1.33742)	9.
16.730	30.210	1.33796 (1.33812)	16.
18.540	33.478	1.33855 (1.33863)	8.

NOTE: Miyake data in parentheses. Last column shows the difference Δn × 10^5.
λ = 589.3 nm, p = 0 (atmospheric).

A comparison of another kind may be made with Rusby's data (see Section 2). His measurements represent the difference in index between a seawater sample and 35‰ Copenhagen Standard Seawater (refractive index anomaly) and are accurate to the seventh decimal place (4 x 10^{-7}). These data are the most accurate, as well as the most precise ever taken for seawater. Whereas our data are accurate to only the fifth decimal place, a useful comparison can, nevertheless, be made. Tables 5-3(a) and 5-3(b) compare these data in two groups, i.e., for two different salinity series. The column labeled "Present Study" contains data, derived through interpolation of our tables, and provides the difference in index from that at 35‰ salinity. This column is presented with sixth-decimal-place precision, even though the accuracy is only to the fifth decimal place (3 x 10^{-5}), in order to show the surprisingly small differences that were found. In all cases, between salinities of 33 and 38‰ the errors are below 1 x 10^{-5}; an amazing agreement of values whose accuracy differs by two orders of magnitude. Note that an index difference of 1 x 10^{-5} corresponds to about 0.05‰ in salinity.

This comparison with Rusby's very accurate data, even though at only one wavelength and at a restricted range of temperatures and salinities, provides an assuring confirmation of the index increments as determined by our procedure using the data base of Mehu and Johannin-Gilles.

There are two points to be clarified here: First, in Table 5-3(a) at salinities below 33‰, our values and Rusby's differ by more than one unit in the fifth decimal place. Rusby has stated that for salinities below 35‰ the standard deviation of his measurements was larger than above that value, but this cannot account for the entire difference. If the difference is real, it would appear that the index behaves in a slightly nonlinear manner for salinities below 33‰, which in one sense may justify M-G's data (see Figure 4-1) which show a drop in index at around 26‰ salinity. This drop, however, recovers at lower

Table 5-3. Comparison of Rusby (1967) refractive index anomaly data with interpolated values of present study.

(a) λ = 546.1 nm, p = 0 (atmospheric), T = 20°C

	20.00°C						
S ‰	Present Study x 10^5	Rusby x 10^5	Difference Δn x 10^5	S ‰	Present Study x 10^5	Rusby x 10^5	Difference Δn x 10^5
30.867	-76.3	-80.21	-3.9	35.000	0.0	0.0	-0.0
31.299	-68.4	-71.62	-3.2	35.053	0.9	1.11	0.3
31.634	-62.2	-64.88	-2.7	35.148	2.6	2.87	0.3
32.324	-49.5	-51.48	-2.0	35.335	6.1	6.27	0.2
32.447	-47.3	-48.76	-1.5	35.392	7.2	7.42	0.3
32.787	-41.1	-42.35	-1.2	35.495	9.1	9.26	0.2
32.984	-37.4	-38.29	-0.9	35.573	10.5	10.72	0.2
33.133	-34.7	-35.43	-0.7	35.708	13.0	13.26	0.3
33.222	-33.0	-33.85	-0.9	35.854	15.7	15.90	0.2
33.389	-29.9	-30.78	-0.8	36.010	18.6	18.84	0.2
33.579	-26.4	-27.14	-0.7	36.128	20.7	21.00	0.3
33.843	-21.5	-21.86	-0.4	36.401	25.8	26.01	0.2
34.010	-18.5	-18.83	-0.3	36.870	34.4	34.66	0.2
34.056	-17.6	-17.80	-0.2	37.073	38.2	38.26	0.0
34.257	-13.9	-14.08	-0.2	37.170	39.9	40.21	0.3
34.427	-10.7	-10.90	-0.2	37.571	47.4	47.10	-0.3
34.683	-6.0	-5.79	0.2	38.152	58.1	57.59	-0.5
34.900	-2.0	-1.74	0.3	38.582	66.0	65.34	-0.7
34.976	-0.5	-0.31	0.2	38.770	69.5	68.75	-0.8

Table 5-3 cont.

(b) $\lambda = 546.1$ nm, p = 0 (atmospheric), T = 17.3, 20.1, 25.3, 30.1 °C.
This is a different series of salinities than those of Table 5-3a.
Blanks indicate no entries.

	17.30°C			20.10°C			25.30°C			30.10°C		
S ‰	Present Study x 10^5	Rusby x 10^6	Difference $\Delta n \times 10^5$	Present Study x 10^5	Rusby x 10^6	Difference $\Delta n \times 10^5$	Present Study x 10^5	Rusby x 10^6	Difference $\Delta n \times 10^5$	Present Study x 10^5	Rusby x 10^5	Difference $\Delta n \times 10^5$
33.827	-22.0	-21.94	0.1	-21.6	-21.78	-0.1	-21.5	-21.61	-0.2	-21.4	-21.48	-0.1
34.082	-17.3	-17.22	0.0	-17.1	-17.07	0.0	-16.9	-16.92	-0.0	-16.8	-16.73	0.1
34.242	-14.2	-14.27	-0.1	-14.0	-14.17	-0.2	-13.8	-14.03	-0.2	-13.7	-13.81	-0.1
34.254	-14.1	-13.97	0.1	-13.7	-13.77	-0.0	-13.6	-13.70	-0.1	-13.5	-13.60	-0.1
34.747	-4.8	-4.82	-0.1	-4.8	-4.77	-0.0	-4.7	-4.71	-0.0	-4.7		
35.000	0.0	0.0	-0.0	0.0	0.0	-0.0	0.0	0.0	-0.0	0.0	0.0	-0.0
35.685	12.6	12.64	0.1	12.7	12.62	-0.1	12.4	12.48	0.1	12.7	12.37	-0.3
35.898	16.6	16.58	-0.0	16.7	16.58	-0.1	16.3	16.37	0.1	16.5	16.23	-0.3
36.179	21.6	21.78	0.1	21.7	21.74	-0.0	21.6	0.0		21.7		
36.451	26.9	27.05	0.2	26.8	26.81	0.0	26.5	26.53	0.0	26.5	26.36	-0.2
36.658	30.6	30.70	0.1	30.5	30.62	0.1	30.3	30.24	-0.1	30.2	30.01	-0.2
36.857	34.3	34.47	0.1	34.2	34.38	0.1	34.0	34.01	-0.0	34.0		
36.889	34.9	35.11	0.2	34.8	34.90	0.1	34.5	34.68	0.2	34.4	34.25	-0.2

salinities as is seen in the same figure. It should be recalled here that we have ignored this behavior in building our tables. The second point is that in Table 5-3(b) at S = 36.857‰ and T = 25.30°C, Rusby showed that $\Delta n = 43.01 \times 10^{-5}$, which was obviously a typographical error as can be readily seen from the data trends. We have corrected this value to 34.01×10^{-5}.

Table 5-4 presents a comparison of Krummel's data (see Section 2) with our values (taken directly from Table A-3(h) in Appendix A), where the difference between the values is observed to change almost linearly. Any number of reasons could be proposed for this type of disagreement; however, it does not appear to be a temperature effect. For pure water (S = 0‰), Tilton and Taylor give a value of 1.3331584, as compared with Krummel's value determined many years earlier.

Table 5-4. Comparison of Krummel (1907) data with interpolated values of present study.

S ‰	Present Study	Krummel	$\Delta n \times 10^5$
0	1.33316	1.33308	-8
5	1.33408	1.33405	-3
10	1.33499	1.33502	3
15	1.33591	1.33598	7
20	1.33683	1.33694	11
25	1.33774	1.33790	16
30	1.33866	1.33885	19
35	1.33958	1.33981	23
40	1.34050	1.34077	27

NOTE: $\lambda = 589.3$ nm, p = 0 (atmospheric), T = 18°C.

In Subsection 4.2 where the data of Mehu and Johannin-Gilles (see also Section 2) were presented (Table 4-1), it was stated that we eliminated their values at three chlorinities to obtain the data in Table 4-2 from which the tables in Appendix A were constructed. These data are compared with ours in Table 5-5, where the M-G data are shown in parentheses. We did not include the chlorinities 0 and 19.373‰

Table 5-5. Comparison of previously ignored Mehu and Johannin-Gilles (1968) data with interpolated values of present study.

			1 °C		5 °C		10 °C		15 °C		20 °C		25 °C		30 °C	
λ nm	Cℓ (‰)	S (‰)	n	Δn	n	Δn	n	Δn	n	Δn	n	Δn	n	Δn	n	Δn
404.7	4.887	8.829	1.34556 (1.34563)	7.	1.34545 (1.34552)	6.	1.34522 (1.34528)	6.	1.34488 (1.34493)	5.	1.34444 (1.34448)	4.	1.34393 (1.34395)	2.	1.34333 (1.34335)	2.
	9.603	17.348	1.34731 (1.34722)	-9.	1.34717 (1.34710)	-7.	1.34691 (1.34685)	-6.	1.34654 (1.34650)	-4.	1.34609 (1.34607)	-2.	1.34556 (1.34556)	0.	1.34495 (1.34497)	2.
	14.589	26.354	1.34915 (1.34903)	-12.	1.34898 (1.34887)	-11.	1.34869 (1.34856)	-13.	1.34830 (1.34814)	-16.	1.34783 (1.34763)	-20.	1.34728 (1.34706)	-22.	1.34666 (1.34643)	-23.
435.8	4.887	8.829	1.34300 (1.34306)	6.	1.34290 (1.34295)	5.	1.34266 (1.34271)	5.	1.34232 (1.34236)	4.	1.34189 (1.34192)	3.	1.34137 (1.34139)	2.	1.34078 (1.34078)	-0.
	9.603	17.348	1.34473 (1.34465)	-8.	1.34459 (1.34454)	-5.	1.34433 (1.34428)	-5.	1.34396 (1.34392)	-4.	1.34351 (1.34349)	-2.	1.34298 (1.34298)	-0.	1.34238 (1.34239)	1.
	14.589	26.354	1.34655 (1.34643)	-12.	1.34639 (1.34626)	-13.	1.34609 (1.34595)	-14.	1.34569 (1.34553)	-16.	1.34523 (1.34504)	-19.	1.34468 (1.34447)	-22.	1.34407 (1.34385)	-22.
467.8	4.887	8.829	1.34090 (1.34096)	6.	1.34080 (1.34085)	5.	1.34057 (1.34061)	4.	1.34022 (1.34026)	4.	1.33979 (1.33982)	3.	1.33928 (1.33930)	2.	1.33870 (1.33869)	-1.
	9.603	17.348	1.34261 (1.34254)	-7.	1.34248 (1.34244)	-4.	1.34221 (1.34217)	-4.	1.34184 (1.34180)	-4.	1.34139 (1.34136)	-3.	1.34087 (1.34085)	-2.	1.34028 (1.34027)	-1.
	14.589	26.354	1.34441 (1.34429)	-12.	1.34425 (1.34412)	-13.	1.34396 (1.34381)	-15.	1.34355 (1.34339)	-16.	1.34308 (1.34291)	-17.	1.34255 (1.34235)	-20.	1.34195 (1.34173)	-22.
480.0	4.887	8.829	1.34020 (1.34026)	6.	1.34010 (1.34015)	5.	1.33987 (1.33991)	4.	1.33953 (1.33957)	4.	1.33910 (1.33913)	3.	1.33859 (1.33860)	1.	1.33801 (1.33800)	-1.
	9.603	17.348	1.34191 (1.34185)	-6.	1.34178 (1.34173)	-5.	1.34151 (1.34147)	-4.	1.34115 (1.34111)	-4.	1.34070 (1.34067)	-3.	1.34017 (1.34016)	-1.	1.33958 (1.33958)	-0.
	14.589	26.354	1.34371 (1.34359)	-12.	1.34355 (1.34341)	-14.	1.34325 (1.34310)	-15.	1.34286 (1.34270)	-16.	1.34239 (1.34221)	-18.	1.34184 (1.34165)	-19.	1.34124 (1.34104)	-20.
508.5	4.887	8.829	1.33876 (1.33881)	5.	1.33866 (1.33871)	5.	1.33843 (1.33847)	4.	1.33810 (1.33814)	4.	1.33767 (1.33770)	3.	1.33716 (1.33718)	2.	1.33658 (1.33659)	1.
	9.603	17.348	1.34046 (1.34041)	-5.	1.34033 (1.34029)	-4.	1.34006 (1.34002)	-4.	1.33970 (1.33966)	-4.	1.33925 (1.33922)	-3.	1.33874 (1.33872)	-2.	1.33814 (1.33814)	-0.
	14.589	26.354	1.34225 (1.34212)	-13.	1.34209 (1.34195)	-14.	1.34178 (1.34163)	-15.	1.34139 (1.34124)	-15.	1.34092 (1.34075)	-17.	1.34039 (1.34020)	-19.	1.33979 (1.33959)	-20.
546.1	4.887	8.829	1.33718 (1.33723)	5.	1.33708 (1.33712)	4.	1.33685 (1.33690)	5.	1.33651 (1.33655)	4.	1.33609 (1.33612)	3.	1.33559 (1.33561)	2.	1.33501 (1.33502)	1.
	9.603	17.348	1.33886 (1.33884)	-2.	1.33873 (1.33871)	-2.	1.33847 (1.33844)	-3.	1.33810 (1.33807)	-3.	1.33767 (1.33764)	-3.	1.33714 (1.33714)	-1.	1.33656 (1.33656)	-0.
	14.589	26.354	1.34064 (1.34052)	-12.	1.34047 (1.34034)	-13.	1.34018 (1.34004)	-14.	1.33979 (1.33962)	-17.	1.33932 (1.33915)	-17.	1.33879 (1.33861)	-18.	1.33820 (1.33800)	-20.
577.0	4.887	8.829	1.33608 (1.33612)	4.	1.33598 (1.33603)	5.	1.33575 (1.33579)	4.	1.33542 (1.33545)	3.	1.33499 (1.33502)	2.	1.33449 (1.33451)	2.	1.33392 (1.33393)	1.
	9.603	17.348	1.33775 (1.33773)	-2.	1.33763 (1.33762)	-1.	1.33736 (1.33734)	-2.	1.33700 (1.33698)	-2.	1.33655 (1.33653)	-2.	1.33603 (1.33602)	-1.	1.33546 (1.33547)	1.
	14.589	26.354	1.33952 (1.33939)	-13.	1.33937 (1.33922)	-15.	1.33906 (1.33891)	-15.	1.33867 (1.33850)	-17.	1.33820 (1.33803)	-17.	1.33767 (1.33749)	-18.	1.33709 (1.33689)	-20.
579.1	4.887	8.829	1.33601 (1.33605)	4.	1.33591 (1.33596)	5.	1.33569 (1.33573)	4.	1.33535 (1.33538)	3.	1.33492 (1.33495)	3.	1.33442 (1.33444)	2.	1.33385 (1.33386)	1.
	9.603	17.348	1.33768 (1.33766)	-2.	1.33756 (1.33755)	-1.	1.33730 (1.33728)	-2.	1.33693 (1.33691)	-2.	1.33648 (1.33646)	-3.	1.33597 (1.33595)	-2.	1.33539 (1.33540)	1.
	14.589	26.354	1.33945 (1.33932)	-13.	1.33930 (1.33915)	-15.	1.33900 (1.33885)	-15.	1.33860 (1.33843)	-17.	1.33813 (1.33796)	-18.	1.33760 (1.33742)	-18.	1.33702 (1.33682)	-20.
589.3	4.887	8.829	1.33568 (1.33573)	5.	1.33558 (1.33563)	5.	1.33536 (1.33540)	4.	1.33502 (1.33506)	4.	1.33460 (1.33463)	3.	1.33409 (1.33412)	3.	1.33353 (1.33354)	1.
	9.603	17.348	1.33735 (1.33734)	-1.	1.33722 (1.33722)	-0.	1.33696 (1.33695)	-1.	1.33660 (1.33658)	-2.	1.33615 (1.33614)	-2.	1.33564 (1.33563)	-1.	1.33506 (1.33507)	1.
	14.589	26.354	1.33911 (1.33899)	-12.	1.33896 (1.33881)	-15.	1.33866 (1.33851)	-15.	1.33827 (1.33810)	-17.	1.33780 (1.33763)	-17.	1.33726 (1.33709)	-17.	1.33668 (1.33649)	-19.
643.8	4.887	8.829	1.33413 (1.33419)	6.	1.33403 (1.33408)	5.	1.33380 (1.33385)	5.	1.33348 (1.33352)	4.	1.33306 (1.33309)	3.	1.33256 (1.33259)	3.	1.33199 (1.33201)	2.
	9.603	17.348	1.33579 (1.33580)	1.	1.33566 (1.33566)	-0.	1.33540 (1.33540)	-0.	1.33505 (1.33504)	-1.	1.33461 (1.33459)	-2.	1.33409 (1.33409)	0.	1.33351 (1.33352)	1.
	14.589	26.354	1.33755 (1.33742)	-13.	1.33739 (1.33724)	-15.	1.33709 (1.33693)	-16.	1.33671 (1.33654)	-17.	1.33624 (1.33607)	-17.	1.33571 (1.33554)	-17.	1.33511 (1.33494)	-17.

NOTE: Mehu and Johannin-Gilles data in parentheses. Column under Δn shows the difference Δn × 10^5. The systematic trends of Δn × 10^5 are evident, as also shown in Figure 4-1. $p = 0$ (atmospheric).

since our values are actually the same as theirs. The second column for each temperature contains the difference $\Delta n \times 10^5$ between our values and theirs. The striking feature of this column is the very systematic distribution of the differences according to salinity, as shown also in Figure 4-1 where our values are shown by the straight lines, and the differences $\Delta n \times 10^5$ represent the distance of the points from the lines. This systematic behavior holds at all wavelengths, with the $\Delta n \times 10^5$ discrepancies being positive at S = 8.829‰, small positive and negative at S = 17.348‰, and much more negative at S = 26.354‰. There is also a tendency for $\Delta n \times 10^5$ to decrease algebraically (i.e., not in absolute value) as the temperature increases. In our work we have assumed that the dependence of the index of refraction on salinity is linear up to 43‰, a premise that originated from the works of Utterback, *et al.*, Miyake, and even M-G themselves. One cannot, however, completely ignore the fact that the differences $\Delta n \times 10^5$ in Table 5-5 repeat themselves at all wavelengths and with the same systematic behavior, and that they are greater than the stated accuracy of "within" 3×10^{-5}. There is always the possibility that the same seawater samples were used at all wavelengths and that their chlorinity was not properly determined. If that were true, however, in Figure 4-1 the points would be equally distant from the lines, horizontally, at any particular salinity, which is not the case. The same figure shows the discrepancies to be greatest at the salinity of 26.354‰ (Cl = 14.589‰), which would indicate a nonlinear salinity dependence of index in a region around this value. In the comparison with Rusby's data, Table 5-3(a), there is an indication of this nonlinear behavior for salinities of 32.787 to 30.867‰ (considering that our values in this table are linear), but we cannot be sure this is a real trend, and Rusby's values, unfortunately, do not extend to any lower salinities. This nonlinearity certainly does not appear in Table 5-1 where the Utterback, *et al.*, data are compared, or in Table 5-2 where the Miyake data are compared.

Such considerations as these prompted us to accept *a priori* a linear salinity dependence of the index of refraction. Nevertheless, the suspicion remains that the index curves may not be linear with salinity, but the accuracy and the precision of existing measurements and/or their limited coverage do not, as yet, permit resolution of this question.

We next turn to Tornoe (1900) (see Section 2) who took his measurements using a variation of the Halwachs method. Since he was interested in obtaining salinity from the refractive properties of seawater, he presented his results in terms of the refractive angle 2α measured on his apparatus, which is related to the index of refraction of pure water n_w and seawater n_s by the formula

$$(n - 1) = \frac{\sin^2\alpha}{n_w^2 \cdot (n + 1)} \quad \text{where } n = \frac{n_s}{n_w} \tag{5.1}$$

which may be more simply written,

$$n_s = \sqrt{n_w^2 + \sin^2\alpha} \ . \tag{5.2}$$

Tornoe's work consisted in gravimetrically determining the salinities of his samples (see below), and then measuring the refractive angle 2α while varying temperature for each sample. From these data he developed two formulae, one relating the index to salinity and the other the index to specific gravity (the latter taken from Knudsen's Tables). These are

$$\log n_{17.5} = 6.14340\ S - 0.00006\ S^2 \qquad \text{at } T = 17.5°C \tag{5.3}$$

and

$$n_t - n_{17.5} = 0.216\ (\gamma_t - \gamma_{17.5}) \qquad \text{at any } T \tag{5.4}$$

where S is salinity, n_t is the ratio n_s/n_w at some temperature t and $n_{17.5}$ is the same ratio at 17.5°C, γ_t is the ratio of specific weights of seawater at temperature t to pure water at temperature t, and $\gamma_{17.5}$ the same ratio at 17.5°C. No mention is made of how these formulae were obtained; but if they were derived from his data, temperature does not appear to have been adequately covered for most of the salinities (see below). From the above formulae, Tornoe developed numerical tables providing the dependence of 2α on salinity (9.84 to 38.45‰) and temperature (6 to 22°C). To check the validity of these tables, he reversed his procedure and computed the salinities by using his original measurements of 2α and his tables. The results of his 73 comparisons indicated discrepancies between computed and measured salinities of less than 0.05‰ for 59 pairs, and up to 0.07‰ for only 4 pairs, with an average error of 0.027‰, which is very good indeed, considering the procedures available for these measurements 75 years ago.

The original determination of the salinities, done gravimetrically, was computed from the empirical relation (see Tornoe, 1895)

$$S = 1315\ (\gamma_{17.5} - 1)\ . \tag{5.5}$$

However, according to Riley and Chester (1971) (see Section 3), this gravimetric "salinity" of Tornoe and the Knudsen salinity should differ by 0.45 percent. In the comparison presented in Table 5-6, between our values and Tornoe's, his salinities were taken at face value and this adjustment was not made. We do comment, however, on what the difference would be.

As is shown in Table 5-6, at two salinities a wide temperature range is covered, but at the other salinities the temperatures bracket 17.5°C, which was the generally accepted "standard room temperature" at that time. The differences between our values and Tornoe's, expressed as $\Delta n \times 10^5$, are impressively small, with better agreement at the lower temperatures. When as an exercise, we adjusted Tornoe's salinities by the above mentioned 0.45 percent, the differences were reversed, with the agreement at the higher temperatures (above 14°C) being better than one unit in the fifth decimal place, and up to three units at the lower temperatures, which is also an acceptable result; i.e., within our 3×10^{-5} accuracy, even though Tornoe's accuracy is not specified.

Table 5-6. Comparison of Tornoe (1900) with interpolated values of present study.

(a) λ = 589.3 nm, p = 0 (atmospheric), S = 33.86 ‰

T °C	S = 33.86 ‰		
	Present Study	Tornoe	$\Delta n \times 10^5$
7.1	1.340285	1.340290	0.5
7.6	1.340254	1.340259	0.5
7.7	1.340246	1.340247	0.1
8.1	1.340219	1.340223	0.4
8.2	1.340214	1.340209	-0.5
8.6	1.340185	1.340191	0.6
8.9	1.340164	1.340168	0.4
10.9	1.340013	1.340018	0.6
11.0	1.340004	1.340012	0.8
14.0	1.339747	1.339752	0.5
14.1	1.339739	1.339756	1.7
14.3	1.339721	1.339737	1.6
14.8	1.339675	1.339699	2.4
17.4	1.339429	1.339458	2.9
17.6	1.339410	1.339440	3.1
17.7	1.339399	1.339432	3.2
17.8	1.339390	1.339433	4.3
18.1	1.339360	1.339402	4.2
18.3	1.339340	1.339379	3.9
18.7	1.339300	1.339343	4.3
21.1	1.339051	1.339086	3.4
21.3	1.339030	1.339064	3.3
21.5	1.339008	1.339040	3.1

(b) λ = 589.3 nm, p = 0 (atmospheric), S = 34.64 ‰

T °C	S = 34.64 ‰		
	Present Study	Tornoe	$\Delta n \times 10^5$
5.9	1.340508	1.340516	0.9
6.5	1.340471	1.340475	0.4
7.0	1.340442	1.340456	1.4
7.4	1.340417	1.340429	1.2
7.8	1.340389	1.340393	0.4
9.9	1.340239	1.340244	0.6
10.0	1.340231	1.340239	0.8
10.2	1.340215	1.340227	1.2
10.4	1.340199	1.340209	1.0
14.8	1.339820	1.339855	3.5
15.4	1.339764	1.339798	3.4
16.0	1.339706	1.339753	4.7
16.5	1.339660	1.339708	4.9
17.2	1.339592	1.339623	3.1
17.5	1.339561	1.339599	3.7
17.7	1.339542	1.339581	3.8
17.9	1.339522	1.339563	4.1
18.1	1.339502	1.339535	3.2
18.3	1.339482	1.339518	3.5
20.2	1.339290	1.339329	3.9
20.3	1.339278	1.339311	3.2
20.4	1.339269	1.339295	2.7
20.6	1.339248	1.339268	2.0

(c) Tornoe data in parentheses. Column under Δn shows difference $\Delta n \times 10^5$.
λ = 589.3 nm, p = 0 (atmospheric). Blanks indicate no entries.

T °C	S = 10.14 ‰		S = 20.02 ‰		S = 25.02 ‰		S = 29.97 ‰		S = 31.96 ‰		S = 33.00 ‰		S = 36.02 ‰	
	n	Δn	n	Δn	n	Δn	n	Δn	n	Δn	n	Δn	n	Δn
17.0					1.337839 (1.337865)	2.6							1.339866 (1.339890)	2.4
17.2			1.336903 (1.336920)	1.7			1.338735 (1.338761)	2.7			1.339291 (1.339327)	3.6		
17.3					1.337812 (1.337838)	2.6								
17.4	1.335069 (1.335086)	1.7					1.338716 (1.338745)	3.0	1.339083 (1.339110)	2.8	1.339272 (1.339303)	3.1	1.339827 (1.339858)	3.1
17.5					1.337793 (1.337825)	3.1	1.338705 (1.338737)	3.2						
17.6			1.336866 (1.336886)	2.0					1.339064 (1.339092)	2.9	1.339252 (1.339284)	3.2		
17.7	1.335043 (1.335062)	1.9												
17.8									1.339044 (1.339075)	3.1			1.339787 (1.339817)	3.1
17.9									1.339033 (1.339066)	3.2	1.339223 (1.339256)	3.3		
18.0													1.339767 (1.339803)	3.6

Recalling that our values are linear with salinity and observing the size of the differences $\Delta n \times 10^5$ at around 17.5°C, we do not comprehend Tornoe's reasons for developing the above nonlinear relationship, which can be rewritten as

$$n_{s_{17.5}} = n_{w_{17.5}} \, 10^{(6.14340\,S - 0.00006\,S^2)} \, . \tag{5.6}$$

We find that the above nonlinear relationship with the two empirical coefficients, and our assumed linear relationship $n_s = n_w + aS$ (at some temperature) with the one-empirical constant a, agree quite well in numerical terms. Thus we believe that the simpler linear relationship is better qualified to represent the dependence of the index of refraction on salinity. Tornoe used pure water data taken from Rosetti's Tables which appeared in Landolt-Bornstein, while we have used the more accurate Tilton and Taylor data.

It is therefore concluded that even Tornoe's data suggest the linear relationship of index and salinity within the 3 units in the fifth-decimal-place accuracy which we have claimed throughout.

We now turn to two sets of measurements of the index of refraction of seawater, which have been characterized by specific gravity and temperature, rather than salinity and temperature. These are the works of Bein, Hirsekorn, and Moller (1935) and of Vaurabourg (1921b). Bein, *et al.*, have used the parameter $\rho_{17.5}$ (see Eq. 3.9) to essentially characterize salinity, while Vaurabourg used σ_0 (see Eq. 3.8). From Knudsen's Tables, which provide the correspondence between salinity, $\rho_{17.5}$ and σ_0, we have converted directly to salinity before proceeding to compare with our values.

In the work of Bein, *et al.*, (see Section 2) measurements of the refracting angle α were first made using the Halwachs apparatus, and these were used to calibrate an interferometer which was subsequently used to measure $\rho_{17.5}$ directly. We will ignore here the "derived" interferometric data and concentrate only on the basic Halwachs method. This necessitates knowledge of the index of pure water n_w and of the refracting angle α to compute the index of seawater, through

$$n_s = \sqrt{n_w^2 + \sin^2 \alpha} \tag{5.7}$$

which was also used by Tornoe. For the comparison with our values, we have used the measured angles, α, from Bien, *et al.*, and values from Tilton and Taylor (1938) for the index of pure water n_w. In the measurements of Bein, *et al.*, 11 seawater samples were examined at different temperatures, at the four helium-lines 447.1, 501.6, 587.6, and 667.8 nm. The actual apparatus used was a very elaborate version of the Halwachs method which could measure angles to a few seconds of arc, corresponding to the sixth decimal place in index (5 seconds corresponded to approximately 3×10^{-6} in index). The comparison of the values of index of refraction of seawater as computed above with our interpolated values is shown in Table 5-7. It should be pointed out that at 667.8 nm our values are extrapolated. It is evident from this table that the observed differences are not randomly distributed, since for 29 of the 31 pairs, the values of Bein,

Table 5-7. Comparison of Bein, *et al.* data with interpolated values of present study.

			447.1 nm			501.6 nm			587.6 nm			667.8 nm		
$\rho_{17.5}$	S (‰)	T °C	Present Study	Bein *et al.*	$\Delta n \times 10^5$	Present Study	Bein *et al.*	$\Delta n \times 10^5$	Present Study	Bein *et al.*	$\Delta n \times 10^5$	Present Study	Bein *et al.*	$\Delta n \times 10^5$
23.626	30.936	16.93	1.345589			1.342412	1.342478	6.6	1.338991	1.339055	6.4	1.336761		
23.638	30.948	19.70	1.345323			1.342140	1.342209	6.9	1.338723	1.338791	6.8	1.336490		
23.651	30.972	19.76	1.345322			1.342138	1.342209	7.1	1.338720	1.338791	7.1	1.336488		
24.629	32.248	16.79	1.345852	1.345925	7.3	1.342671	1.342738	6.7	1.339248	1.339312	6.4	1.337014		
25.440	33.310	16.72	1.346062	1.346135	7.3	1.342877	1.342945	6.8	1.339449	1.339515	6.6	1.337214		
26.215	34.325	16.74	1.346252	1.346325	7.2	1.343064	1.343135	7.1	1.339636	1.339699	6.3	1.337399		
26.949	35.278	18.47	1.346269	1.346335	6.7	1.343074	1.343140	6.6	1.339643	1.339706	6.4	1.337399		
26.976	35.316	17.09	1.346409	1.346484	7.5	1.343217	1.343077	-14.0	1.339785	1.339851	6.7	1.337543	1.337831	28.8
27.806	36.396	17.76	1.346550	1.346621	7.1	1.343353	1.343425	7.2	1.339916	1.339984	6.8	1.337674	1.337749	7.5
28.869	37.788	18.37	1.346752			1.343553	1.343625	7.2	1.340112	1.340183	7.2	1.337866	1.337943	7.7
28.926	37.852	20.23	1.346575			1.343371	1.343442	7.1	1.339931	1.340001	7.1	1.337683		

NOTE: Salinities obtained from Knudsen's Tables (1901). p = 0 (atmospheric).
Blanks indicate no entries.

et al., are higher by 6 or 7 x 10^{-5} in index. Discrepancies above 10 x 10^{-5} we attribute to erroneous reporting. We recognize that the discrepancies between the index values of Bein, *et al.*, and our own are of the order of 7 x 10^{-5}, but we cannot provide an explanation – especially since Bein's data are supposed to provide sixth decimal place accuracy. It would seem that the source of these almost-constant differences lies in some systematic experimental errors, which were not accounted for by Bein, *et al.*, or by the choice of n_w.

Before proceeding, some comments are in order on the tables computed by Saint-Guilly (1954), which are based on Bein's, *et al.*, interferometric data, which we have not considered here. These were expressed as the difference in index between seawater and pure water ($n_s - n_w$) through

$$n_s - n_w = \frac{0.00024168 \cdot \rho_{17.5}}{1 \pm A_t} \tag{5.8}$$

(to be found on p. 161 in Bein's work), where A_t provides a temperature correction, and $A_t = 0$ at 20°C. According to Bein this relation holds for "white-light" or "He-yellow" (587.6 nm), but he also mentions that the compensation point for the interferometer (which employed "white light") corresponds to 559 nm, which is very confusing. What Saint-Guilly did was to take the values of n_w from Tilton and Taylor (1938) at the completely unrelated wavelength of 589.3 nm (Sodium D-lines) and add the $n_s - n_w$ of Bein, *et al.* We strongly object to this apparently arbitrary combination of data valid at different wavelengths, and we would like to caution users of Saint-Guilly's tables as to their validity.

As a final comparison with earlier work, we consider Vaurabourg's data (1921a,b). This work was undertaken in conjunction with Thoulet (1921) who was more interested in the descriptive oceanography than in the physical constants. The data presented in Vaurabourg (1921a) include the correspondence of density to index of refraction at given values of σ_0, in 5°C temperature increments at the Sodium D-lines (589.3 nm). A total of eight seawater samples were measured, plus a pure water sample. In his 1921b paper the same data are presented but interpolated to temperature increments of 1°C, and some numerical values have been changed by at least one unit in the fifth decimal place. A much greater discrepancy than found with earlier comparisons is evident in Table 5-8. Utterback, *et al.*, criticized Vaurabourg's data, which they found to be high, and attributed the discrepancies to the Fery and Zeiss refractometers which were used and which, according to Utterback, *et al.*, can only provide the index to the fourth decimal place, even though Vaurabourg presented five. Because of this, we do not consider this comparison to be valid and present it only for the sake of completeness.

Table 5-8. Comparison of Vaurabourg (1921) with interpolated values of present study.

		0 °C		5 °C		10 °C		15 °C		20 °C		25 °C		30 °C	
σ_0	S (‰)	n	Δn x 10^5	n	Δn x 10^5	n	Δn x 10^5	n	Δn x 10^5	n	Δn x 10^5	n	Δn x 10^5	n	Δn x 10^5
0	0.0	1.33395 (1.33406)	11.	1.33388 (1.33395)	7.	1.33369 (1.33374)	5.	1.33339 (1.33343)	4.	1.33299 (1.33303)	4.	1.33250 (1.33255)	5.	1.33194 (1.33200)	6.
4	5.04	1.33494 (1.33507)	13.	1.33485 (1.33494)	9.	1.33464 (1.33470)	6.	1.33432 (1.33437)	5.	1.33391 (1.33396)	5.	1.33341 (1.33347)	6.	1.33284 (1.33291)	7.
8	9.98	1.33592 (1.33604)	12.	1.33580 (1.33589)	9.	1.33557 (1.33565)	8.	1.33524 (1.33530)	6.	1.33481 (1.33488)	7.	1.33430 (1.34389)	958.	1.33373 (1.33382)	8.
12	14.94	1.33689 (1.33702)	13.	1.33676 (1.33685)	9.	1.33651 (1.33660)	9.	1.33615 (1.33624)	9.	1.33572 (1.33581)	9.	1.33520 (1.33530)	10.	1.33463 (1.33473)	10.
16	19.92	1.33787 (1.33800)	12.	1.33772 (1.33781)	9.	1.33745 (1.33753)	8.	1.33707 (1.33718)	10.	1.33662 (1.33673)	11.	1.33610 (1.33622)	12.	1.33552 (1.33564)	12.
20	23.00	1.33885 (1.33897)	12.	1.33868 (1.33877)	9.	1.33839 (1.33848)	9.	1.33800 (1.33811)	11.	1.33753 (1.33766)	13.	1.33700 (1.33713)	13.	1.33642 (1.33655)	13.
24	29.88	1.33983 (1.33995)	12.	1.33964 (1.33973)	9.	1.33933 (1.33943)	10.	1.33892 (1.33905)	13.	1.33844 (1.33858)	14.	1.33790 (1.33805)	15.	1.33731 (1.33746)	14.
28	34.85	1.34081 (1.34092)	11.	1.34060 (1.34069)	9.	1.34027 (1.34038)	11.	1.33984 (1.33999)	15.	1.33935 (1.33951)	16.	1.33880 (1.33897)	17.	1.33821 (1.33836)	15.
32	39.79	1.34178 (1.34190)	12.	1.34155 (1.34165)	10.	1.34120 (1.34133)	13.	1.34076 (1.34092)	16.	1.34025 (1.34043)	18.	1.33969 (1.33988)	19.	1.33910 (1.33927)	17.

NOTE: Vaurabourg data in parentheses. Column under Δn indicates the difference Δn × 10^5. Large discrepancies due to Vaurabourg's reduced accuracy ($\approx 1 \times 10^{-4}$). $\lambda = 589.3$ nm, p = 0 (atmospheric).

This completes the comparisons between our work and the work of previous investigators. It is difficult to determine whose measurements more accurately represent the physical quantity of the index of refraction – the Utterback, *et al.* data appear to be slightly high; Miyake and Krummel indicate lower values at low salinities and higher values at higher salinities. The agreement with the refractive index anomaly of Rusby is excellent, while comparison with M-G's discarded data raises some questions. Finally, the comparison with Bein, *et al.*, and with Vaurabourg implies their values are high.

However, our contribution through this study is the construction of a composite body of data which yields complete coverage of the index of refraction surface, is internally self-consistent, and has the physically gratifying property of smooth functional dependence on the parameters salinity, temperature, wavelength, and pressure. We believe we have retained the accuracies of the investigators whose data we have used and the above comparisons demonstrate, within their limitations, that this may very well be so.

The tables presented in Appendix A should be more than adequate for most engineering applications and can also serve as a basis for evaluating the potential of the methods that could be employed to measure salinity or specific gravity for oceanographic work.

6. REQUIREMENTS FOR THE DETERMINATION OF SALINITY AND SPECIFIC GRAVITY (DENSITY) USING THE INDEX OF REFRACTION OF SEAWATER

In this section we consider a subject that has been constantly recurring in the oceanographic literature – namely that of using the index of refraction to obtain other properties of seawater (salinity, specific gravity). This subject raises two questions, (1) whether the sought-after relationship is meaningful (i.e., single valued, with small variance, etc.) and (2) whether such a relationship can be routinely measured with sufficient accuracy to comprise an alternative to presently accepted methods of obtaining salinity and specific gravity. Specific gravity will be considered here in the form of σ_t (defined in Section 3), i.e., at atmospheric pressure.

Let it be stated at the outset that the reason specific gravity is generally employed instead of density is because specific gravity is a relative quantity* and can be measured more easily than density. As a matter of fact, the determination of the (absolute) density of seawater has not as yet been accomplished, and is a subject occupying the Joint Panel on Oceanographic Tables and Standards under the sponsorship of UNESCO.

The presently accepted, most accurate method of obtaining the **salinity** is through the conductivity ratio, i.e., the ratio of electrical conductivities between a seawater sample and Copenhagen Standard Seawater, preferably at 15°C (to suppress degassing). This method enables the determination of salinity to 0.001 ‰. Present-day routine methods need not be as precise but they must be more precise than 0.01 ‰.

In order to obtain values of **specific gravity** σ_t to an accuracy of 0.001 it is also necessary to measure temperature to an accuracy of ± 0.001°C. For routine methods, however, an accuracy of slightly better than 0.01 in σ_t is sufficient.

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* Specific gravity is the ratio of the density of a seawater sample at some temperature t to the density of pure water at 4°C and is a dimensionless quantity.

The distinction between a laboratory measurement which establishes a relationship and the routine measurements which use it must be made, since the required accuracy is approximately an order of magnitude greater for the former than for the latter.

Preliminary to our discussion, it is assumed that any such relationship will be established at atmospheric pressure, so that the pressure will not be considered as a variable. In addition, the index of refraction measurements must be performed at a generally accepted wavelength. Most of the early work favored the Sodium D-lines (589.0 and 589.6 nm, with the mean value 589.3 nm) which are a doublet and are unsuitable for the present purpose. Rusby (1967) has used the green Hg-line (546.227 nm in vacuo) which we consider to be a good choice.

SALINITY TO INDEX OF REFRACTION RELATIONSHIP

A quick reference to Table A-3(e) in Appendix A indicates that a typical salinity gradient is dn/ds = 0.0002 per unit of salinity (1 ‰). Therefore, in order to obtain salinities to 0.001 ‰ it is necessary to measure the index of refraction to 0.0000002, i.e., two units in the seventh decimal place, and this under a temperature control greater than 0.01 °C.

If this could be done in a laboratory experiment to establish a good relationship with little scatter in the correlation, then routine methods for the determination of salinity to 0.01 ‰ need only be accurate to 0.000002, i.e., two units in the sixth decimal place. This places awesome demands on the measurement of the index of refraction. A more convenient method is to measure the refractive index anomaly, i.e., the difference in index between a sample and Copenhagen Standard Seawater, which Rusby has so successfully (and laboriously) done to an accuracy of 0.0000004, i.e., four units in the seventh decimal place (see Sections 2 and 5). With this accuracy and with temperature control better than 0.01 °C the relationship of index of refraction to salinity can provide salinities to 0.002 ‰. This is exactly what Rusby did, and developed a polynomial expression providing salinity (from the refractive index anomaly and the temperature) with a standard deviation of about 0.0055 ‰ (see Section 5). To employ this relationship for routine determinations of salinity, an interferometric instrument would be required and perhaps a more compact one than was used by Rusby. The problems that would arise – those of temperature control of the the two fluids, of the precise knowledge of the container lengths, of the stability of the whole apparatus over the long term, of counting the fractions of interference fringes, etc. – pose an interesting challenge to optical engineering. Such an instrument has been built and used by Russian scientists (Vel 'Mozhnaya, 1960) but the mean accuracy in salinity is from 0.01 to 0.05 ‰ depending on the size of the cuvette containing the fluids. Improvement of this instrument could possibly provide the answer for routine work. The above author states that the use of his instrument is "simple and most convenient."

Much less accurate measurements using the index of refraction have been undertaken by Williams, Farrugia, Ekker, and Haden (1964) who have employed a differential refractometer to obtain chlorinity in brackish Louisiana waters. They claim the refractive index anomaly can be measured to $\pm 2 \times 10^{-6}$ which is an amazing accuracy for a small portable standard (non-interferometric) refractometer. The instrument uses a very small quantity of seawater but it unfortunately permits some evaporation to take place, which considerably reduces its real accuracy. Behrens (1965) has also discussed a refractometer of low accuracy (~1 ‰) but of very great range (0 to 200 ‰) to be used in tidal pools and brines of enclosed waters. It is an inexpensive instrument to be used for crude determinations and is certainly inadequate to meet the requirements exposed above.

SPECIFIC GRAVITY (σ_t) TO INDEX OF REFRACTION RELATIONSHIP

To determine a correspondence between index of refraction and σ_t, two possible methods exist. The first would measure the temperature and then the salinity using the index of refraction as described above, and then indirectly compute σ_t through the analytical expression provided by Cox, McCartney and Culkin (1970). This would perhaps be the simplest way. The second would actually perform simultaneous measurements of specific gravity and of the index of refraction at the same temperature in order to develop a direct relationship between the two. To obtain σ_t to 0.001 (i.e., specific gravity to 0.000001) it is necessary to measure the index to 2×10^{-7} and the temperature to better than 0.01°C. Here again a comparative method, based on the difference from Copenhagen Standard Seawater would greatly facilitate matters, but is not as simple as was the case with salinity. Having established a relationship between index and σ_t, an interferometer could be calibrated so as to provide σ_t directly when the temperature is known. The application of this method would be fraught with the same difficulties as would be that for the determination of salinity, mentioned above. Bein, *et al.* (1935), see Sections 2 and 5, actually developed such an interferometer which provided values of the parameter $\rho_{17.5}$ (see Eq. 3.9) for which temperature corrections could be obtained from an accompanying table. Measurements obtained in this manner were reported to 0.001 with the implication that $\rho_{17.5}$ and, therefore, also σ_t can be determined to the same accuracy. (See Eq. 5.8.)

We do not have much faith in the possibilities of an interferometer to directly provide values of σ_t to this great accuracy (not just precision), and our reasons are explained below. If, however, we are proved wrong and this procedure can be put into practice, it would signify considerable progress and greatly improve oceanographic procedures. Should such a breakthrough be achieved, the construction of a similar underwater instrument could be envisioned. It would be used in much the same way as today's CTD (conductivity/temperature/depth meter) is employed to obtain measurements *in situ*.

RELEVANCE OF INDEX MEASUREMENTS FOR OCEANOGRAPHIC PURPOSES

We now return to the more fundamental question mentioned earlier, of whether a relationship between the index of refraction and salinity or specific gravity can actually be meaningful, i.e., whether actual measurements will have very little scatter around some functional relationship that could provide salinity to ± 0.001 ‰ or σ_t to ± 0.001 when the index of refraction[†] is measured to two units in the seventh decimal place.

The principal difficulty lies with the problem of constancy of composition of seawater (see Section 3). To attain the accuracies stated above, it is obvious that all ionic constituents contributing more than one part per million by weight must retain a constant concentration ratio with respect to the $C\ell$ ion. This includes quite a large number of chemical species, the most important of which are $C\ell$, Na, SO_4, Mg, Ca, K, HCO_3, Br, Sr, B, F, (Riley & Chester, 1971).

[†] or the refractive index anomaly

The composition is actually only approximately constant but it holds better in the open oceans where the salinities range only between 33 and 37‰, than it does in coastal regions where dilution with river water occurs. River water as a rule contains very little $C\ell$, and the ratios of $SO_4/C\ell$, $HCO_3/C\ell$, K/Na, Mg/Na, Ca/Mg are much greater than in seawater. Thus, the composition of the Baltic and Black Seas is appreciably altered. The deep oceans also have a higher $Ca/C\ell$ ratio and also possibly a higher $Mg/C\ell$ ratio. In anoxic basins $SO_4/C\ell$ is decreased, due to the increase in sulphide. Freezing (sea ice) also tends to fractionate the elements of seawater. In addition, precipitation and dissolution of carbonate minerals (e.g., the Bahama Banks), submarine volcanism (e.g., the oceanic ridges), admixture with geological brines (e.g., the Red Sea), all tend to alter the composition of seawater. Evaporation in isolated basins and exchange of ions with the atmosphere also have an appreciable effect on seawater composition.

From another point of view, the isotopic composition of the water itself can be of importance for precision work (Cox, McCartney, Culkin, 1968) and the amount of dissolved gases also affect the composition to some extent.

Because of these factors, all of which contribute to the alteration of the composition of seawater which in turn affects the various physical properties in different ways leading to noninvariant relationships, the validity of a direct relationship between index of refraction and salinity or specific gravity (to some specified accuracy) must be very carefully examined.

It should also be noted that even though an increase in the number of ions in seawater generally contributes to an increase in index, salinity, and specific gravity, the Mg ions contribute negatively to the index of refraction (see Table 3-1). This makes the requirement of constancy of composition all the more evident.

As an indication of conditions in actual practice, Rusby's (1967) work may serve as an example, (see Sections 2 and 5). In his work a third-degree polynominal fitted to the data to relate refractive index anomaly to salinity, showed a standard deviation in S of 0.0055‰ from the experimental points. However, the maximum deviation of the computed values from the true – as contrasted with the experimental values – is supposed to be less than this. It was also found that larger deviations appeared below S = 35‰. Rusby stated that for routine application of refractive index measurements to derive salinity, the single most important factor is the water handling problem – transfusion, rinsing of containers, contamination, and evaporation – the errors from which are almost impossible to quantify.

7. EXAMPLES FOR USING THE INDEX OF REFRACTION TABLES

The tables of the index of refraction of seawater have all been placed in Appendix A for ease of reference. Their use is quite straightforward, and linear interpolation between the listed values is satisfactory throughout.

Tables A-1(a) through (p), A-2(a) through (j), and A-3(a) through (i) apply for a given constant wavelength and provide the index of refraction for any temperature and salinity at atmospheric pressure. Table A-4(a) through (t) applies for given constant salinities and provides the behavior with wavelength and temperature at atmospheric pressure. Table A-5(a),(b) enables the computation of index at pressures above atmospheric for any wavelength and temperature but only at 35‰ salinity, while Table A-6(a),(b) does the same for S = 0‰ (pure water).

The first four examples below provide the index for atmospheric pressure and serve to demonstrate the use of the tables, while Examples 5 and 6 apply to higher pressures.

Example 1

To find the index of refraction for values explicitly listed, simply look up the appropriate table.

e.g.: For $\lambda = 546.1$ nm, T = 18°C, S = 34‰ from Table A-3(e).

$$\underline{n = 1.34093}$$

Example 2

If the value of any parameter is not explicitly listed, interpolate linearly between those values bracketing the parameter.

e.g.: For $\lambda = 546.1$ nm, T = 18°C, S = 34.48‰ interpolate linearly between the salinities 34‰ and 35‰ from Table A-3(e).

	S = 34‰	S = 35‰
T = 18°C	1.34093	1.34112

⇨

	S = 34.48‰
T = 18°C	1.34102

thus, $\underline{n = 1.34102}$

Example 3

To find the index for λ = 546.1 nm, T = 18.2°C and S = 34.48‰, proceed as follows, interpolating both for temperature and salinity, from Table A-3(e). The order of interpolation is immaterial.

	S = 34‰	S = 35‰
T = 18°C	1.34093	1.34112
T = 20°C	1.34073	1.34092

⇨

	S = 34.48‰
T = 18°C	1.34102
T = 20°C	1.34082

⇨

	S = 34.48‰
T = 18.2°C	1.34100

thus, n = 1.34100

Example 4

To find the index for λ = 507 nm, T = 21.3°C, S = 34.88‰ none of which is explicitly listed in the tables, proceed as in Example 3 for the wavelengths, 500 nm and 520 nm from Tables A-1(f) and (g), and then interpolate between the two wavelengths.

λ = 500nm

	S = 34‰	S = 35‰
T = 20°C	1.34276	1.34295
T = 22°C	1.34255	1.34273

⇨

	S = 34.88‰
T = 20°C	1.342927
T = 22°C	1.342708

⇨

	S = 34.88‰
T = 21.3°C	1.342784

⇘

λ = 507nm
1.34245

⇗

λ = 520nm

	S = 34‰	S = 35‰
T = 20°C	1.34181	1.34200
T = 22°C	1.34160	1.34179

⇨

	S = 34.88‰
T = 20°C	1.341977
T = 22°C	1.341767

⇨

	S = 34.88‰
T = 21.3°C	1.341840

thus, n = 1.34245

To obtain the index of refraction at pressures above atmospheric, Table A-5 and/or A-6 are to be used in conjunction with Tables A-1 through A-4.

Since A-5 and A-6 hold for S = 35‰ and S = 0‰ respectively, it is necessary to first find the index at the particular combination of wavelength, temperature, and pressure for S = 35‰ and repeat the same for S = 0‰. Finally interpolate linearly the two resulting values to arrive at the desired index for the specified salinity. The following two examples will demonstrate their use.

Example 5

Find the index of refraction of standard seawater (35‰), for the wavelength λ = 457.9 nm, at T = 18°C, and p = 250 kg/cm^2 gage. These values of the three parameters are explicitly listed, so proceed as follows: First, find the index at atmospheric pressure using Table A-2(b); then, add the increment given in Table A-5(a); and finally, add algebraically the increment given in Table A-5(b). Thus,

From Table A-2(b) (atmospheric pressure)	n = 1.34553
From Table A-5(a)	Δn = + 0.00351
From Table A-5(b) linearly interpolating between λ = 440nm and λ = 460nm	Δn = + 0.00002
	1.34906

therefore, n = 1.34906

Example 6

In order to find the index for the same wavelength, temperature, and pressure as in Example 5 but for a salinity of 30‰, use must be made of both Table A-5 and A-6.

For the salinity 35‰ we found n = 1.34906 above.

For the salinity 0‰(pure water) we have:

From Table A-2(b) (atmospheric pressure)	n = 1.33890
From Table A-6(a)	Δn = + 0.00350
From Table A-6(b) linearly interpolating between λ = 440 and 460 nm	Δn = + 0.00002
	n = 1.34242

It is now only necessary to interpolate linearly between the two salinities.

λ = 457.9nm T = 18°C	S = 35‰, n = 1.34906	⇨	S = 30‰, n = 1.34811
p = 250 kg/cm^2	S = 0‰, n = 1.34242		

thus n = 1.34811

In any use of the tables of index of refraction, linear interpolation is satisfactory for providing the value of index to the fifth decimal place since the tables have been quite densely interpolated. Tables A-1 through A-4 have an accuracy "within" 3×10^{-5}, while Table A-5 is accurate to $\pm 6 \times 10^{-5}$ and Table A-6 to $\pm 10 \times 10^{-5}$.

We have compiled here some representative values of the index of refraction of seawater for extreme values of the parameters, namely T = 0 and 30°C, S = 0 and 35‰, $\lambda = 400$ and 700nm, p = 0 and 1000 kg/cm² gage. The index of refraction is a function $n(T,S,\lambda,p)$ so we have also presented the partial derivatives to indicate the magnitudes of these quantities.

Table 7-1. The index of refraction and its derivatives, computed for extreme values of the four parameters, i.e. at $\lambda = 400$ and 700nm, S = 0 and 35‰, T = 0 and 30°C, P = 0 and 1100 kg/cm² gage.

p kg/cm²	T °C	S ‰	λ nm	n	$\frac{\Delta n}{1\text{ nm}} \times 10^5$	$\frac{\Delta n}{1‰} \times 10^5$	$\frac{\Delta n}{1°C} \times 10^5$	$\frac{\Delta n}{1\text{ kg/cm}^2} \times 10^5$
0	0	0	400	1.344186	-9.02	20.65	- 0.75	1.62
0	0	0	700	1.331084	-2.18	19.46	- 0.25	1.60
0	0	35	400	1.351415	-9.27	20.65	- 4.85	1.56
0	0	35	700	1.337906	-2.25	19.46	- 3.15	1.52
0	30	0	400	1.342081	-8.94	19.05	-12.10	1.38
0	30	0	700	1.329128	-2.09	17.66	-11.50	1.36
0	30	35	400	1.348752	-9.30	19.05	-12.95	1.40
0	30	35	700	1.335316	-2.17	17.66	-12.55	1.36
1100	0	0	400	1.360076	-9.17	19.46	-11.25	1.32
1100	0	0	700	1.346604	-2.28	18.14	-10.75	1.28
1100	0	35	400	1.366885	-9.42	19.46	-11.85	1.24
1100	0	35	700	1.352956	-2.40	18.14	-10.15	1.20
1100	30	0	400	1.356281	-9.09	18.74	-16.10	1.18
1100	30	0	700	1.342958	-2.19	17.22	-15.50	1.14
1100	30	35	400	1.362842	-9.45	18.74	-14.45	1.16
1100	30	35	700	1.348986	-2.32	17.22	-14.05	1.12

NOTE: The above derivatives are actually mean slopes over some interval, namely, 10 nm for $\Delta n/\Delta\lambda$, 2°C for $\Delta n/\Delta T$, 50 kg/cm² for $\Delta n/\Delta p$. In the case of salinity the interval is immaterial since the functional behavior is linear and the slope is constant over the whole range.

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APPENDIX A. TABLES OF THE INDEX OF REFRACTION OF SEAWATER

Tables of smoothed, interpolated indices of refraction of seawater are presented in Appendix A. The ranges of the variables, salinity, temperature and pressure cover those of interest in oceanography. Wavelengths are limited to the visible spectral region, i.e., 400 to 700 nanometers. For most applications the desired index can be obtained either directly from Tables A-1 through A-4 or by linear interpolation between adjacent values in one of these tables. Should the index be required at other than atmospheric pressure, the user must resort to Tables A-5 and A-6 to obtain an index correction or increment which must then be applied to the index value for atmospheric pressure obtained from Tables A-1 through A-4. For many problems involving high pressures the salinity will be close to 35‰ and in these cases the required index increment can be obtained using Tables A-5(a,b) only. Section 7 details the procedures to be used in utilizing the tables.

Immediately preceding each group of tables some summary information is presented on their use, format and data base. Details regarding the selection of the primary input data and the procedures used in generating the tables are presented in Section 4. Because of the multidimensional nature of the tables and the difficulty of visualizing the manner in which the index varies with the four independent variables, a set of six three-dimensional plots is presented in Fig. A-1, each showing index as a function of two variables with the other two held constant. Figures A-1a, b, and c are for a fixed wavelength (550 nanometers) and show typical index surfaces for combinations of two of the three oceanographic variables, temperature, salinity, and pressure. Figures A-1d, e, and f all have wavelength displayed along the horizontal abscissa and show the dispersion surface for the oceanographic variables. Conventional two-dimensional plots are presented as Figs. 4-2, 4-3, and 4-4 in the text.

The Tables A-1 through A-6 that follow are separated into three groups. Tables A-1, A-2, and A-3 present the dependence of index on temperature and salinity at atmospheric pressure for various particular wavelengths. Table A-4 presents the index dependence on temperature and wavelength at atmospheric pressure for particular salinities. Finally, Tables A-5 and A-6, which are directly additive to Tables A-1 through A-4, permit extension of the latter to higher pressures for any temperature, wavelength, and salinity.

The values of index of refraction are with respect to air.

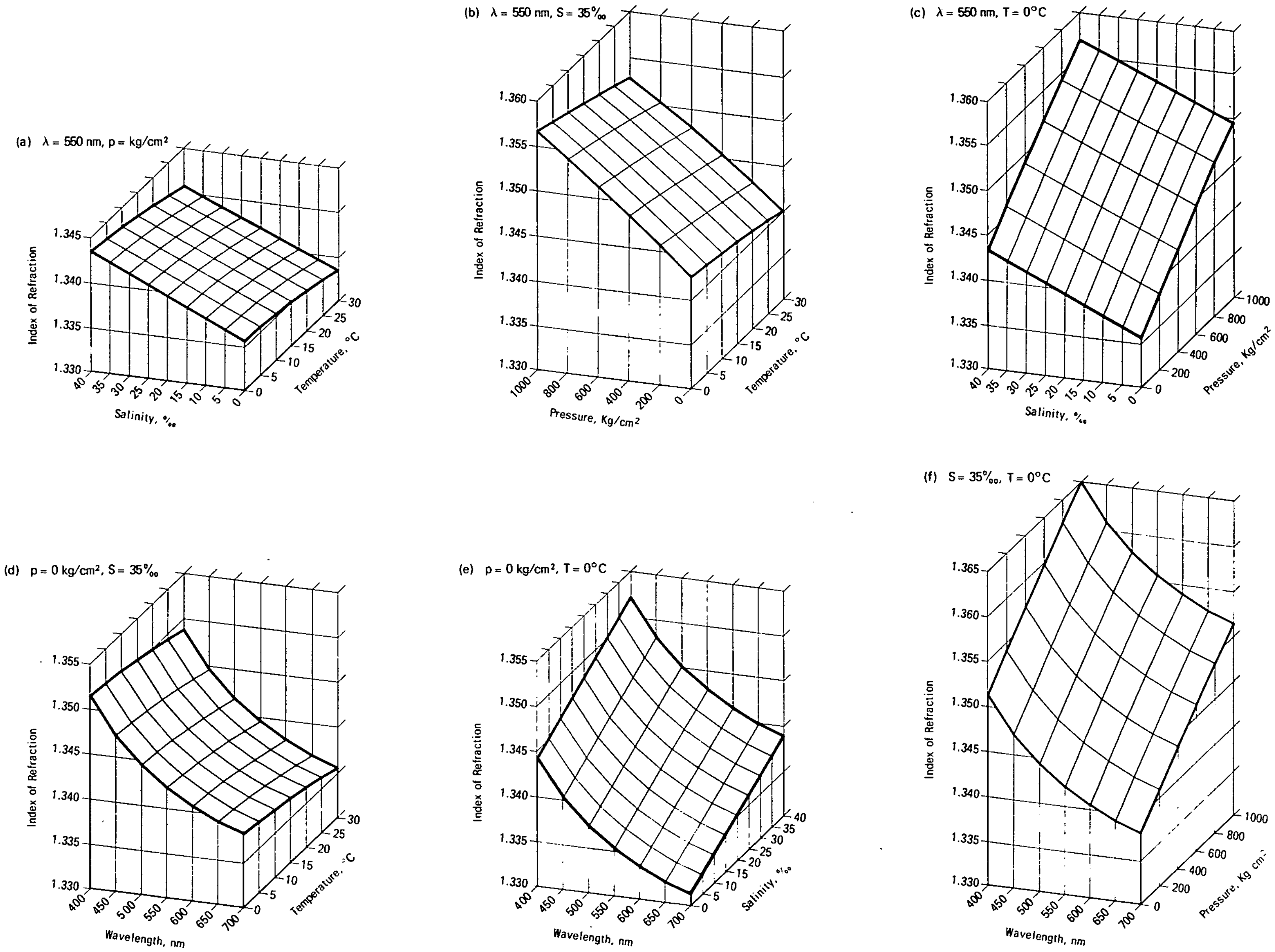


Fig. A-1. Three-dimensional plots of the index of refraction of seawater as function of salinity, temperature, pressure, and wavelength. In each plot two of the variables have been held fixed as indicated. Each plot starts at the same index value, viz. 1.330, and has the same vertical scale to aid in the visualization of the relative effect changes in each of the parameters have on index.

TABLES A-1, A-2, A-3

Atmospheric Pressure

These tables have been based on the data of Mehu and Johannin-Gilles (1968). Three of their original chlorinities have been discarded. The abridged table, on which our tables have been based, is given as Table 4-2 in Subsection 4.2 and includes:

Wavelength: 404.7(Hg), 435.8(Hg), 467.8(Cd), 480.0(Cd), 408.5(Cd), 546.1(Hg), 577.0(Kr), 579.1(Hg), 589.3(Na), 643.8(Cd) nm

Chlorinity: 0.0, 19.373‰

Salinity: 0.0, 34.998‰ (computed)

Temperature: 1°, 5°, 10°, 15°, 20°, 25°, 30°C

These tables give the temperature and salinity dependence of the index of refraction of seawater (with respect to air) at atmospheric pressure for particular wavelengths. They are accurate to "within" 3×10^{-5} in the interpolated wavelength range of 404.7 to 643.8 nm and slightly less accurate outside this range.

Table A-1: For an equispaced wavelength increment of 20 nm and covers the range 400 to 700 nm. For closer spacing, see Table A-4.

Table A-2: For selected laser lines; namely, 441.6(HeCd), 457.9(A), 476.5(A), 488.0(A), 496.5(A), 514.5(A), 532.0(NdYag), 568.2(Kr), 632.8(He), 647.1(Kr).

Table A-3: For M-G's original wavelengths given above, except for $\lambda = 480.0$ nm included in Table A-1.

The temperatures are given every 2°C between 0 and 30°C and the salinities every 5‰ between 0 and 30‰ and every 1‰ between 30 and 43‰.

Table A-1. INDEX OF REFRACTION OF SEAWATER

Equispaced Wavelengths, every 20 nm – Atmospheric Pressure

(a)

λ = **400 nm**

TEMP °C	SALINITY (‰)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.34418	1.34521	1.34625	1.34728	1.34831	1.34935	1.35038	1.35059	1.35079	1.35100
2.0	1.34417	1.34519	1.34621	1.34723	1.34825	1.34928	1.35030	1.35050	1.35071	1.35091
4.0	1.34413	1.34514	1.34616	1.34717	1.34818	1.34919	1.35020	1.35040	1.35061	1.35081
6.0	1.34408	1.34508	1.34608	1.34708	1.34809	1.34909	1.35009	1.35030	1.35050	1.35070
8.0	1.34400	1.34500	1.34599	1.34699	1.34799	1.34898	1.34998	1.35018	1.35038	1.35058
10.0	1.34391	1.34489	1.34589	1.34688	1.34787	1.34886	1.34985	1.35005	1.35025	1.35044
12.0	1.34379	1.34478	1.34576	1.34675	1.34773	1.34872	1.34970	1.34990	1.35010	1.35030
14.0	1.34366	1.34464	1.34562	1.34660	1.34758	1.34856	1.34954	1.34974	1.34993	1.35013
16.0	1.34351	1.34448	1.34546	1.34643	1.34741	1.34839	1.34936	1.34956	1.34975	1.34995
18.0	1.34334	1.34431	1.34529	1.34626	1.34723	1.34820	1.34917	1.34937	1.34956	1.34976
20.0	1.34316	1.34413	1.34510	1.34607	1.34703	1.34800	1.34897	1.34916	1.34936	1.34955
22.0	1.34297	1.34394	1.34490	1.34586	1.34683	1.34779	1.34876	1.34895	1.34914	1.34933
24.0	1.34277	1.34373	1.34469	1.34565	1.34661	1.34758	1.34853	1.34873	1.34892	1.34911
26.0	1.34256	1.34351	1.34447	1.34543	1.34639	1.34734	1.34830	1.34849	1.34868	1.34887
28.0	1.34233	1.34328	1.34424	1.34519	1.34614	1.34710	1.34805	1.34825	1.34844	1.34863
30.0	1.34209	1.34304	1.34399	1.34494	1.34589	1.34685	1.34780	1.34799	1.34818	1.34837

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.35121	1.35141	1.35162	1.35183	1.35203	1.35224	1.35245	1.35265	1.35286	1.35307
2.0	1.35111	1.35132	1.35152	1.35173	1.35193	1.35213	1.35234	1.35254	1.35275	1.35295
4.0	1.35101	1.35121	1.35141	1.35162	1.35182	1.35202	1.35222	1.35243	1.35263	1.35283
6.0	1.35090	1.35110	1.35130	1.35150	1.35170	1.35190	1.35210	1.35230	1.35250	1.35270
8.0	1.35078	1.35098	1.35117	1.35137	1.35157	1.35177	1.35197	1.35217	1.35237	1.35257
10.0	1.35064	1.35084	1.35104	1.35124	1.35143	1.35163	1.35183	1.35203	1.35223	1.35243
12.0	1.35049	1.35069	1.35089	1.35108	1.35128	1.35148	1.35168	1.35187	1.35207	1.35227
14.0	1.35032	1.35052	1.35072	1.35091	1.35111	1.35131	1.35150	1.35170	1.35189	1.35209
16.0	1.35014	1.35034	1.35053	1.35073	1.35092	1.35112	1.35131	1.35151	1.35170	1.35190
18.0	1.34995	1.35014	1.35034	1.35053	1.35073	1.35092	1.35111	1.35131	1.35150	1.35170
20.0	1.34974	1.34994	1.35013	1.35033	1.35052	1.35071	1.35091	1.35110	1.35129	1.35149
22.0	1.34953	1.34972	1.34991	1.35011	1.35030	1.35049	1.35069	1.35088	1.35107	1.35126
24.0	1.34930	1.34950	1.34969	1.34988	1.35007	1.35026	1.35046	1.35065	1.35084	1.35103
26.0	1.34907	1.34926	1.34945	1.34964	1.34983	1.35002	1.35022	1.35041	1.35060	1.35079
28.0	1.34882	1.34901	1.34920	1.34939	1.34958	1.34977	1.34997	1.35016	1.35035	1.35054
30.0	1.34856	1.34875	1.34894	1.34913	1.34932	1.34951	1.34970	1.34989	1.35008	1.35027

(b)

λ = **420 nm**

TEMP °C	SALINITY (‰)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.34243	1.34345	1.34448	1.34550	1.34653	1.34756	1.34858	1.34879	1.34899	1.34920
2.0	1.34241	1.34343	1.34444	1.34546	1.34647	1.34749	1.34850	1.34871	1.34891	1.34911
4.0	1.34238	1.34338	1.34439	1.34540	1.34640	1.34741	1.34841	1.34861	1.34881	1.34901
6.0	1.34232	1.34332	1.34432	1.34531	1.34631	1.34731	1.34830	1.34850	1.34870	1.34890
8.0	1.34225	1.34324	1.34423	1.34521	1.34620	1.34719	1.34818	1.34838	1.34858	1.34878
10.0	1.34215	1.34313	1.34412	1.34510	1.34608	1.34707	1.34805	1.34825	1.34844	1.34864
12.0	1.34204	1.34301	1.34399	1.34497	1.34595	1.34692	1.34790	1.34809	1.34829	1.34848
14.0	1.34191	1.34288	1.34385	1.34482	1.34579	1.34676	1.34774	1.34793	1.34813	1.34832
16.0	1.34176	1.34272	1.34369	1.34466	1.34563	1.34659	1.34756	1.34775	1.34795	1.34814
18.0	1.34160	1.34256	1.34352	1.34449	1.34545	1.34641	1.34738	1.34757	1.34776	1.34795
20.0	1.34142	1.34238	1.34334	1.34430	1.34526	1.34622	1.34718	1.34737	1.34756	1.34775
22.0	1.34123	1.34219	1.34314	1.34410	1.34505	1.34601	1.34697	1.34716	1.34735	1.34754
24.0	1.34102	1.34198	1.34293	1.34388	1.34484	1.34579	1.34674	1.34693	1.34712	1.34731
26.0	1.34081	1.34175	1.34271	1.34366	1.34460	1.34555	1.34650	1.34669	1.34688	1.34707
28.0	1.34058	1.34152	1.34247	1.34342	1.34436	1.34531	1.34626	1.34645	1.34663	1.34682
30.0	1.34034	1.34128	1.34222	1.34317	1.34411	1.34505	1.34600	1.34619	1.34637	1.34656

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34940	1.34961	1.34981	1.35002	1.35023	1.35043	1.35063	1.35084	1.35104	1.35125
2.0	1.34931	1.34952	1.34972	1.34992	1.35013	1.35033	1.35053	1.35073	1.35094	1.35114
4.0	1.34921	1.34941	1.34962	1.34982	1.35002	1.35022	1.35042	1.35062	1.35082	1.35102
6.0	1.34910	1.34930	1.34950	1.34970	1.34990	1.35010	1.35030	1.35049	1.35070	1.35089
8.0	1.34898	1.34917	1.34937	1.34957	1.34977	1.34996	1.35016	1.35036	1.35056	1.35075
10.0	1.34884	1.34903	1.34923	1.34943	1.34962	1.34982	1.35002	1.35021	1.35041	1.35060
12.0	1.34868	1.34888	1.34907	1.34927	1.34946	1.34966	1.34985	1.35005	1.35024	1.35044
14.0	1.34851	1.34871	1.34890	1.34910	1.34929	1.34949	1.34968	1.34988	1.35007	1.35026
16.0	1.34833	1.34853	1.34872	1.34892	1.34911	1.34930	1.34950	1.34969	1.34988	1.35008
18.0	1.34815	1.34834	1.34853	1.34873	1.34892	1.34911	1.34930	1.34950	1.34969	1.34988
20.0	1.34795	1.34814	1.34833	1.34852	1.34871	1.34891	1.34910	1.34929	1.34948	1.34967
22.0	1.34773	1.34792	1.34811	1.34830	1.34850	1.34869	1.34888	1.34907	1.34926	1.34945
24.0	1.34750	1.34769	1.34789	1.34808	1.34826	1.34846	1.34865	1.34884	1.34903	1.34922
26.0	1.34726	1.34745	1.34764	1.34783	1.34802	1.34821	1.34840	1.34859	1.34878	1.34897
28.0	1.34701	1.34720	1.34739	1.34758	1.34777	1.34796	1.34815	1.34834	1.34853	1.34872
30.0	1.34675	1.34694	1.34713	1.34732	1.34751	1.34769	1.34788	1.34807	1.34826	1.34845

Table A-1. (cont)

(c)

λ = **440 nm**

TEMP	SALINITY (0/00)									
°C	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.34092	1.34194	1.34295	1.34397	1.34499	1.34601	1.34702	1.34723	1.34743	1.34763
2.0	1.34090	1.34191	1.34292	1.34393	1.34493	1.34594	1.34695	1.34715	1.34735	1.34756
4.0	1.34087	1.34187	1.34287	1.34387	1.34486	1.34586	1.34686	1.34706	1.34726	1.34746
6.0	1.34081	1.34180	1.34279	1.34378	1.34478	1.34577	1.34676	1.34695	1.34715	1.34735
8.0	1.34074	1.34172	1.34270	1.34369	1.34467	1.34565	1.34664	1.34683	1.34703	1.34722
10.0	1.34065	1.34162	1.34260	1.34357	1.34455	1.34552	1.34650	1.34669	1.34689	1.34708
12.0	1.34053	1.34150	1.34247	1.34344	1.34440	1.34537	1.34634	1.34654	1.34673	1.34692
14.0	1.34039	1.34136	1.34232	1.34328	1.34425	1.34521	1.34618	1.34637	1.34656	1.34675
16.0	1.34025	1.34121	1.34216	1.34312	1.34408	1.34504	1.34600	1.34619	1.34638	1.34657
18.0	1.34009	1.34104	1.34200	1.34295	1.34391	1.34486	1.34581	1.34600	1.34620	1.34639
20.0	1.33991	1.34086	1.34182	1.34277	1.34372	1.34467	1.34562	1.34581	1.34600	1.34619
22.0	1.33973	1.34067	1.34162	1.34257	1.34351	1.34446	1.34541	1.34560	1.34579	1.34598
24.0	1.33952	1.34047	1.34141	1.34235	1.34330	1.34424	1.34519	1.34537	1.34556	1.34575
26.0	1.33931	1.34025	1.34119	1.34213	1.34307	1.34401	1.34495	1.34514	1.34533	1.34552
28.0	1.33908	1.34002	1.34095	1.34189	1.34283	1.34377	1.34471	1.34489	1.34508	1.34527
30.0	1.33884	1.33977	1.34071	1.34164	1.34258	1.34351	1.34445	1.34464	1.34482	1.34501

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34784	1.34804	1.34825	1.34845	1.34865	1.34885	1.34906	1.34926	1.34947	1.34967
2.0	1.34776	1.34796	1.34816	1.34836	1.34856	1.34876	1.34897	1.34917	1.34937	1.34957
4.0	1.34766	1.34786	1.34806	1.34826	1.34846	1.34866	1.34886	1.34906	1.34926	1.34946
6.0	1.34755	1.34774	1.34794	1.34814	1.34834	1.34854	1.34874	1.34893	1.34913	1.34933
8.0	1.34742	1.34762	1.34781	1.34801	1.34821	1.34840	1.34860	1.34879	1.34899	1.34919
10.0	1.34728	1.34747	1.34767	1.34786	1.34806	1.34825	1.34845	1.34864	1.34884	1.34903
12.0	1.34712	1.34731	1.34751	1.34770	1.34790	1.34809	1.34828	1.34848	1.34867	1.34886
14.0	1.34695	1.34714	1.34733	1.34753	1.34772	1.34791	1.34811	1.34830	1.34849	1.34868
16.0	1.34677	1.34696	1.34715	1.34734	1.34753	1.34773	1.34792	1.34811	1.34830	1.34849
18.0	1.34658	1.34677	1.34696	1.34715	1.34734	1.34753	1.34772	1.34792	1.34811	1.34830
20.0	1.34638	1.34657	1.34676	1.34695	1.34714	1.34733	1.34752	1.34771	1.34790	1.34809
22.0	1.34616	1.34635	1.34655	1.34674	1.34692	1.34711	1.34730	1.34749	1.34768	1.34787
24.0	1.34594	1.34613	1.34632	1.34651	1.34670	1.34688	1.34707	1.34726	1.34745	1.34764
26.0	1.34570	1.34589	1.34608	1.34627	1.34646	1.34664	1.34683	1.34702	1.34721	1.34740
28.0	1.34546	1.34564	1.34583	1.34602	1.34621	1.34639	1.34658	1.34677	1.34696	1.34715
30.0	1.34520	1.34539	1.34557	1.34576	1.34595	1.34613	1.34632	1.34651	1.34670	1.34688

(d)

λ = **460 nm**

TEMP	SALINITY (0/00)									
°C	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33960	1.34061	1.34162	1.34263	1.34364	1.34465	1.34566	1.34586	1.34607	1.34627
2.0	1.33959	1.34059	1.34159	1.34259	1.34359	1.34459	1.34559	1.34579	1.34599	1.34619
4.0	1.33956	1.34055	1.34154	1.34253	1.34352	1.34451	1.34551	1.34571	1.34590	1.34610
6.0	1.33950	1.34048	1.34147	1.34245	1.34343	1.34442	1.34540	1.34560	1.34580	1.34599
8.0	1.33943	1.34040	1.34138	1.34235	1.34333	1.34431	1.34528	1.34548	1.34567	1.34587
10.0	1.33933	1.34030	1.34127	1.34224	1.34321	1.34418	1.34515	1.34534	1.34553	1.34573
12.0	1.33921	1.34018	1.34114	1.34210	1.34306	1.34402	1.34499	1.34518	1.34537	1.34556
14.0	1.33908	1.34004	1.34099	1.34195	1.34290	1.34386	1.34482	1.34501	1.34520	1.34539
16.0	1.33893	1.33988	1.34083	1.34178	1.34273	1.34368	1.34464	1.34483	1.34502	1.34521
18.0	1.33877	1.33971	1.34066	1.34161	1.34255	1.34350	1.34445	1.34464	1.34482	1.34502
20.0	1.33860	1.33954	1.34048	1.34142	1.34236	1.34331	1.34425	1.34444	1.34463	1.34482
22.0	1.33841	1.33935	1.34029	1.34123	1.34216	1.34311	1.34404	1.34423	1.34442	1.34461
24.0	1.33821	1.33915	1.34008	1.34102	1.34195	1.34289	1.34382	1.34401	1.34420	1.34439
26.0	1.33800	1.33893	1.33986	1.34080	1.34173	1.34266	1.34360	1.34378	1.34397	1.34415
28.0	1.33777	1.33870	1.33963	1.34056	1.34149	1.34243	1.34336	1.34354	1.34373	1.34391
30.0	1.33753	1.33846	1.33939	1.34032	1.34124	1.34217	1.34311	1.34329	1.34348	1.34366

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34647	1.34667	1.34688	1.34708	1.34728	1.34748	1.34768	1.34788	1.34808	1.34829
2.0	1.34639	1.34660	1.34680	1.34700	1.34719	1.34740	1.34760	1.34779	1.34799	1.34820
4.0	1.34630	1.34650	1.34670	1.34690	1.34709	1.34729	1.34749	1.34769	1.34789	1.34809
6.0	1.34619	1.34639	1.34658	1.34678	1.34698	1.34717	1.34737	1.34757	1.34777	1.34796
8.0	1.34606	1.34626	1.34646	1.34665	1.34685	1.34704	1.34724	1.34743	1.34763	1.34782
10.0	1.34592	1.34612	1.34631	1.34650	1.34670	1.34689	1.34708	1.34728	1.34747	1.34767
12.0	1.34576	1.34595	1.34614	1.34634	1.34653	1.34672	1.34691	1.34711	1.34730	1.34749
14.0	1.34558	1.34577	1.34596	1.34616	1.34635	1.34654	1.34673	1.34692	1.34711	1.34730
16.0	1.34540	1.34559	1.34578	1.34597	1.34616	1.34635	1.34654	1.34673	1.34692	1.34711
18.0	1.34521	1.34539	1.34558	1.34577	1.34596	1.34615	1.34634	1.34653	1.34672	1.34691
20.0	1.34501	1.34519	1.34538	1.34557	1.34576	1.34595	1.34613	1.34632	1.34651	1.34670
22.0	1.34480	1.34498	1.34517	1.34536	1.34554	1.34573	1.34592	1.34611	1.34630	1.34648
24.0	1.34457	1.34476	1.34495	1.34513	1.34532	1.34551	1.34569	1.34588	1.34607	1.34626
26.0	1.34434	1.34453	1.34471	1.34490	1.34509	1.34527	1.34546	1.34565	1.34584	1.34602
28.0	1.34410	1.34429	1.34447	1.34466	1.34485	1.34503	1.34522	1.34540	1.34559	1.34578
30.0	1.34385	1.34403	1.34422	1.34441	1.34459	1.34478	1.34496	1.34515	1.34534	1.34552

Table A-1. (cont)

(e)

λ = 480 nm

TEMP °C	SALINITY (°/oo)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33844	1.33945	1.34045	1.34146	1.34246	1.34346	1.34447	1.34467	1.34487	1.34507
2.0	1.33843	1.33942	1.34042	1.34141	1.34241	1.34341	1.34440	1.34460	1.34480	1.34500
4.0	1.33839	1.33938	1.34037	1.34135	1.34234	1.34333	1.34432	1.34451	1.34471	1.34491
6.0	1.33834	1.33932	1.34029	1.34127	1.34225	1.34323	1.34421	1.34441	1.34460	1.34480
8.0	1.33826	1.33923	1.34020	1.34118	1.34215	1.34312	1.34409	1.34428	1.34448	1.34467
10.0	1.33817	1.33913	1.34010	1.34106	1.34203	1.34299	1.34395	1.34415	1.34434	1.34453
12.0	1.33806	1.33901	1.33997	1.34093	1.34189	1.34284	1.34380	1.34399	1.34418	1.34438
14.0	1.33793	1.33888	1.33983	1.34078	1.34173	1.34269	1.34364	1.34383	1.34402	1.34421
16.0	1.33778	1.33873	1.33967	1.34062	1.34157	1.34251	1.34346	1.34365	1.34384	1.34403
18.0	1.33762	1.33856	1.33951	1.34045	1.34139	1.34233	1.34327	1.34346	1.34365	1.34384
20.0	1.33745	1.33839	1.33932	1.34026	1.34120	1.34213	1.34307	1.34326	1.34345	1.34363
22.0	1.33726	1.33819	1.33912	1.34006	1.34099	1.34192	1.34286	1.34305	1.34323	1.34342
24.0	1.33705	1.33798	1.33891	1.33984	1.34078	1.34171	1.34264	1.34282	1.34301	1.34319
26.0	1.33684	1.33776	1.33869	1.33962	1.34055	1.34148	1.34240	1.34259	1.34277	1.34296
28.0	1.33661	1.33754	1.33846	1.33939	1.34031	1.34124	1.34216	1.34235	1.34253	1.34272
30.0	1.33638	1.33730	1.33822	1.33915	1.34007	1.34099	1.34191	1.34210	1.34228	1.34247

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34527	1.34548	1.34567	1.34588	1.34608	1.34628	1.34648	1.34668	1.34688	1.34708
2.0	1.34520	1.34540	1.34560	1.34580	1.34600	1.34619	1.34639	1.34659	1.34679	1.34699
4.0	1.34511	1.34530	1.34550	1.34570	1.34590	1.34609	1.34629	1.34649	1.34668	1.34688
6.0	1.34499	1.34519	1.34539	1.34558	1.34578	1.34597	1.34617	1.34636	1.34656	1.34676
8.0	1.34487	1.34506	1.34526	1.34545	1.34564	1.34584	1.34603	1.34623	1.34642	1.34662
10.0	1.34473	1.34492	1.34511	1.34530	1.34550	1.34569	1.34588	1.34607	1.34627	1.34646
12.0	1.34457	1.34476	1.34495	1.34514	1.34533	1.34553	1.34572	1.34591	1.34610	1.34629
14.0	1.34440	1.34459	1.34478	1.34497	1.34516	1.34535	1.34554	1.34573	1.34592	1.34611
16.0	1.34422	1.34441	1.34459	1.34478	1.34497	1.34516	1.34535	1.34554	1.34573	1.34592
18.0	1.34403	1.34421	1.34440	1.34459	1.34478	1.34497	1.34516	1.34534	1.34553	1.34572
20.0	1.34382	1.34401	1.34419	1.34438	1.34457	1.34476	1.34495	1.34513	1.34532	1.34551
22.0	1.34361	1.34379	1.34398	1.34416	1.34435	1.34454	1.34473	1.34491	1.34510	1.34528
24.0	1.34338	1.34356	1.34375	1.34394	1.34412	1.34431	1.34450	1.34468	1.34487	1.34505
26.0	1.34314	1.34333	1.34352	1.34370	1.34389	1.34407	1.34426	1.34444	1.34463	1.34481
28.0	1.34290	1.34309	1.34327	1.34346	1.34364	1.34383	1.34401	1.34420	1.34438	1.34457
30.0	1.34265	1.34284	1.34302	1.34321	1.34339	1.34358	1.34376	1.34395	1.34413	1.34432

(f)

λ = 500 nm

TEMP °C	SALINITY (°/oo)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33742	1.33841	1.33942	1.34042	1.34142	1.34242	1.34342	1.34362	1.34382	1.34402
2.0	1.33740	1.33839	1.33939	1.34038	1.34137	1.34236	1.34335	1.34355	1.34375	1.34395
4.0	1.33737	1.33835	1.33933	1.34032	1.34130	1.34228	1.34327	1.34346	1.34366	1.34386
6.0	1.33731	1.33828	1.33926	1.34023	1.34121	1.34218	1.34316	1.34335	1.34355	1.34374
8.0	1.33723	1.33820	1.33917	1.34013	1.34110	1.34207	1.34303	1.34323	1.34342	1.34361
10.0	1.33714	1.33810	1.33906	1.34002	1.34098	1.34194	1.34290	1.34309	1.34328	1.34347
12.0	1.33703	1.33798	1.33894	1.33989	1.34084	1.34179	1.34274	1.34293	1.34313	1.34332
14.0	1.33691	1.33785	1.33880	1.33974	1.34069	1.34164	1.34258	1.34277	1.34296	1.34315
16.0	1.33677	1.33771	1.33864	1.33959	1.34053	1.34146	1.34240	1.34259	1.34278	1.34297
18.0	1.33661	1.33754	1.33847	1.33941	1.34035	1.34128	1.34221	1.34240	1.34259	1.34278
20.0	1.33643	1.33736	1.33829	1.33922	1.34015	1.34108	1.34202	1.34220	1.34239	1.34257
22.0	1.33624	1.33717	1.33809	1.33902	1.33995	1.34088	1.34181	1.34199	1.34218	1.34236
24.0	1.33604	1.33696	1.33789	1.33881	1.33974	1.34066	1.34159	1.34177	1.34196	1.34214
26.0	1.33583	1.33675	1.33767	1.33859	1.33952	1.34044	1.34136	1.34154	1.34173	1.34191
28.0	1.33560	1.33652	1.33744	1.33836	1.33928	1.34020	1.34112	1.34130	1.34149	1.34167
30.0	1.33537	1.33628	1.33720	1.33812	1.33904	1.33995	1.34087	1.34106	1.34124	1.34142

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34422	1.34442	1.34462	1.34482	1.34502	1.34522	1.34542	1.34562	1.34582	1.34602
2.0	1.34415	1.34434	1.34454	1.34474	1.34494	1.34514	1.34533	1.34553	1.34573	1.34593
4.0	1.34405	1.34425	1.34445	1.34464	1.34484	1.34504	1.34523	1.34543	1.34563	1.34582
6.0	1.34394	1.34413	1.34433	1.34452	1.34472	1.34491	1.34511	1.34530	1.34550	1.34569
8.0	1.34381	1.34400	1.34420	1.34439	1.34458	1.34478	1.34497	1.34516	1.34535	1.34555
10.0	1.34366	1.34385	1.34405	1.34424	1.34443	1.34462	1.34481	1.34500	1.34520	1.34539
12.0	1.34351	1.34370	1.34389	1.34408	1.34427	1.34446	1.34465	1.34484	1.34503	1.34522
14.0	1.34334	1.34353	1.34372	1.34391	1.34410	1.34429	1.34447	1.34466	1.34485	1.34504
16.0	1.34316	1.34334	1.34353	1.34372	1.34391	1.34410	1.34429	1.34447	1.34466	1.34485
18.0	1.34296	1.34315	1.34334	1.34352	1.34371	1.34390	1.34409	1.34427	1.34446	1.34465
20.0	1.34276	1.34295	1.34313	1.34332	1.34351	1.34369	1.34388	1.34406	1.34425	1.34444
22.0	1.34255	1.34273	1.34292	1.34311	1.34329	1.34348	1.34366	1.34385	1.34403	1.34422
24.0	1.34233	1.34251	1.34270	1.34288	1.34307	1.34326	1.34344	1.34362	1.34381	1.34399
26.0	1.34210	1.34228	1.34247	1.34265	1.34284	1.34302	1.34321	1.34339	1.34358	1.34376
28.0	1.34186	1.34204	1.34223	1.34241	1.34259	1.34278	1.34296	1.34315	1.34333	1.34351
30.0	1.34160	1.34179	1.34197	1.34215	1.34234	1.34252	1.34271	1.34289	1.34307	1.34326

Table A-1. (cont)

(g)

λ = 520 nm

TEMP °C	SALINITY (‰)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33649	1.33749	1.33849	1.33949	1.34048	1.34148	1.34248	1.34268	1.34288	1.34307
2.0	1.33648	1.33747	1.33846	1.33944	1.34043	1.34142	1.34241	1.34260	1.34280	1.34300
4.0	1.33645	1.33742	1.33840	1.33938	1.34036	1.34134	1.34232	1.34251	1.34271	1.34291
6.0	1.33639	1.33736	1.33833	1.33930	1.34027	1.34124	1.34221	1.34241	1.34260	1.34280
8.0	1.33632	1.33728	1.33824	1.33921	1.34017	1.34113	1.34209	1.34229	1.34248	1.34267
10.0	1.33623	1.33718	1.33814	1.33909	1.34005	1.34100	1.34196	1.34215	1.34234	1.34253
12.0	1.33612	1.33707	1.33801	1.33896	1.33991	1.34085	1.34180	1.34199	1.34218	1.34237
14.0	1.33599	1.33693	1.33787	1.33881	1.33975	1.34069	1.34163	1.34182	1.34201	1.34220
16.0	1.33585	1.33678	1.33772	1.33865	1.33958	1.34052	1.34145	1.34164	1.34183	1.34202
18.0	1.33569	1.33662	1.33755	1.33848	1.33941	1.34034	1.34126	1.34145	1.34164	1.34182
20.0	1.33551	1.33644	1.33737	1.33829	1.33922	1.34015	1.34107	1.34126	1.34144	1.34163
22.0	1.33533	1.33625	1.33717	1.33810	1.33902	1.33994	1.34087	1.34105	1.34123	1.34142
24.0	1.33513	1.33605	1.33697	1.33789	1.33881	1.33973	1.34065	1.34084	1.34102	1.34120
26.0	1.33492	1.33584	1.33676	1.33767	1.33859	1.33951	1.34043	1.34061	1.34079	1.34097
28.0	1.33470	1.33561	1.33653	1.33744	1.33836	1.33927	1.34019	1.34037	1.34055	1.34074
30.0	1.33445	1.33537	1.33628	1.33720	1.33811	1.33902	1.33994	1.34012	1.34030	1.34049
	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34328	1.34347	1.34368	1.34387	1.34407	1.34427	1.34447	1.34467	1.34487	1.34507
2.0	1.34320	1.34339	1.34359	1.34379	1.34399	1.34418	1.34438	1.34458	1.34478	1.34497
4.0	1.34310	1.34330	1.34349	1.34369	1.34388	1.34408	1.34427	1.34447	1.34467	1.34486
6.0	1.34299	1.34318	1.34338	1.34357	1.34376	1.34396	1.34415	1.34435	1.34454	1.34474
8.0	1.34286	1.34306	1.34325	1.34344	1.34363	1.34383	1.34402	1.34421	1.34440	1.34460
10.0	1.34272	1.34291	1.34310	1.34329	1.34348	1.34368	1.34387	1.34406	1.34425	1.34444
12.0	1.34256	1.34275	1.34294	1.34313	1.34332	1.34351	1.34370	1.34389	1.34408	1.34426
14.0	1.34239	1.34257	1.34276	1.34295	1.34314	1.34333	1.34352	1.34371	1.34389	1.34408
16.0	1.34220	1.34239	1.34257	1.34276	1.34295	1.34314	1.34332	1.34351	1.34370	1.34388
18.0	1.34201	1.34220	1.34238	1.34257	1.34275	1.34294	1.34313	1.34331	1.34350	1.34368
20.0	1.34181	1.34200	1.34218	1.34237	1.34255	1.34274	1.34292	1.34311	1.34329	1.34348
22.0	1.34160	1.34179	1.34197	1.34216	1.34234	1.34253	1.34271	1.34289	1.34308	1.34327
24.0	1.34139	1.34157	1.34175	1.34194	1.34212	1.34231	1.34249	1.34268	1.34286	1.34304
26.0	1.34116	1.34134	1.34153	1.34171	1.34189	1.34208	1.34226	1.34245	1.34263	1.34281
28.0	1.34092	1.34110	1.34128	1.34147	1.34165	1.34184	1.34202	1.34220	1.34239	1.34257
30.0	1.34067	1.34085	1.34103	1.34122	1.34140	1.34158	1.34176	1.34195	1.34213	1.34231

(h)

λ = 540 nm

TEMP °C	SALINITY (‰)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33567	1.33667	1.33766	1.33865	1.33965	1.34064	1.34164	1.34183	1.34203	1.34223
2.0	1.33565	1.33664	1.33762	1.33861	1.33959	1.34057	1.34156	1.34175	1.34195	1.34215
4.0	1.33562	1.33659	1.33757	1.33854	1.33952	1.34049	1.34146	1.34166	1.34185	1.34205
6.0	1.33557	1.33654	1.33750	1.33847	1.33943	1.34040	1.34136	1.34156	1.34175	1.34194
8.0	1.33550	1.33646	1.33742	1.33838	1.33934	1.34029	1.34125	1.34144	1.34163	1.34183
10.0	1.33541	1.33636	1.33732	1.33827	1.33922	1.34017	1.34112	1.34131	1.34150	1.34169
12.0	1.33530	1.33624	1.33719	1.33813	1.33907	1.34002	1.34096	1.34115	1.34134	1.34153
14.0	1.33517	1.33611	1.33704	1.33798	1.33891	1.33985	1.34079	1.34097	1.34116	1.34135
16.0	1.33502	1.33595	1.33689	1.33782	1.33875	1.33968	1.34061	1.34079	1.34098	1.34117
18.0	1.33487	1.33579	1.33672	1.33765	1.33857	1.33950	1.34042	1.34061	1.34080	1.34098
20.0	1.33470	1.33562	1.33654	1.33747	1.33839	1.33931	1.34023	1.34042	1.34060	1.34079
22.0	1.33451	1.33543	1.33635	1.33727	1.33819	1.33911	1.34003	1.34021	1.34039	1.34058
24.0	1.33431	1.33523	1.33614	1.33706	1.33797	1.33889	1.33981	1.33999	1.34017	1.34035
26.0	1.33410	1.33501	1.33593	1.33684	1.33775	1.33867	1.33958	1.33976	1.33994	1.34013
28.0	1.33387	1.33478	1.33570	1.33661	1.33752	1.33843	1.33934	1.33952	1.33971	1.33989
30.0	1.33363	1.33454	1.33545	1.33637	1.33728	1.33818	1.33909	1.33928	1.33946	1.33964
	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34243	1.34263	1.34283	1.34302	1.34323	1.34342	1.34362	1.34382	1.34402	1.34422
2.0	1.34234	1.34254	1.34274	1.34293	1.34313	1.34333	1.34352	1.34372	1.34392	1.34411
4.0	1.34224	1.34244	1.34263	1.34283	1.34302	1.34322	1.34341	1.34361	1.34380	1.34399
6.0	1.34214	1.34233	1.34252	1.34271	1.34291	1.34310	1.34329	1.34349	1.34368	1.34387
8.0	1.34202	1.34221	1.34240	1.34259	1.34279	1.34298	1.34317	1.34336	1.34355	1.34374
10.0	1.34188	1.34207	1.34226	1.34245	1.34264	1.34283	1.34302	1.34321	1.34340	1.34359
12.0	1.34172	1.34191	1.34209	1.34228	1.34247	1.34266	1.34285	1.34304	1.34323	1.34342
14.0	1.34154	1.34173	1.34191	1.34210	1.34229	1.34248	1.34266	1.34285	1.34304	1.34323
16.0	1.34136	1.34154	1.34173	1.34191	1.34210	1.34229	1.34247	1.34266	1.34285	1.34303
18.0	1.34117	1.34135	1.34154	1.34172	1.34191	1.34209	1.34228	1.34247	1.34265	1.34284
20.0	1.34097	1.34116	1.34134	1.34152	1.34171	1.34189	1.34208	1.34226	1.34245	1.34263
22.0	1.34076	1.34095	1.34113	1.34131	1.34150	1.34168	1.34186	1.34205	1.34223	1.34242
24.0	1.34054	1.34072	1.34091	1.34109	1.34127	1.34145	1.34164	1.34182	1.34200	1.34219
26.0	1.34031	1.34049	1.34067	1.34086	1.34104	1.34122	1.34140	1.34159	1.34177	1.34195
28.0	1.34007	1.34025	1.34043	1.34062	1.34080	1.34098	1.34116	1.34134	1.34153	1.34171
30.0	1.33982	1.34000	1.34019	1.34037	1.34055	1.34073	1.34091	1.34110	1.34128	1.34146

Table A-1. (cont)

(i)

λ = **560 nm**

TEMP	SALINITY (0/00)									
°C	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33495	1.33594	1.33692	1.33791	1.33890	1.33988	1.34087	1.34107	1.34126	1.34147
2.0	1.33493	1.33591	1.33688	1.33787	1.33885	1.33982	1.34081	1.34100	1.34120	1.34139
4.0	1.33489	1.33586	1.33683	1.33781	1.33878	1.33975	1.34072	1.34091	1.34111	1.34130
6.0	1.33483	1.33579	1.33675	1.33772	1.33868	1.33964	1.34061	1.34080	1.34100	1.34119
8.0	1.33475	1.33571	1.33666	1.33762	1.33857	1.33953	1.34048	1.34067	1.34087	1.34105
10.0	1.33466	1.33561	1.33655	1.33750	1.33845	1.33940	1.34034	1.34053	1.34072	1.34091
12.0	1.33455	1.33549	1.33643	1.33737	1.33831	1.33925	1.34019	1.34038	1.34057	1.34076
14.0	1.33443	1.33536	1.33630	1.33723	1.33817	1.33910	1.34003	1.34022	1.34041	1.34060
16.0	1.33429	1.33522	1.33615	1.33707	1.33801	1.33893	1.33986	1.34005	1.34023	1.34042
18.0	1.33414	1.33506	1.33599	1.33690	1.33783	1.33875	1.33968	1.33986	1.34004	1.34022
20.0	1.33397	1.33488	1.33581	1.33672	1.33764	1.33855	1.33948	1.33966	1.33984	1.34002
22.0	1.33378	1.33469	1.33561	1.33652	1.33743	1.33834	1.33926	1.33945	1.33963	1.33981
24.0	1.33358	1.33449	1.33540	1.33631	1.33722	1.33813	1.33904	1.33922	1.33941	1.33959
26.0	1.33337	1.33428	1.33518	1.33609	1.33700	1.33790	1.33881	1.33899	1.33918	1.33936
28.0	1.33315	1.33405	1.33496	1.33586	1.33677	1.33767	1.33858	1.33876	1.33895	1.33913
30.0	1.33292	1.33382	1.33472	1.33563	1.33653	1.33744	1.33835	1.33853	1.33871	1.33888

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34166	1.34186	1.34205	1.34225	1.34245	1.34265	1.34284	1.34305	1.34324	1.34344
2.0	1.34159	1.34179	1.34198	1.34218	1.34237	1.34257	1.34276	1.34296	1.34316	1.34335
4.0	1.34149	1.34169	1.34188	1.34208	1.34227	1.34246	1.34267	1.34285	1.34305	1.34325
6.0	1.34138	1.34157	1.34176	1.34196	1.34215	1.34234	1.34254	1.34273	1.34292	1.34311
8.0	1.34125	1.34144	1.34163	1.34182	1.34201	1.34220	1.34239	1.34258	1.34278	1.34297
10.0	1.34110	1.34129	1.34148	1.34167	1.34186	1.34205	1.34224	1.34243	1.34262	1.34281
12.0	1.34095	1.34113	1.34132	1.34151	1.34170	1.34188	1.34207	1.34226	1.34245	1.34264
14.0	1.34078	1.34097	1.34115	1.34134	1.34153	1.34171	1.34190	1.34208	1.34227	1.34246
16.0	1.34060	1.34079	1.34097	1.34116	1.34134	1.34153	1.34171	1.34190	1.34208	1.34227
18.0	1.34041	1.34059	1.34078	1.34096	1.34115	1.34133	1.34152	1.34170	1.34189	1.34207
20.0	1.34021	1.34039	1.34057	1.34076	1.34094	1.34113	1.34131	1.34149	1.34168	1.34186
22.0	1.33999	1.34017	1.34036	1.34054	1.34073	1.34091	1.34109	1.34127	1.34146	1.34164
24.0	1.33977	1.33995	1.34013	1.34032	1.34050	1.34068	1.34087	1.34105	1.34123	1.34141
26.0	1.33955	1.33972	1.33990	1.34009	1.34027	1.34045	1.34063	1.34081	1.34099	1.34118
28.0	1.33931	1.33949	1.33967	1.33985	1.34003	1.34022	1.34040	1.34058	1.34076	1.34094
30.0	1.33907	1.33925	1.33943	1.33961	1.33979	1.33998	1.34016	1.34033	1.34051	1.34070

(j)

λ = **580 nm**

TEMP	SALINITY (0/00)									
°C	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33425	1.33524	1.33622	1.33721	1.33819	1.33918	1.34016	1.34036	1.34056	1.34076
2.0	1.33424	1.33522	1.33619	1.33717	1.33815	1.33912	1.34010	1.34030	1.34049	1.34069
4.0	1.33420	1.33517	1.33614	1.33711	1.33808	1.33905	1.34002	1.34021	1.34041	1.34060
6.0	1.33415	1.33511	1.33607	1.33703	1.33800	1.33896	1.33992	1.34011	1.34030	1.34050
8.0	1.33408	1.33503	1.33599	1.33694	1.33789	1.33885	1.33980	1.33999	1.34018	1.34037
10.0	1.33399	1.33494	1.33588	1.33683	1.33777	1.33872	1.33966	1.33985	1.34004	1.34023
12.0	1.33388	1.33482	1.33576	1.33669	1.33763	1.33857	1.33951	1.33969	1.33988	1.34007
14.0	1.33375	1.33468	1.33561	1.33654	1.33748	1.33841	1.33934	1.33953	1.33971	1.33990
16.0	1.33360	1.33453	1.33546	1.33638	1.33731	1.33823	1.33916	1.33934	1.33953	1.33971
18.0	1.33345	1.33437	1.33529	1.33621	1.33713	1.33805	1.33897	1.33916	1.33934	1.33952
20.0	1.33328	1.33419	1.33511	1.33603	1.33694	1.33786	1.33877	1.33896	1.33914	1.33932
22.0	1.33309	1.33400	1.33491	1.33583	1.33674	1.33765	1.33856	1.33874	1.33893	1.33911
24.0	1.33289	1.33380	1.33471	1.33562	1.33653	1.33743	1.33834	1.33852	1.33871	1.33889
26.0	1.33268	1.33359	1.33449	1.33540	1.33631	1.33721	1.33812	1.33830	1.33848	1.33866
28.0	1.33246	1.33336	1.33427	1.33517	1.33608	1.33698	1.33788	1.33806	1.33824	1.33843
30.0	1.33223	1.33313	1.33403	1.33494	1.33584	1.33674	1.33764	1.33782	1.33801	1.33819

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34095	1.34115	1.34135	1.34155	1.34174	1.34194	1.34214	1.34233	1.34253	1.34273
2.0	1.34088	1.34108	1.34128	1.34147	1.34167	1.34186	1.34206	1.34225	1.34245	1.34264
4.0	1.34079	1.34099	1.34118	1.34138	1.34157	1.34177	1.34196	1.34215	1.34235	1.34254
6.0	1.34069	1.34088	1.34107	1.34126	1.34146	1.34165	1.34184	1.34203	1.34223	1.34242
8.0	1.34056	1.34075	1.34094	1.34114	1.34133	1.34152	1.34171	1.34190	1.34209	1.34228
10.0	1.34042	1.34061	1.34080	1.34099	1.34118	1.34136	1.34155	1.34174	1.34193	1.34212
12.0	1.34026	1.34045	1.34063	1.34082	1.34101	1.34120	1.34138	1.34157	1.34176	1.34195
14.0	1.34008	1.34027	1.34046	1.34064	1.34083	1.34102	1.34120	1.34139	1.34157	1.34176
16.0	1.33990	1.34008	1.34027	1.34045	1.34064	1.34083	1.34101	1.34119	1.34138	1.34157
18.0	1.33971	1.33989	1.34008	1.34026	1.34044	1.34063	1.34081	1.34100	1.34118	1.34136
20.0	1.33951	1.33969	1.33987	1.34005	1.34024	1.34042	1.34060	1.34079	1.34097	1.34115
22.0	1.33929	1.33947	1.33966	1.33984	1.34002	1.34020	1.34039	1.34057	1.34075	1.34093
24.0	1.33907	1.33925	1.33943	1.33961	1.33980	1.33998	1.34016	1.34034	1.34052	1.34070
26.0	1.33884	1.33902	1.33920	1.33938	1.33957	1.33975	1.33993	1.34011	1.34029	1.34047
28.0	1.33861	1.33879	1.33897	1.33915	1.33933	1.33951	1.33969	1.33987	1.34005	1.34023
30.0	1.33837	1.33855	1.33873	1.33891	1.33909	1.33927	1.33945	1.33963	1.33981	1.33999

Table A-1. (cont)

(k)

λ = **600 nm**

TEMP °C	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33363	1.33461	1.33559	1.33658	1.33756	1.33853	1.33951	1.33972	1.33991	1.34012
2.0	1.33361	1.33458	1.33555	1.33653	1.33751	1.33848	1.33945	1.33965	1.33984	1.34004
4.0	1.33357	1.33454	1.33550	1.33647	1.33744	1.33840	1.33937	1.33956	1.33976	1.33995
6.0	1.33352	1.33448	1.33544	1.33640	1.33735	1.33831	1.33928	1.33946	1.33966	1.33985
8.0	1.33345	1.33440	1.33536	1.33631	1.33725	1.33821	1.33916	1.33935	1.33954	1.33973
10.0	1.33337	1.33431	1.33525	1.33620	1.33714	1.33808	1.33903	1.33921	1.33940	1.33959
12.0	1.33326	1.33419	1.33513	1.33607	1.33700	1.33793	1.33887	1.33905	1.33924	1.33943
14.0	1.33313	1.33406	1.33498	1.33592	1.33684	1.33777	1.33869	1.33888	1.33907	1.33925
16.0	1.33300	1.33391	1.33483	1.33575	1.33667	1.33759	1.33851	1.33869	1.33888	1.33906
18.0	1.33284	1.33375	1.33467	1.33558	1.33650	1.33741	1.33833	1.33851	1.33869	1.33887
20.0	1.33267	1.33358	1.33449	1.33540	1.33631	1.33721	1.33813	1.33831	1.33849	1.33867
22.0	1.33249	1.33339	1.33430	1.33520	1.33610	1.33701	1.33792	1.33810	1.33828	1.33846
24.0	1.33229	1.33319	1.33409	1.33499	1.33589	1.33679	1.33770	1.33788	1.33806	1.33824
26.0	1.33207	1.33297	1.33387	1.33477	1.33567	1.33657	1.33747	1.33765	1.33783	1.33801
28.0	1.33185	1.33275	1.33365	1.33454	1.33544	1.33634	1.33724	1.33742	1.33760	1.33778
30.0	1.33163	1.33252	1.33342	1.33431	1.33521	1.33610	1.33700	1.33718	1.33736	1.33754

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34030	1.34051	1.34070	1.34090	1.34109	1.34129	1.34148	1.34169	1.34188	1.34207
2.0	1.34023	1.34043	1.34062	1.34082	1.34101	1.34121	1.34140	1.34160	1.34179	1.34199
4.0	1.34015	1.34034	1.34053	1.34073	1.34092	1.34111	1.34131	1.34150	1.34169	1.34189
6.0	1.34004	1.34024	1.34042	1.34062	1.34081	1.34100	1.34120	1.34138	1.34158	1.34177
8.0	1.33993	1.34012	1.34030	1.34049	1.34068	1.34087	1.34107	1.34126	1.34145	1.34163
10.0	1.33978	1.33997	1.34016	1.34035	1.34053	1.34073	1.34091	1.34110	1.34129	1.34148
12.0	1.33961	1.33980	1.33999	1.34017	1.34036	1.34055	1.34074	1.34093	1.34111	1.34130
14.0	1.33943	1.33962	1.33981	1.33999	1.34018	1.34036	1.34055	1.34074	1.34092	1.34111
16.0	1.33925	1.33943	1.33961	1.33980	1.33998	1.34017	1.34035	1.34054	1.34072	1.34091
18.0	1.33905	1.33924	1.33942	1.33960	1.33979	1.33997	1.34015	1.34034	1.34052	1.34070
20.0	1.33885	1.33904	1.33922	1.33940	1.33958	1.33977	1.33995	1.34013	1.34031	1.34050
22.0	1.33864	1.33883	1.33901	1.33918	1.33937	1.33955	1.33973	1.33991	1.34010	1.34027
24.0	1.33842	1.33860	1.33878	1.33896	1.33914	1.33932	1.33950	1.33969	1.33987	1.34005
26.0	1.33819	1.33837	1.33855	1.33873	1.33891	1.33909	1.33927	1.33946	1.33964	1.33981
28.0	1.33796	1.33814	1.33832	1.33850	1.33868	1.33886	1.33904	1.33922	1.33940	1.33958
30.0	1.33772	1.33790	1.33808	1.33825	1.33843	1.33862	1.33880	1.33697	1.33915	1.33933

(l)

λ = **620 nm**

TEMP °C	SALINITY ($^0/_{00}$)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33306	1.33404	1.33501	1.33600	1.33698	1.33795	1.33893	1.33914	1.33932	1.33953
2.0	1.33304	1.33401	1.33498	1.33595	1.33693	1.33789	1.33887	1.33906	1.33926	1.33946
4.0	1.33300	1.33396	1.33492	1.33589	1.33685	1.33782	1.33879	1.33898	1.33918	1.33936
6.0	1.33295	1.33390	1.33486	1.33581	1.33677	1.33772	1.33869	1.33888	1.33907	1.33926
8.0	1.33288	1.33363	1.33477	1.33572	1.33667	1.33762	1.33858	1.33876	1.33895	1.33914
10.0	1.33279	1.33373	1.33467	1.33561	1.33656	1.33750	1.33844	1.33863	1.33881	1.33900
12.0	1.33269	1.33362	1.33455	1.33549	1.33642	1.33735	1.33828	1.33847	1.33865	1.33884
14.0	1.33257	1.33349	1.33441	1.33534	1.33626	1.33719	1.33811	1.33829	1.33848	1.33867
16.0	1.33243	1.33334	1.33426	1.33518	1.33610	1.33701	1.33793	1.33811	1.33830	1.33848
18.0	1.33228	1.33318	1.33410	1.33501	1.33592	1.33683	1.33774	1.33792	1.33811	1.33829
20.0	1.33211	1.33301	1.33392	1.33482	1.33573	1.33663	1.33755	1.33773	1.33791	1.33809
22.0	1.33192	1.33282	1.33372	1.33462	1.33553	1.33643	1.33734	1.33752	1.33769	1.33788
24.0	1.33172	1.33262	1.33352	1.33442	1.33531	1.33621	1.33712	1.33730	1.33747	1.33766
26.0	1.33151	1.33241	1.33330	1.33420	1.33509	1.33599	1.33689	1.33707	1.33724	1.33743
28.0	1.33129	1.33218	1.33307	1.33397	1.33486	1.33576	1.33666	1.33684	1.33701	1.33719
30.0	1.33106	1.33195	1.33284	1.33374	1.33463	1.33552	1.33642	1.33660	1.33677	1.33695

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.33972	1.33992	1.34011	1.34031	1.34050	1.34071	1.34089	1.34110	1.34129	1.34149
2.0	1.33965	1.33985	1.34004	1.34024	1.34043	1.34062	1.34082	1.34101	1.34121	1.34140
4.0	1.33956	1.33975	1.33994	1.34014	1.34033	1.34052	1.34072	1.34091	1.34110	1.34130
6.0	1.33946	1.33965	1.33983	1.34003	1.34022	1.34041	1.34060	1.34079	1.34099	1.34118
8.0	1.33933	1.33953	1.33971	1.33990	1.34009	1.34028	1.34047	1.34066	1.34085	1.34104
10.0	1.33919	1.33938	1.33957	1.33976	1.33994	1.34013	1.34032	1.34051	1.34070	1.34088
12.0	1.33903	1.33921	1.33940	1.33959	1.33977	1.33996	1.34015	1.34034	1.34052	1.34071
14.0	1.33885	1.33903	1.33922	1.33941	1.33959	1.33978	1.33996	1.34015	1.34033	1.34052
16.0	1.33866	1.33885	1.33903	1.33921	1.33940	1.33958	1.33977	1.33995	1.34013	1.34032
18.0	1.33847	1.33865	1.33884	1.33902	1.33920	1.33939	1.33957	1.33975	1.33993	1.34012
20.0	1.33827	1.33845	1.33863	1.33882	1.33900	1.33918	1.33936	1.33954	1.33972	1.33991
22.0	1.33806	1.33824	1.33842	1.33860	1.33878	1.33896	1.33914	1.33932	1.33951	1.33969
24.0	1.33784	1.33802	1.33820	1.33838	1.33856	1.33874	1.33892	1.33910	1.33928	1.33946
26.0	1.33761	1.33779	1.33797	1.33815	1.33833	1.33851	1.33868	1.33887	1.33905	1.33922
28.0	1.33737	1.33755	1.33773	1.33791	1.33809	1.33827	1.33845	1.33863	1.33881	1.33898
30.0	1.33713	1.33731	1.33749	1.33766	1.33784	1.33803	1.33820	1.33838	1.33856	1.33874

Table A-1. (cont)

(m)

λ = 640 nm

TEMP	SALINITY (0/00)									
°C	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33251	1.33349	1.33447	1.33545	1.33643	1.33741	1.33840	1.33859	1.33879	1.33898
2.0	1.33250	1.33347	1.33444	1.33541	1.33638	1.33735	1.33833	1.33852	1.33872	1.33891
4.0	1.33246	1.33343	1.33439	1.33535	1.33631	1.33728	1.33824	1.33843	1.33863	1.33882
6.0	1.33241	1.33336	1.33432	1.33527	1.33622	1.33718	1.33814	1.33833	1.33852	1.33871
8.0	1.33234	1.33328	1.33423	1.33518	1.33612	1.33707	1.33802	1.33821	1.33840	1.33859
10.0	1.33225	1.33319	1.33413	1.33506	1.33600	1.33694	1.33788	1.33807	1.33826	1.33845
12.0	1.33215	1.33308	1.33401	1.33494	1.33587	1.33680	1.33773	1.33792	1.33810	1.33829
14.0	1.33203	1.33295	1.33387	1.33480	1.33572	1.33664	1.33757	1.33775	1.33794	1.33812
16.0	1.33189	1.33280	1.33372	1.33464	1.33556	1.33647	1.33739	1.33757	1.33776	1.33794
18.0	1.33173	1.33264	1.33355	1.33447	1.33538	1.33629	1.33720	1.33738	1.33757	1.33775
20.0	1.33156	1.33247	1.33337	1.33428	1.33519	1.33609	1.33700	1.33718	1.33736	1.33754
22.0	1.33138	1.33228	1.33318	1.33408	1.33499	1.33589	1.33679	1.33697	1.33715	1.33733
24.0	1.33118	1.33208	1.33298	1.33388	1.33477	1.33567	1.33657	1.33675	1.33693	1.33711
26.0	1.33097	1.33187	1.33276	1.33366	1.33455	1.33545	1.33635	1.33652	1.33670	1.33689
28.0	1.33075	1.33164	1.33254	1.33343	1.33432	1.33522	1.33611	1.33629	1.33647	1.33665
30.0	1.33052	1.33141	1.33230	1.33319	1.33408	1.33498	1.33587	1.33605	1.33623	1.33640

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.33918	1.33937	1.33957	1.33976	1.33996	1.34016	1.34036	1.34055	1.34075	1.34094
2.0	1.33910	1.33930	1.33949	1.33969	1.33988	1.34007	1.34027	1.34046	1.34066	1.34085
4.0	1.33901	1.33920	1.33940	1.33959	1.33978	1.33997	1.34017	1.34036	1.34055	1.34075
6.0	1.33890	1.33909	1.33928	1.33947	1.33966	1.33986	1.34005	1.34024	1.34043	1.34062
8.0	1.33877	1.33896	1.33915	1.33934	1.33953	1.33972	1.33991	1.34010	1.34029	1.34048
10.0	1.33863	1.33882	1.33901	1.33920	1.33938	1.33957	1.33976	1.33995	1.34014	1.34032
12.0	1.33848	1.33866	1.33885	1.33903	1.33922	1.33941	1.33959	1.33978	1.33996	1.34015
14.0	1.33831	1.33849	1.33867	1.33886	1.33904	1.33923	1.33941	1.33960	1.33978	1.33997
16.0	1.33812	1.33831	1.33849	1.33867	1.33886	1.33904	1.33922	1.33941	1.33959	1.33977
18.0	1.33793	1.33811	1.33829	1.33848	1.33866	1.33884	1.33902	1.33921	1.33939	1.33957
20.0	1.33773	1.33791	1.33809	1.33827	1.33845	1.33863	1.33882	1.33900	1.33918	1.33936
22.0	1.33751	1.33770	1.33788	1.33805	1.33824	1.33842	1.33860	1.33878	1.33896	1.33914
24.0	1.33729	1.33747	1.33765	1.33783	1.33801	1.33819	1.33837	1.33855	1.33873	1.33891
26.0	1.33706	1.33724	1.33742	1.33760	1.33778	1.33796	1.33814	1.33832	1.33850	1.33868
28.0	1.33683	1.33700	1.33718	1.33736	1.33754	1.33772	1.33790	1.33808	1.33826	1.33843
30.0	1.33658	1.33676	1.33694	1.33712	1.33730	1.33747	1.33765	1.33783	1.33801	1.33819

(n)

λ = 660 nm

TEMP	SALINITY (0/00)									
°C	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33201	1.33298	1.33396	1.33494	1.33592	1.33690	1.33788	1.33807	1.33827	1.33846
2.0	1.33199	1.33296	1.33393	1.33490	1.33587	1.33684	1.33781	1.33800	1.33820	1.33839
4.0	1.33195	1.33291	1.33387	1.33484	1.33580	1.33676	1.33772	1.33791	1.33811	1.33830
6.0	1.33190	1.33285	1.33380	1.33476	1.33571	1.33666	1.33762	1.33781	1.33800	1.33819
8.0	1.33183	1.33277	1.33372	1.33466	1.33561	1.33655	1.33750	1.33769	1.33788	1.33806
10.0	1.33174	1.33268	1.33361	1.33455	1.33549	1.33642	1.33736	1.33755	1.33774	1.33792
12.0	1.33164	1.33257	1.33350	1.33442	1.33535	1.33628	1.33721	1.33740	1.33758	1.33777
14.0	1.33152	1.33244	1.33336	1.33428	1.33521	1.33613	1.33705	1.33724	1.33742	1.33760
16.0	1.33138	1.33229	1.33321	1.33413	1.33504	1.33596	1.33687	1.33706	1.33724	1.33742
18.0	1.33122	1.33213	1.33304	1.33395	1.33486	1.33577	1.33668	1.33687	1.33705	1.33723
20.0	1.33105	1.33196	1.33286	1.33377	1.33467	1.33558	1.33648	1.33666	1.33685	1.33703
22.0	1.33087	1.33177	1.33267	1.33357	1.33447	1.33537	1.33627	1.33645	1.33663	1.33681
24.0	1.33067	1.33157	1.33247	1.33336	1.33426	1.33516	1.33606	1.33624	1.33642	1.33659
26.0	1.33047	1.33136	1.33225	1.33315	1.33404	1.33494	1.33583	1.33601	1.33619	1.33637
28.0	1.33025	1.33114	1.33203	1.33292	1.33381	1.33470	1.33559	1.33577	1.33595	1.33613
30.0	1.33001	1.33090	1.33179	1.33268	1.33357	1.33446	1.33535	1.33553	1.33571	1.33588

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.33866	1.33885	1.33905	1.33924	1.33944	1.33964	1.33983	1.34003	1.34022	1.34042
2.0	1.33858	1.33878	1.33897	1.33917	1.33936	1.33955	1.33975	1.33994	1.34014	1.34033
4.0	1.33849	1.33868	1.33888	1.33907	1.33926	1.33945	1.33965	1.33984	1.34003	1.34022
6.0	1.33838	1.33857	1.33876	1.33895	1.33914	1.33933	1.33952	1.33971	1.33990	1.34010
8.0	1.33825	1.33844	1.33863	1.33882	1.33901	1.33920	1.33939	1.33958	1.33977	1.33995
10.0	1.33811	1.33830	1.33849	1.33867	1.33886	1.33905	1.33924	1.33942	1.33961	1.33980
12.0	1.33796	1.33814	1.33833	1.33851	1.33870	1.33889	1.33907	1.33926	1.33944	1.33963
14.0	1.33779	1.33797	1.33816	1.33834	1.33853	1.33871	1.33890	1.33908	1.33926	1.33945
16.0	1.33760	1.33779	1.33797	1.33815	1.33834	1.33852	1.33870	1.33889	1.33907	1.33925
18.0	1.33741	1.33759	1.33778	1.33796	1.33814	1.33832	1.33850	1.33869	1.33887	1.33905
20.0	1.33721	1.33739	1.33757	1.33775	1.33793	1.33811	1.33829	1.33848	1.33866	1.33884
22.0	1.33700	1.33718	1.33735	1.33753	1.33772	1.33790	1.33808	1.33826	1.33844	1.33862
24.0	1.33677	1.33695	1.33713	1.33731	1.33749	1.33767	1.33785	1.33803	1.33821	1.33839
26.0	1.33654	1.33672	1.33690	1.33708	1.33726	1.33744	1.33762	1.33780	1.33798	1.33815
28.0	1.33631	1.33649	1.33666	1.33684	1.33702	1.33720	1.33738	1.33755	1.33773	1.33791
30.0	1.33606	1.33624	1.33642	1.33660	1.33677	1.33695	1.33713	1.33731	1.33748	1.33766

Table A-1. (cont)

(o)

λ = 680 nm

TEMP °C	SALINITY (‰) 0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33153	1.33250	1.33348	1.33446	1.33543	1.33641	1.33739	1.33758	1.33778	1.33797
2.0	1.33152	1.33248	1.33345	1.33442	1.33539	1.33636	1.33732	1.33752	1.33771	1.33790
4.0	1.33148	1.33244	1.33340	1.33436	1.33532	1.33628	1.33724	1.33743	1.33762	1.33782
6.0	1.33143	1.33238	1.33333	1.33428	1.33524	1.33619	1.33714	1.33733	1.33752	1.33771
8.0	1.33136	1.33230	1.33325	1.33419	1.33513	1.33608	1.33702	1.33721	1.33740	1.33759
10.0	1.33127	1.33221	1.33314	1.33408	1.33501	1.33595	1.33688	1.33707	1.33726	1.33745
12.0	1.33117	1.33210	1.33302	1.33395	1.33488	1.33581	1.33673	1.33692	1.33711	1.33729
14.0	1.33105	1.33197	1.33289	1.33381	1.33473	1.33565	1.33657	1.33675	1.33694	1.33712
16.0	1.33091	1.33182	1.33274	1.33365	1.33456	1.33547	1.33639	1.33657	1.33675	1.33694
18.0	1.33075	1.33166	1.33257	1.33348	1.33438	1.33529	1.33620	1.33638	1.33656	1.33674
20.0	1.33059	1.33149	1.33239	1.33329	1.33419	1.33509	1.33600	1.33618	1.33636	1.33654
22.0	1.33040	1.33130	1.33220	1.33310	1.33399	1.33489	1.33579	1.33597	1.33615	1.33633
24.0	1.33021	1.33110	1.33200	1.33289	1.33379	1.33468	1.33558	1.33575	1.33593	1.33611
26.0	1.33000	1.33090	1.33179	1.33268	1.33357	1.33446	1.33535	1.33553	1.33571	1.33589
28.0	1.32978	1.33067	1.33156	1.33245	1.33334	1.33423	1.33512	1.33530	1.33547	1.33565
30.0	1.32955	1.33044	1.33133	1.33221	1.33310	1.33399	1.33487	1.33505	1.33523	1.33540

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.33817	1.33836	1.33856	1.33875	1.33895	1.33914	1.33934	1.33953	1.33973	1.33992
2.0	1.33810	1.33829	1.33848	1.33868	1.33887	1.33907	1.33926	1.33945	1.33965	1.33984
4.0	1.33801	1.33820	1.33839	1.33858	1.33878	1.33897	1.33916	1.33935	1.33954	1.33974
6.0	1.33790	1.33809	1.33828	1.33847	1.33866	1.33885	1.33904	1.33923	1.33942	1.33961
8.0	1.33777	1.33796	1.33815	1.33834	1.33653	1.33872	1.33891	1.33909	1.33928	1.33947
10.0	1.33763	1.33782	1.33801	1.33819	1.33838	1.33857	1.33875	1.33894	1.33913	1.33932
12.0	1.33748	1.33766	1.33785	1.33803	1.33822	1.33840	1.33859	1.33878	1.33896	1.33915
14.0	1.33731	1.33749	1.33768	1.33786	1.33804	1.33823	1.33841	1.33860	1.33878	1.33896
16.0	1.33712	1.33730	1.33748	1.33767	1.33785	1.33803	1.33821	1.33840	1.33858	1.33876
18.0	1.33692	1.33710	1.33728	1.33747	1.33765	1.33783	1.33801	1.33819	1.33837	1.33855
20.0	1.33672	1.33690	1.33708	1.33726	1.33744	1.33762	1.33780	1.33798	1.33816	1.33834
22.0	1.33651	1.33669	1.33687	1.33705	1.33722	1.33741	1.33758	1.33776	1.33794	1.33812
24.0	1.33629	1.33647	1.33665	1.33683	1.33701	1.33719	1.33736	1.33754	1.33772	1.33790
26.0	1.33607	1.33625	1.33642	1.33660	1.33678	1.33696	1.33714	1.33732	1.33749	1.33767
28.0	1.33583	1.33601	1.33618	1.33636	1.33654	1.33672	1.33690	1.33707	1.33725	1.33743
30.0	1.33558	1.33576	1.33593	1.33611	1.33629	1.33647	1.33664	1.33682	1.33700	1.33718

(p)

λ = 700 nm

TEMP °C	SALINITY (‰) 0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33108	1.33206	1.33303	1.33401	1.33498	1.33596	1.33693	1.33712	1.33732	1.33751
2.0	1.33108	1.33204	1.33301	1.33398	1.33494	1.33591	1.33687	1.33707	1.33726	1.33745
4.0	1.33105	1.33201	1.33297	1.33393	1.33488	1.33584	1.33680	1.33699	1.33718	1.33737
6.0	1.33100	1.33195	1.33290	1.33385	1.33480	1.33575	1.33670	1.33689	1.33708	1.33727
8.0	1.33093	1.33187	1.33281	1.33376	1.33470	1.33564	1.33658	1.33677	1.33696	1.33715
10.0	1.33084	1.33178	1.33271	1.33364	1.33458	1.33551	1.33644	1.33663	1.33682	1.33700
12.0	1.33074	1.33166	1.33259	1.33352	1.33444	1.33537	1.33629	1.33648	1.33667	1.33685
14.0	1.33061	1.33153	1.33245	1.33337	1.33429	1.33521	1.33613	1.33631	1.33650	1.33668
16.0	1.33047	1.33138	1.33229	1.33321	1.33412	1.33503	1.33594	1.33612	1.33630	1.33648
18.0	1.33032	1.33122	1.33213	1.33303	1.33393	1.33484	1.33574	1.33592	1.33610	1.33628
20.0	1.33015	1.33105	1.33195	1.33285	1.33374	1.33464	1.33554	1.33572	1.33590	1.33608
22.0	1.32997	1.33087	1.33176	1.33265	1.33355	1.33444	1.33533	1.33551	1.33569	1.33587
24.0	1.32978	1.33067	1.33156	1.33245	1.33334	1.33424	1.33513	1.33531	1.33548	1.33566
26.0	1.32957	1.33046	1.33135	1.33224	1.33313	1.33402	1.33491	1.33509	1.33527	1.33545
28.0	1.32936	1.33024	1.33113	1.33202	1.33290	1.33379	1.33468	1.33486	1.33503	1.33521
30.0	1.32913	1.33001	1.33089	1.33178	1.33266	1.33355	1.33443	1.33461	1.33478	1.33496

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.33771	1.33790	1.33810	1.33829	1.33849	1.33868	1.33888	1.33907	1.33927	1.33946
2.0	1.33765	1.33784	1.33803	1.33823	1.33842	1.33861	1.33881	1.33900	1.33919	1.33939
4.0	1.33757	1.33776	1.33795	1.33814	1.33833	1.33852	1.33872	1.33891	1.33910	1.33929
6.0	1.33746	1.33765	1.33784	1.33803	1.33822	1.33841	1.33860	1.33879	1.33898	1.33917
8.0	1.33733	1.33752	1.33771	1.33790	1.33809	1.33827	1.33846	1.33865	1.33884	1.33903
10.0	1.33719	1.33738	1.33756	1.33775	1.33794	1.33813	1.33831	1.33850	1.33869	1.33887
12.0	1.33704	1.33722	1.33741	1.33759	1.33778	1.33796	1.33815	1.33833	1.33852	1.33870
14.0	1.33686	1.33705	1.33723	1.33742	1.33760	1.33778	1.33797	1.33815	1.33834	1.33852
16.0	1.33667	1.33685	1.33703	1.33721	1.33740	1.33758	1.33776	1.33794	1.33812	1.33831
18.0	1.33646	1.33664	1.33682	1.33700	1.33718	1.33737	1.33755	1.33773	1.33791	1.33809
20.0	1.33626	1.33644	1.33662	1.33679	1.33697	1.33715	1.33733	1.33751	1.33769	1.33787
22.0	1.33605	1.33623	1.33641	1.33659	1.33676	1.33694	1.33712	1.33730	1.33748	1.33766
24.0	1.33584	1.33602	1.33620	1.33637	1.33655	1.33673	1.33691	1.33709	1.33727	1.33744
26.0	1.33563	1.33580	1.33598	1.33616	1.33634	1.33652	1.33669	1.33687	1.33705	1.33723
28.0	1.33539	1.33557	1.33574	1.33592	1.33610	1.33628	1.33645	1.33663	1.33681	1.33699
30.0	1.33514	1.33532	1.33549	1.33567	1.33585	1.33602	1.33620	1.33638	1.33655	1.33673

Table A-2. INDEX OF REFRACTION OF SEAWATER
Selected Laser Wavelengths – Atmospheric Pressure

(a)

[HeCd] λ = **441.6 nm**

TEMP °C	SALINITY (‰)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.34081	1.34182	1.34284	1.34386	1.34487	1.34589	1.34691	1.34711	1.34732	1.34752
2.0	1.34079	1.34180	1.34281	1.34382	1.34482	1.34583	1.34684	1.34704	1.34724	1.34744
4.0	1.34076	1.34176	1.34276	1.34375	1.34475	1.34575	1.34675	1.34695	1.34715	1.34735
6.0	1.34070	1.34169	1.34268	1.34367	1.34466	1.34565	1.34664	1.34684	1.34704	1.34724
8.0	1.34063	1.34161	1.34259	1.34357	1.34456	1.34554	1.34652	1.34672	1.34692	1.34711
10.0	1.34053	1.34151	1.34248	1.34346	1.34443	1.34541	1.34639	1.34658	1.34678	1.34697
12.0	1.34042	1.34138	1.34235	1.34332	1.34429	1.34526	1.34623	1.34642	1.34662	1.34681
14.0	1.34028	1.34125	1.34221	1.34317	1.34414	1.34510	1.34606	1.34626	1.34645	1.34664
16.0	1.34014	1.34109	1.34205	1.34301	1.34397	1.34493	1.34588	1.34608	1.34627	1.34646
18.0	1.33998	1.34093	1.34188	1.34284	1.34379	1.34475	1.34570	1.34589	1.34608	1.34627
20.0	1.33980	1.34075	1.34170	1.34265	1.34360	1.34455	1.34550	1.34569	1.34588	1.34607
22.0	1.33961	1.34056	1.34151	1.34245	1.34340	1.34435	1.34529	1.34548	1.34567	1.34586
24.0	1.33941	1.34035	1.34130	1.34224	1.34318	1.34413	1.34507	1.34526	1.34545	1.34564
26.0	1.33920	1.34014	1.34108	1.34202	1.34296	1.34390	1.34484	1.34503	1.34521	1.34540
28.0	1.33897	1.33990	1.34084	1.34178	1.34272	1.34365	1.34459	1.34478	1.34497	1.34516
30.0	1.33872	1.33966	1.34060	1.34153	1.34247	1.34340	1.34434	1.34452	1.34471	1.34490

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34772	1.34793	1.34813	1.34833	1.34854	1.34874	1.34894	1.34914	1.34935	1.34955
2.0	1.34764	1.34784	1.34805	1.34825	1.34845	1.34865	1.34885	1.34905	1.34925	1.34945
4.0	1.34754	1.34775	1.34795	1.34814	1.34834	1.34854	1.34874	1.34894	1.34914	1.34934
6.0	1.34743	1.34763	1.34783	1.34803	1.34823	1.34842	1.34862	1.34882	1.34902	1.34921
8.0	1.34731	1.34750	1.34770	1.34790	1.34809	1.34829	1.34848	1.34868	1.34888	1.34907
10.0	1.34716	1.34736	1.34755	1.34775	1.34795	1.34814	1.34833	1.34853	1.34872	1.34892
12.0	1.34700	1.34720	1.34739	1.34759	1.34778	1.34797	1.34817	1.34836	1.34855	1.34875
14.0	1.34683	1.34702	1.34722	1.34741	1.34760	1.34780	1.34799	1.34818	1.34837	1.34857
16.0	1.34665	1.34684	1.34703	1.34723	1.34742	1.34761	1.34780	1.34799	1.34818	1.34838
18.0	1.34646	1.34665	1.34684	1.34704	1.34722	1.34742	1.34761	1.34780	1.34799	1.34818
20.0	1.34626	1.34645	1.34664	1.34683	1.34702	1.34721	1.34740	1.34759	1.34778	1.34797
22.0	1.34605	1.34624	1.34643	1.34662	1.34681	1.34700	1.34719	1.34738	1.34756	1.34776
24.0	1.34583	1.34601	1.34620	1.34639	1.34658	1.34677	1.34696	1.34715	1.34733	1.34752
26.0	1.34559	1.34578	1.34597	1.34615	1.34634	1.34653	1.34672	1.34691	1.34709	1.34728
28.0	1.34534	1.34553	1.34572	1.34591	1.34609	1.34628	1.34647	1.34666	1.34684	1.34703
30.0	1.34509	1.34527	1.34546	1.34565	1.34583	1.34602	1.34621	1.34639	1.34658	1.34677

(b)

[A] λ = **457.9 nm**

TEMP °C	SALINITY (‰)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33973	1.34074	1.34176	1.34276	1.34378	1.34479	1.34580	1.34600	1.34620	1.34641
2.0	1.33972	1.34072	1.34172	1.34272	1.34373	1.34473	1.34573	1.34593	1.34613	1.34633
4.0	1.33969	1.34066	1.34167	1.34266	1.34366	1.34465	1.34564	1.34584	1.34604	1.34624
6.0	1.33963	1.34062	1.34160	1.34258	1.34357	1.34455	1.34554	1.34574	1.34593	1.34613
8.0	1.33956	1.34053	1.34151	1.34249	1.34346	1.34444	1.34542	1.34561	1.34581	1.34600
10.0	1.33946	1.34043	1.34140	1.34237	1.34334	1.34431	1.34528	1.34547	1.34567	1.34586
12.0	1.33934	1.34031	1.34127	1.34223	1.34320	1.34416	1.34512	1.34531	1.34551	1.34570
14.0	1.33921	1.34017	1.34112	1.34208	1.34304	1.34399	1.34495	1.34514	1.34533	1.34552
16.0	1.33906	1.34001	1.34096	1.34191	1.34287	1.34382	1.34477	1.34496	1.34515	1.34534
18.0	1.33890	1.33985	1.34079	1.34174	1.34269	1.34364	1.34458	1.34477	1.34496	1.34515
20.0	1.33873	1.33967	1.34061	1.34156	1.34250	1.34344	1.34438	1.34457	1.34476	1.34495
22.0	1.33854	1.33948	1.34042	1.34136	1.34230	1.34324	1.34418	1.34437	1.34455	1.34474
24.0	1.33835	1.33928	1.34022	1.34115	1.34209	1.34303	1.34396	1.34415	1.34433	1.34452
26.0	1.33813	1.33907	1.34000	1.34093	1.34186	1.34280	1.34373	1.34392	1.34410	1.34429
28.0	1.33790	1.33883	1.33977	1.34070	1.34163	1.34256	1.34349	1.34368	1.34386	1.34405
30.0	1.33766	1.33859	1.33952	1.34045	1.34138	1.34231	1.34324	1.34343	1.34361	1.34380

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34661	1.34681	1.34701	1.34721	1.34741	1.34762	1.34782	1.34802	1.34822	1.34843
2.0	1.34653	1.34673	1.34693	1.34713	1.34733	1.34753	1.34773	1.34793	1.34813	1.34833
4.0	1.34643	1.34663	1.34683	1.34703	1.34723	1.34743	1.34763	1.34783	1.34803	1.34822
6.0	1.34632	1.34652	1.34672	1.34692	1.34711	1.34731	1.34751	1.34770	1.34790	1.34810
8.0	1.34620	1.34640	1.34659	1.34679	1.34698	1.34718	1.34737	1.34757	1.34776	1.34796
10.0	1.34605	1.34625	1.34644	1.34664	1.34683	1.34702	1.34722	1.34741	1.34761	1.34780
12.0	1.34589	1.34609	1.34628	1.34647	1.34666	1.34686	1.34705	1.34724	1.34743	1.34763
14.0	1.34572	1.34591	1.34610	1.34629	1.34648	1.34667	1.34686	1.34706	1.34725	1.34744
16.0	1.34553	1.34572	1.34591	1.34610	1.34629	1.34648	1.34667	1.34686	1.34706	1.34725
18.0	1.34534	1.34553	1.34572	1.34591	1.34610	1.34629	1.34648	1.34667	1.34686	1.34704
20.0	1.34514	1.34533	1.34552	1.34571	1.34589	1.34608	1.34627	1.34646	1.34665	1.34684
22.0	1.34493	1.34512	1.34530	1.34549	1.34568	1.34587	1.34606	1.34624	1.34643	1.34662
24.0	1.34471	1.34490	1.34508	1.34527	1.34546	1.34565	1.34583	1.34602	1.34621	1.34639
26.0	1.34446	1.34466	1.34485	1.34504	1.34523	1.34541	1.34560	1.34579	1.34597	1.34616
28.0	1.34424	1.34442	1.34461	1.34479	1.34498	1.34517	1.34535	1.34554	1.34573	1.34591
30.0	1.34398	1.34417	1.34436	1.34454	1.34473	1.34491	1.34510	1.34529	1.34547	1.34566

Table A-2. (cont)

(c)

[A] λ = 476.5 nm

TEMP	SALINITY (‰)																			
°C	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.33863	1.33964	1.34064	1.34165	1.34265	1.34366	1.34466	1.34487	1.34507	1.34527	1.34547	1.34567	1.34587	1.34607	1.34627	1.34647	1.34668	1.34688	1.34708	1.34728
2.0	1.33862	1.33961	1.34061	1.34161	1.34260	1.34360	1.34460	1.34480	1.34499	1.34519	1.34539	1.34559	1.34579	1.34599	1.34619	1.34639	1.34659	1.34679	1.34699	1.34719
4.0	1.33858	1.33957	1.34056	1.34155	1.34253	1.34352	1.34451	1.34471	1.34490	1.34510	1.34530	1.34550	1.34570	1.34589	1.34609	1.34629	1.34649	1.34668	1.34688	1.34708
6.0	1.33853	1.33951	1.34049	1.34147	1.34245	1.34343	1.34441	1.34460	1.34480	1.34499	1.34519	1.34539	1.34558	1.34578	1.34597	1.34617	1.34636	1.34656	1.34676	1.34695
8.0	1.33845	1.33942	1.34040	1.34137	1.34234	1.34331	1.34429	1.34448	1.34467	1.34487	1.34506	1.34526	1.34545	1.34565	1.34584	1.34604	1.34623	1.34642	1.34662	1.34681
10.0	1.33836	1.33932	1.34029	1.34125	1.34222	1.34318	1.34415	1.34434	1.34453	1.34473	1.34492	1.34511	1.34531	1.34550	1.34569	1.34589	1.34608	1.34627	1.34647	1.34666
12.0	1.33825	1.33920	1.34016	1.34112	1.34208	1.34304	1.34400	1.34419	1.34438	1.34457	1.34476	1.34495	1.34515	1.34534	1.34553	1.34572	1.34591	1.34610	1.34630	1.34649
14.0	1.33811	1.33907	1.34002	1.34097	1.34193	1.34288	1.34383	1.34402	1.34421	1.34440	1.34459	1.34478	1.34497	1.34516	1.34536	1.34554	1.34573	1.34593	1.34612	1.34631
16.0	1.33797	1.33892	1.33986	1.34081	1.34176	1.34270	1.34365	1.34384	1.34403	1.34422	1.34441	1.34460	1.34479	1.34498	1.34517	1.34536	1.34554	1.34574	1.34592	1.34611
18.0	1.33781	1.33875	1.33969	1.34064	1.34158	1.34252	1.34346	1.34365	1.34384	1.34403	1.34422	1.34441	1.34459	1.34478	1.34497	1.34516	1.34535	1.34554	1.34573	1.34591
20.0	1.33764	1.33857	1.33951	1.34045	1.34139	1.34232	1.34326	1.34345	1.34364	1.34383	1.34401	1.34420	1.34439	1.34458	1.34476	1.34495	1.34514	1.34533	1.34552	1.34570
22.0	1.33745	1.33838	1.33931	1.34025	1.34118	1.34212	1.34305	1.34324	1.34342	1.34361	1.34380	1.34398	1.34417	1.34436	1.34455	1.34473	1.34492	1.34511	1.34529	1.34548
24.0	1.33724	1.33817	1.33910	1.34004	1.34097	1.34190	1.34283	1.34301	1.34320	1.34339	1.34357	1.34376	1.34395	1.34413	1.34432	1.34450	1.34469	1.34488	1.34506	1.34525
26.0	1.33703	1.33796	1.33888	1.33981	1.34074	1.34167	1.34260	1.34278	1.34297	1.34315	1.34334	1.34352	1.34371	1.34389	1.34408	1.34427	1.34445	1.34464	1.34482	1.34501
28.0	1.33680	1.33773	1.33865	1.33958	1.34051	1.34143	1.34236	1.34254	1.34273	1.34291	1.34310	1.34328	1.34347	1.34365	1.34384	1.34402	1.34421	1.34439	1.34458	1.34476
30.0	1.33657	1.33749	1.33841	1.33934	1.34026	1.34119	1.34211	1.34229	1.34248	1.34266	1.34285	1.34303	1.34322	1.34340	1.34359	1.34377	1.34396	1.34414	1.34433	1.34451

(d)

[A] λ = 488.0 nm

TEMP	SALINITY (‰)																			
°C	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.33802	1.33902	1.34003	1.34103	1.34203	1.34303	1.34404	1.34424	1.34444	1.34464	1.34484	1.34504	1.34524	1.34544	1.34564	1.34584	1.34604	1.34624	1.34645	1.34664
2.0	1.33801	1.33900	1.34000	1.34099	1.34198	1.34298	1.34397	1.34417	1.34437	1.34457	1.34477	1.34497	1.34516	1.34536	1.34556	1.34576	1.34596	1.34616	1.34636	1.34656
4.0	1.33797	1.33896	1.33994	1.34093	1.34191	1.34290	1.34389	1.34408	1.34428	1.34448	1.34467	1.34487	1.34507	1.34526	1.34546	1.34566	1.34586	1.34606	1.34625	1.34645
6.0	1.33791	1.33889	1.33987	1.34085	1.34182	1.34280	1.34378	1.34397	1.34417	1.34436	1.34456	1.34476	1.34495	1.34515	1.34534	1.34554	1.34573	1.34593	1.34612	1.34632
8.0	1.33784	1.33881	1.33978	1.34075	1.34172	1.34269	1.34366	1.34385	1.34404	1.34424	1.34443	1.34462	1.34482	1.34501	1.34521	1.34540	1.34560	1.34579	1.34598	1.34618
10.0	1.33775	1.33871	1.33967	1.34063	1.34160	1.34256	1.34352	1.34371	1.34390	1.34410	1.34429	1.34448	1.34467	1.34487	1.34506	1.34525	1.34544	1.34564	1.34583	1.34602
12.0	1.33764	1.33859	1.33955	1.34050	1.34146	1.34241	1.34337	1.34356	1.34375	1.34394	1.34413	1.34432	1.34451	1.34471	1.34490	1.34509	1.34528	1.34547	1.34566	1.34585
14.0	1.33751	1.33846	1.33941	1.34036	1.34131	1.34226	1.34321	1.34339	1.34359	1.34377	1.34397	1.34416	1.34434	1.34453	1.34472	1.34492	1.34510	1.34529	1.34548	1.34567
16.0	1.33737	1.33831	1.33925	1.34020	1.34114	1.34208	1.34303	1.34322	1.34341	1.34360	1.34379	1.34397	1.34416	1.34435	1.34454	1.34473	1.34492	1.34511	1.34529	1.34548
18.0	1.33721	1.33815	1.33908	1.34002	1.34096	1.34190	1.34284	1.34303	1.34322	1.34340	1.34359	1.34378	1.34397	1.34415	1.34434	1.34453	1.34472	1.34491	1.34509	1.34528
20.0	1.33703	1.33797	1.33890	1.33984	1.34077	1.34170	1.34264	1.34283	1.34301	1.34320	1.34339	1.34357	1.34376	1.34395	1.34414	1.34432	1.34451	1.34470	1.34488	1.34507
22.0	1.33684	1.33777	1.33870	1.33963	1.34057	1.34149	1.34243	1.34262	1.34280	1.34299	1.34317	1.34336	1.34354	1.34373	1.34392	1.34410	1.34429	1.34448	1.34466	1.34485
24.0	1.33664	1.33756	1.33849	1.33942	1.34035	1.34128	1.34221	1.34239	1.34258	1.34276	1.34295	1.34313	1.34332	1.34351	1.34369	1.34388	1.34406	1.34425	1.34443	1.34462
26.0	1.33642	1.33735	1.33827	1.33920	1.34012	1.34105	1.34198	1.34216	1.34234	1.34253	1.34272	1.34290	1.34309	1.34327	1.34346	1.34364	1.34383	1.34401	1.34419	1.34438
28.0	1.33620	1.33712	1.33804	1.33897	1.33989	1.34081	1.34173	1.34192	1.34210	1.34229	1.34247	1.34266	1.34284	1.34303	1.34321	1.34340	1.34358	1.34376	1.34395	1.34413
30.0	1.33596	1.33688	1.33780	1.33872	1.33965	1.34057	1.34149	1.34167	1.34185	1.34204	1.34222	1.34241	1.34259	1.34277	1.34296	1.34314	1.34333	1.34351	1.34370	1.34388

Table A-2. (cont)

(e)

[A] λ = **496.5 nm**

TEMP °C	SALINITY (‰)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33759	1.33859	1.33959	1.34059	1.34159	1.34259	1.34360	1.34380	1.34400	1.34419
2.0	1.33757	1.33857	1.33956	1.34055	1.34154	1.34254	1.34353	1.34373	1.34393	1.34412
4.0	1.33754	1.33852	1.33951	1.34049	1.34148	1.34246	1.34344	1.34364	1.34384	1.34403
6.0	1.33748	1.33846	1.33943	1.34041	1.34138	1.34236	1.34333	1.34353	1.34372	1.34392
8.0	1.33741	1.33837	1.33934	1.34031	1.34128	1.34224	1.34321	1.34340	1.34360	1.34379
10.0	1.33731	1.33827	1.33923	1.34019	1.34115	1.34211	1.34307	1.34327	1.34346	1.34365
12.0	1.33720	1.33816	1.33911	1.34006	1.34102	1.34197	1.34292	1.34311	1.34330	1.34350
14.0	1.33708	1.33803	1.33897	1.33992	1.34087	1.34181	1.34276	1.34295	1.34314	1.34333
16.0	1.33694	1.33788	1.33882	1.33976	1.34070	1.34164	1.34258	1.34277	1.34296	1.34315
18.0	1.33678	1.33771	1.33865	1.33959	1.34052	1.34146	1.34239	1.34258	1.34277	1.34296
20.0	1.33660	1.33753	1.33846	1.33940	1.34033	1.34126	1.34219	1.34238	1.34257	1.34275
22.0	1.33641	1.33734	1.33827	1.33920	1.34013	1.34105	1.34198	1.34217	1.34235	1.34254
24.0	1.33621	1.33714	1.33806	1.33899	1.33991	1.34084	1.34177	1.34195	1.34214	1.34232
26.0	1.33599	1.33692	1.33784	1.33877	1.33969	1.34061	1.34154	1.34172	1.34190	1.34209
28.0	1.33577	1.33669	1.33761	1.33853	1.33946	1.34037	1.34130	1.34148	1.34166	1.34185
30.0	1.33554	1.33645	1.33737	1.33829	1.33921	1.34013	1.34105	1.34123	1.34141	1.34160
	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34439	1.34460	1.34480	1.34499	1.34520	1.34540	1.34559	1.34580	1.34600	1.34620
2.0	1.34432	1.34452	1.34472	1.34492	1.34512	1.34532	1.34551	1.34571	1.34591	1.34611
4.0	1.34423	1.34443	1.34462	1.34482	1.34502	1.34521	1.34541	1.34561	1.34580	1.34600
6.0	1.34412	1.34431	1.34451	1.34470	1.34490	1.34509	1.34528	1.34548	1.34568	1.34587
8.0	1.34399	1.34418	1.34437	1.34457	1.34476	1.34495	1.34515	1.34534	1.34553	1.34573
10.0	1.34384	1.34403	1.34423	1.34442	1.34461	1.34480	1.34499	1.34518	1.34538	1.34557
12.0	1.34369	1.34387	1.34407	1.34426	1.34445	1.34464	1.34483	1.34502	1.34521	1.34540
14.0	1.34352	1.34371	1.34390	1.34409	1.34428	1.34447	1.34466	1.34484	1.34503	1.34522
16.0	1.34334	1.34352	1.34371	1.34390	1.34409	1.34428	1.34447	1.34465	1.34484	1.34503
18.0	1.34314	1.34333	1.34352	1.34370	1.34389	1.34408	1.34427	1.34445	1.34464	1.34483
20.0	1.34294	1.34313	1.34331	1.34350	1.34369	1.34387	1.34406	1.34424	1.34443	1.34462
22.0	1.34273	1.34291	1.34310	1.34328	1.34347	1.34366	1.34384	1.34403	1.34421	1.34440
24.0	1.34251	1.34269	1.34288	1.34306	1.34325	1.34343	1.34362	1.34380	1.34399	1.34417
26.0	1.34227	1.34246	1.34264	1.34283	1.34301	1.34320	1.34338	1.34357	1.34375	1.34394
28.0	1.34203	1.34222	1.34240	1.34258	1.34277	1.34295	1.34314	1.34332	1.34351	1.34369
30.0	1.34178	1.34196	1.34215	1.34233	1.34252	1.34270	1.34288	1.34307	1.34325	1.34343

(f)

[A] λ = **514.5 nm**

TEMP °C	SALINITY (‰)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33674	1.33774	1.33873	1.33973	1.34073	1.34173	1.34273	1.34293	1.34312	1.34332
2.0	1.33673	1.33771	1.33870	1.33969	1.34068	1.34167	1.34266	1.34286	1.34305	1.34325
4.0	1.33669	1.33767	1.33865	1.33963	1.34061	1.34159	1.34257	1.34277	1.34296	1.34316
6.0	1.33664	1.33761	1.33858	1.33955	1.34052	1.34149	1.34246	1.34266	1.34285	1.34305
8.0	1.33656	1.33752	1.33849	1.33945	1.34042	1.34138	1.34234	1.34253	1.34273	1.34292
10.0	1.33647	1.33742	1.33838	1.33933	1.34029	1.34125	1.34220	1.34239	1.34259	1.34278
12.0	1.33636	1.33731	1.33826	1.33920	1.34015	1.34110	1.34205	1.34224	1.34243	1.34262
14.0	1.33624	1.33718	1.33812	1.33906	1.34000	1.34094	1.34188	1.34207	1.34226	1.34245
16.0	1.33609	1.33703	1.33796	1.33890	1.33983	1.34077	1.34170	1.34189	1.34208	1.34227
18.0	1.33593	1.33686	1.33779	1.33872	1.33965	1.34058	1.34151	1.34170	1.34189	1.34207
20.0	1.33576	1.33668	1.33761	1.33854	1.33947	1.34039	1.34132	1.34150	1.34169	1.34187
22.0	1.33557	1.33649	1.33742	1.33834	1.33927	1.34019	1.34111	1.34130	1.34148	1.34167
24.0	1.33537	1.33629	1.33722	1.33814	1.33906	1.33998	1.34090	1.34108	1.34127	1.34145
26.0	1.33516	1.33608	1.33700	1.33792	1.33684	1.33976	1.34068	1.34086	1.34104	1.34122
28.0	1.33494	1.33585	1.33677	1.33769	1.33860	1.33952	1.34044	1.34062	1.34080	1.34099
30.0	1.33470	1.33561	1.33653	1.33744	1.33836	1.33927	1.34019	1.34037	1.34055	1.34073
	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34352	1.34372	1.34392	1.34412	1.34432	1.34452	1.34472	1.34492	1.34512	1.34532
2.0	1.34345	1.34365	1.34384	1.34404	1.34424	1.34444	1.34463	1.34483	1.34503	1.34523
4.0	1.34335	1.34355	1.34375	1.34394	1.34414	1.34433	1.34453	1.34473	1.34492	1.34512
6.0	1.34324	1.34344	1.34363	1.34382	1.34402	1.34421	1.34441	1.34460	1.34479	1.34499
8.0	1.34311	1.34331	1.34350	1.34369	1.34388	1.34408	1.34427	1.34446	1.34465	1.34485
10.0	1.34297	1.34316	1.34335	1.34354	1.34373	1.34392	1.34411	1.34431	1.34450	1.34469
12.0	1.34281	1.34300	1.34319	1.34338	1.34357	1.34376	1.34395	1.34414	1.34433	1.34451
14.0	1.34264	1.34282	1.34301	1.34320	1.34339	1.34358	1.34377	1.34396	1.34414	1.34433
16.0	1.34245	1.34264	1.34283	1.34301	1.34320	1.34339	1.34358	1.34376	1.34395	1.34414
18.0	1.34226	1.34245	1.34263	1.34282	1.34300	1.34319	1.34338	1.34356	1.34375	1.34394
20.0	1.34206	1.34225	1.34243	1.34262	1.34280	1.34299	1.34317	1.34336	1.34354	1.34373
22.0	1.34185	1.34204	1.34222	1.34241	1.34259	1.34278	1.34296	1.34315	1.34333	1.34352
24.0	1.34164	1.34182	1.34200	1.34219	1.34237	1.34256	1.34274	1.34293	1.34311	1.34330
26.0	1.34141	1.34159	1.34178	1.34196	1.34214	1.34233	1.34251	1.34270	1.34288	1.34306
28.0	1.34117	1.34135	1.34153	1.34172	1.34190	1.34209	1.34227	1.34245	1.34264	1.34282
30.0	1.34092	1.34110	1.34128	1.34147	1.34165	1.34183	1.34201	1.34220	1.34238	1.34256

Table A-2. (cont)

(g)

[NdYag] **λ = 532.0 nm**

TEMP °C	SALINITY (‰)																			
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.33599	1.33698	1.33798	1.33897	1.33997	1.34097	1.34196	1.34216	1.34236	1.34256	1.34276	1.34295	1.34316	1.34335	1.34356	1.34375	1.34395	1.34415	1.34435	1.34455
2.0	1.33597	1.33696	1.33794	1.33893	1.33991	1.34090	1.34188	1.34208	1.34228	1.34247	1.34267	1.34287	1.34307	1.34326	1.34346	1.34366	1.34385	1.34405	1.34425	1.34444
4.0	1.33594	1.33691	1.33789	1.33886	1.33984	1.34082	1.34179	1.34199	1.34218	1.34238	1.34257	1.34277	1.34296	1.34316	1.34335	1.34355	1.34374	1.34394	1.34413	1.34433
6.0	1.33589	1.33685	1.33782	1.33879	1.33976	1.34072	1.34169	1.34188	1.34208	1.34227	1.34246	1.34266	1.34285	1.34304	1.34324	1.34343	1.34362	1.34382	1.34401	1.34420
8.0	1.33582	1.33678	1.33774	1.33870	1.33966	1.34062	1.34158	1.34177	1.34196	1.34216	1.34235	1.34254	1.34273	1.34292	1.34311	1.34331	1.34350	1.34369	1.34388	1.34407
10.0	1.33573	1.33668	1.33764	1.33859	1.33954	1.34049	1.34145	1.34164	1.34183	1.34202	1.34221	1.34240	1.34259	1.34278	1.34297	1.34316	1.34335	1.34354	1.34373	1.34392
12.0	1.33562	1.33656	1.33751	1.33845	1.33940	1.34034	1.34129	1.34148	1.34166	1.34185	1.34204	1.34223	1.34242	1.34261	1.34280	1.34299	1.34318	1.34337	1.34356	1.34375
14.0	1.33549	1.33642	1.33737	1.33830	1.33924	1.34018	1.34111	1.34130	1.34149	1.34168	1.34187	1.34205	1.34224	1.34243	1.34262	1.34280	1.34299	1.34318	1.34337	1.34355
16.0	1.33534	1.33627	1.33721	1.33814	1.33907	1.34000	1.34093	1.34112	1.34130	1.34149	1.34168	1.34187	1.34205	1.34224	1.34243	1.34261	1.34280	1.34299	1.34317	1.34336
18.0	1.33518	1.33611	1.33704	1.33797	1.33889	1.33982	1.34075	1.34093	1.34112	1.34131	1.34149	1.34168	1.34186	1.34205	1.34223	1.34242	1.34260	1.34279	1.34298	1.34316
20.0	1.33501	1.33594	1.33686	1.33779	1.33871	1.33963	1.34055	1.34074	1.34093	1.34111	1.34130	1.34148	1.34167	1.34185	1.34203	1.34222	1.34240	1.34259	1.34278	1.34296
22.0	1.33483	1.33575	1.33667	1.33759	1.33851	1.33943	1.34035	1.34053	1.34072	1.34090	1.34109	1.34127	1.34146	1.34164	1.34182	1.34201	1.34219	1.34238	1.34256	1.34274
24.0	1.33463	1.33555	1.33646	1.33738	1.33830	1.33922	1.34013	1.34032	1.34050	1.34068	1.34087	1.34105	1.34124	1.34142	1.34160	1.34178	1.34197	1.34215	1.34234	1.34252
26.0	1.33442	1.33533	1.33625	1.33716	1.33808	1.33899	1.33991	1.34009	1.34027	1.34045	1.34064	1.34082	1.34100	1.34119	1.34137	1.34155	1.34174	1.34192	1.34210	1.34228
28.0	1.33419	1.33510	1.33602	1.33693	1.33784	1.33876	1.33967	1.33985	1.34003	1.34021	1.34040	1.34058	1.34076	1.34095	1.34113	1.34131	1.34149	1.34168	1.34186	1.34204
30.0	1.33395	1.33486	1.33577	1.33669	1.33760	1.33851	1.33942	1.33960	1.33978	1.33997	1.34015	1.34033	1.34051	1.34070	1.34088	1.34106	1.34124	1.34143	1.34161	1.34179

(h)

[Kr] **λ = 568.2 nm**

TEMP °C	SALINITY (‰)																			
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.33466	1.33565	1.33662	1.33762	1.33860	1.33958	1.34057	1.34077	1.34096	1.34117	1.34136	1.34156	1.34175	1.34196	1.34214	1.34235	1.34254	1.34274	1.34293	1.34314
2.0	1.33464	1.33562	1.33659	1.33758	1.33855	1.33953	1.34051	1.34070	1.34090	1.34110	1.34129	1.34149	1.34168	1.34188	1.34207	1.34227	1.34247	1.34266	1.34286	1.34306
4.0	1.33461	1.33557	1.33654	1.33751	1.33849	1.33945	1.34043	1.34062	1.34082	1.34101	1.34120	1.34140	1.34159	1.34179	1.34198	1.34217	1.34238	1.34256	1.34276	1.34295
6.0	1.33454	1.33550	1.33646	1.33743	1.33839	1.33935	1.34032	1.34051	1.34070	1.34089	1.34109	1.34128	1.34147	1.34167	1.34186	1.34205	1.34225	1.34243	1.34263	1.34282
8.0	1.33446	1.33541	1.33637	1.33732	1.33828	1.33923	1.34019	1.34038	1.34057	1.34076	1.34095	1.34114	1.34133	1.34153	1.34172	1.34190	1.34210	1.34229	1.34248	1.34267
10.0	1.33437	1.33531	1.33626	1.33721	1.33815	1.33910	1.34005	1.34024	1.34043	1.34062	1.34080	1.34099	1.34118	1.34137	1.34156	1.34175	1.34194	1.34213	1.34232	1.34251
12.0	1.33426	1.33520	1.33614	1.33708	1.33802	1.33896	1.33990	1.34009	1.34027	1.34046	1.34065	1.34084	1.34102	1.34121	1.34140	1.34159	1.34177	1.34196	1.34215	1.34234
14.0	1.33414	1.33507	1.33600	1.33694	1.33787	1.33881	1.33974	1.33993	1.34011	1.34030	1.34048	1.34067	1.34086	1.34104	1.34123	1.34141	1.34160	1.34179	1.34197	1.34216
16.0	1.33401	1.33493	1.33586	1.33678	1.33771	1.33864	1.33957	1.33975	1.33994	1.34012	1.34030	1.34049	1.34068	1.34086	1.34105	1.34123	1.34141	1.34160	1.34178	1.34197
18.0	1.33386	1.33477	1.33570	1.33661	1.33754	1.33845	1.33938	1.33956	1.33974	1.33993	1.34011	1.34030	1.34048	1.34067	1.34085	1.34103	1.34122	1.34140	1.34159	1.34177
20.0	1.33368	1.33459	1.33552	1.33642	1.33735	1.33826	1.33918	1.33936	1.33954	1.33972	1.33991	1.34009	1.34027	1.34046	1.34064	1.34083	1.34101	1.34119	1.34137	1.34156
22.0	1.33350	1.33440	1.33532	1.33622	1.33714	1.33805	1.33896	1.33915	1.33933	1.33951	1.33969	1.33987	1.34006	1.34024	1.34043	1.34061	1.34079	1.34097	1.34115	1.34134
24.0	1.33329	1.33420	1.33511	1.33602	1.33693	1.33783	1.33874	1.33893	1.33911	1.33929	1.33947	1.33965	1.33984	1.34002	1.34020	1.34039	1.34056	1.34074	1.34093	1.34111
26.0	1.33308	1.33399	1.33489	1.33580	1.33670	1.33761	1.33852	1.33870	1.33888	1.33907	1.33925	1.33942	1.33961	1.33979	1.33997	1.34015	1.34033	1.34051	1.34069	1.34088
28.0	1.33286	1.33377	1.33467	1.33557	1.33647	1.33738	1.33829	1.33847	1.33865	1.33883	1.33901	1.33919	1.33937	1.33955	1.33974	1.33992	1.34010	1.34028	1.34046	1.34064
30.0	1.33263	1.33353	1.33444	1.33534	1.33624	1.33714	1.33805	1.33823	1.33841	1.33859	1.33877	1.33896	1.33914	1.33931	1.33949	1.33968	1.33986	1.34003	1.34022	1.34040

Table A-2. (cont)

(i)

[HeNe] λ = 632.8 nm

TEMP	SALINITY (0/00)																			
°C	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.33271	1.33368	1.33467	1.33565	1.33663	1.33761	1.33858	1.33878	1.33898	1.33918	1.33937	1.33957	1.33976	1.33996	1.34016	1.34035	1.34055	1.34075	1.34094	1.34114
2.0	1.33269	1.33366	1.33463	1.33560	1.33658	1.33755	1.33852	1.33871	1.33891	1.33910	1.33930	1.33949	1.33968	1.33988	1.34007	1.34027	1.34046	1.34066	1.34085	1.34105
4.0	1.33265	1.33362	1.33458	1.33554	1.33651	1.33747	1.33844	1.33863	1.33882	1.33901	1.33921	1.33940	1.33959	1.33978	1.33997	1.34017	1.34036	1.34055	1.34075	1.34094
6.0	1.33260	1.33356	1.33451	1.33546	1.33642	1.33737	1.33833	1.33852	1.33871	1.33890	1.33910	1.33929	1.33948	1.33967	1.33986	1.34005	1.34024	1.34043	1.34063	1.34082
8.0	1.33253	1.33348	1.33442	1.33537	1.33632	1.33726	1.33821	1.33840	1.33859	1.33878	1.33897	1.33916	1.33935	1.33954	1.33973	1.33992	1.34011	1.34030	1.34049	1.34068
10.0	1.33244	1.33338	1.33432	1.33526	1.33620	1.33714	1.33808	1.33827	1.33845	1.33864	1.33883	1.33902	1.33921	1.33939	1.33958	1.33977	1.33996	1.34015	1.34033	1.34052
12.0	1.33234	1.33327	1.33420	1.33513	1.33606	1.33699	1.33792	1.33811	1.33830	1.33848	1.33867	1.33886	1.33904	1.33923	1.33942	1.33960	1.33979	1.33998	1.34016	1.34035
14.0	1.33222	1.33314	1.33406	1.33499	1.33591	1.33683	1.33776	1.33794	1.33813	1.33831	1.33850	1.33868	1.33887	1.33905	1.33924	1.33942	1.33961	1.33979	1.33998	1.34016
16.0	1.33208	1.33300	1.33391	1.33483	1.33575	1.33666	1.33758	1.33776	1.33795	1.33813	1.33831	1.33850	1.33868	1.33887	1.33905	1.33923	1.33942	1.33960	1.33978	1.33996
18.0	1.33193	1.33284	1.33375	1.33466	1.33557	1.33648	1.33739	1.33758	1.33776	1.33794	1.33812	1.33830	1.33849	1.33867	1.33885	1.33903	1.33922	1.33940	1.33958	1.33976
20.0	1.33175	1.33266	1.33357	1.33447	1.33538	1.33629	1.33720	1.33738	1.33756	1.33774	1.33792	1.33810	1.33828	1.33846	1.33865	1.33883	1.33901	1.33919	1.33937	1.33955
22.0	1.33157	1.33247	1.33337	1.33428	1.33518	1.33608	1.33699	1.33716	1.33735	1.33753	1.33771	1.33789	1.33807	1.33825	1.33843	1.33861	1.33879	1.33897	1.33915	1.33933
24.0	1.33137	1.33227	1.33317	1.33407	1.33497	1.33587	1.33677	1.33694	1.33712	1.33731	1.33749	1.33767	1.33785	1.33803	1.33821	1.33838	1.33856	1.33875	1.33893	1.33910
26.0	1.33116	1.33206	1.33295	1.33385	1.33475	1.33564	1.33654	1.33672	1.33690	1.33708	1.33726	1.33744	1.33762	1.33779	1.33797	1.33815	1.33833	1.33851	1.33869	1.33887
28.0	1.33094	1.33183	1.33273	1.33362	1.33452	1.33541	1.33630	1.33648	1.33666	1.33684	1.33702	1.33720	1.33738	1.33756	1.33774	1.33791	1.33809	1.33827	1.33845	1.33863
30.0	1.33071	1.33160	1.33249	1.33339	1.33428	1.33517	1.33606	1.33624	1.33642	1.33660	1.33678	1.33696	1.33714	1.33731	1.33749	1.33767	1.33785	1.33803	1.33820	1.33838

(j)

[Kr] λ = 647.1 nm

TEMP	SALINITY (0/00)																			
°C	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.33233	1.33331	1.33429	1.33527	1.33625	1.33723	1.33821	1.33840	1.33860	1.33879	1.33899	1.33919	1.33939	1.33958	1.33978	1.33997	1.34017	1.34036	1.34056	1.34076
2.0	1.33231	1.33329	1.33426	1.33523	1.33620	1.33717	1.33814	1.33833	1.33853	1.33872	1.33892	1.33911	1.33931	1.33950	1.33969	1.33989	1.34008	1.34028	1.34047	1.34066
4.0	1.33228	1.33324	1.33420	1.33517	1.33613	1.33709	1.33805	1.33825	1.33844	1.33863	1.33882	1.33902	1.33921	1.33940	1.33959	1.33978	1.33998	1.34017	1.34036	1.34056
6.0	1.33222	1.33318	1.33413	1.33509	1.33604	1.33700	1.33795	1.33814	1.33833	1.33852	1.33871	1.33890	1.33909	1.33928	1.33947	1.33967	1.33986	1.34005	1.34024	1.34043
8.0	1.33215	1.33310	1.33404	1.33499	1.33593	1.33688	1.33783	1.33802	1.33821	1.33840	1.33858	1.33877	1.33896	1.33915	1.33934	1.33953	1.33972	1.33991	1.34010	1.34029
10.0	1.33206	1.33300	1.33394	1.33488	1.33582	1.33676	1.33769	1.33788	1.33807	1.33826	1.33844	1.33863	1.33882	1.33901	1.33919	1.33938	1.33957	1.33976	1.33995	1.34013
12.0	1.33196	1.33289	1.33382	1.33475	1.33568	1.33661	1.33754	1.33773	1.33792	1.33810	1.33829	1.33847	1.33866	1.33885	1.33903	1.33922	1.33940	1.33959	1.33978	1.33996
14.0	1.33184	1.33276	1.33369	1.33461	1.33554	1.33646	1.33738	1.33757	1.33775	1.33793	1.33812	1.33830	1.33849	1.33867	1.33886	1.33904	1.33923	1.33941	1.33960	1.33978
16.0	1.33170	1.33262	1.33353	1.33445	1.33537	1.33628	1.33720	1.33739	1.33757	1.33775	1.33794	1.33812	1.33830	1.33849	1.33867	1.33885	1.33904	1.33922	1.33940	1.33959
18.0	1.33154	1.33246	1.33337	1.33428	1.33519	1.33610	1.33702	1.33720	1.33738	1.33756	1.33775	1.33793	1.33811	1.33829	1.33847	1.33866	1.33884	1.33902	1.33920	1.33939
20.0	1.33137	1.33228	1.33319	1.33409	1.33500	1.33591	1.33682	1.33700	1.33718	1.33736	1.33754	1.33772	1.33791	1.33809	1.33827	1.33845	1.33863	1.33881	1.33899	1.33917
22.0	1.33119	1.33209	1.33299	1.33390	1.33480	1.33570	1.33661	1.33679	1.33697	1.33715	1.33733	1.33751	1.33769	1.33787	1.33805	1.33823	1.33841	1.33859	1.33877	1.33895
24.0	1.33100	1.33189	1.33279	1.33369	1.33459	1.33549	1.33639	1.33657	1.33675	1.33693	1.33711	1.33729	1.33747	1.33765	1.33782	1.33801	1.33819	1.33837	1.33854	1.33873
26.0	1.33079	1.33168	1.33258	1.33348	1.33437	1.33526	1.33616	1.33634	1.33652	1.33670	1.33688	1.33706	1.33724	1.33741	1.33759	1.33777	1.33795	1.33813	1.33831	1.33849
28.0	1.33057	1.33146	1.33235	1.33325	1.33414	1.33503	1.33593	1.33610	1.33628	1.33646	1.33664	1.33682	1.33700	1.33717	1.33735	1.33753	1.33771	1.33789	1.33807	1.33825
30.0	1.33033	1.33122	1.33212	1.33301	1.33390	1.33479	1.33568	1.33586	1.33604	1.33622	1.33639	1.33657	1.33675	1.33693	1.33711	1.33729	1.33746	1.33764	1.33782	1.33800

Table A-3. INDEX OF REFRACTION OF SEAWATER

Wavelengths used by Mehu and Johannin-Gilles – Atmospheric Pressure

(a)

[Hg] λ = **404.7 nm**

TEMP °C	SALINITY (‰)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.34375	1.34478	1.34581	1.34685	1.34788	1.34891	1.34994	1.35015	1.35035	1.35056
2.0	1.34374	1.34476	1.34578	1.34680	1.34782	1.34884	1.34986	1.35006	1.35027	1.35047
4.0	1.34370	1.34471	1.34573	1.34673	1.34774	1.34875	1.34976	1.34997	1.35017	1.35037
6.0	1.34365	1.34465	1.34565	1.34665	1.34765	1.34866	1.34966	1.34986	1.35006	1.35026
8.0	1.34357	1.34457	1.34556	1.34656	1.34755	1.34854	1.34954	1.34974	1.34994	1.35014
10.0	1.34348	1.34447	1.34545	1.34644	1.34743	1.34842	1.34941	1.34961	1.34981	1.35000
12.0	1.34336	1.34435	1.34533	1.34631	1.34730	1.34828	1.34926	1.34946	1.34966	1.34985
14.0	1.34323	1.34421	1.34519	1.34617	1.34714	1.34812	1.34910	1.34930	1.34949	1.34969
16.0	1.34308	1.34405	1.34503	1.34600	1.34697	1.34795	1.34892	1.34912	1.34931	1.34951
18.0	1.34292	1.34388	1.34486	1.34582	1.34679	1.34776	1.34873	1.34893	1.34912	1.34932
20.0	1.34274	1.34370	1.34467	1.34563	1.34660	1.34757	1.34853	1.34873	1.34892	1.34911
22.0	1.34255	1.34351	1.34447	1.34543	1.34639	1.34736	1.34832	1.34851	1.34871	1.34890
24.0	1.34234	1.34330	1.34426	1.34522	1.34618	1.34714	1.34810	1.34829	1.34848	1.34867
26.0	1.34213	1.34308	1.34404	1.34500	1.34595	1.34691	1.34786	1.34805	1.34825	1.34844
28.0	1.34190	1.34285	1.34380	1.34476	1.34571	1.34666	1.34762	1.34781	1.34800	1.34819
30.0	1.34166	1.34261	1.34356	1.34451	1.34546	1.34641	1.34736	1.34755	1.34774	1.34793

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.35077	1.35097	1.35118	1.35138	1.35159	1.35180	1.35200	1.35221	1.35242	1.35263
2.0	1.35067	1.35088	1.35108	1.35129	1.35149	1.35169	1.35190	1.35210	1.35231	1.35251
4.0	1.35057	1.35077	1.35098	1.35118	1.35138	1.35158	1.35178	1.35199	1.35219	1.35239
6.0	1.35046	1.35066	1.35086	1.35106	1.35126	1.35146	1.35166	1.35186	1.35206	1.35226
8.0	1.35034	1.35054	1.35073	1.35093	1.35113	1.35133	1.35153	1.35173	1.35193	1.35213
10.0	1.35020	1.35040	1.35060	1.35080	1.35099	1.35119	1.35139	1.35158	1.35178	1.35198
12.0	1.35005	1.35025	1.35044	1.35064	1.35083	1.35103	1.35123	1.35143	1.35162	1.35182
14.0	1.34988	1.35008	1.35027	1.35047	1.35066	1.35086	1.35106	1.35125	1.35145	1.35164
16.0	1.34970	1.34990	1.35009	1.35029	1.35048	1.35067	1.35087	1.35106	1.35126	1.35145
18.0	1.34951	1.34970	1.34990	1.35009	1.35029	1.35048	1.35067	1.35087	1.35106	1.35125
20.0	1.34930	1.34950	1.34969	1.34989	1.35008	1.35027	1.35047	1.35066	1.35085	1.35104
22.0	1.34909	1.34928	1.34947	1.34967	1.34986	1.35005	1.35025	1.35044	1.35063	1.35082
24.0	1.34886	1.34906	1.34925	1.34944	1.34963	1.34982	1.35001	1.35021	1.35040	1.35059
26.0	1.34863	1.34882	1.34901	1.34920	1.34939	1.34958	1.34977	1.34996	1.35016	1.35035
28.0	1.34838	1.34857	1.34876	1.34895	1.34914	1.34933	1.34952	1.34971	1.34990	1.35009
30.0	1.34812	1.34831	1.34850	1.34869	1.34888	1.34907	1.34926	1.34945	1.34964	1.34983

(b)

[Hg] λ = **435.8 nm**

TEMP °C	SALINITY (‰)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.34121	1.34223	1.34325	1.34427	1.34529	1.34631	1.34733	1.34753	1.34774	1.34794
2.0	1.34120	1.34221	1.34322	1.34423	1.34523	1.34625	1.34726	1.34746	1.34766	1.34786
4.0	1.34116	1.34216	1.34316	1.34416	1.34516	1.34616	1.34716	1.34737	1.34756	1.34776
6.0	1.34111	1.34210	1.34309	1.34408	1.34507	1.34607	1.34706	1.34726	1.34745	1.34765
8.0	1.34103	1.34202	1.34300	1.34398	1.34497	1.34595	1.34694	1.34713	1.34733	1.34753
10.0	1.34094	1.34191	1.34289	1.34387	1.34485	1.34582	1.34680	1.34700	1.34719	1.34739
12.0	1.34082	1.34179	1.34277	1.34373	1.34471	1.34568	1.34665	1.34684	1.34704	1.34723
14.0	1.34069	1.34165	1.34262	1.34359	1.34455	1.34552	1.34648	1.34667	1.34687	1.34706
16.0	1.34054	1.34150	1.34246	1.34342	1.34439	1.34534	1.34630	1.34650	1.34669	1.34688
18.0	1.34038	1.34134	1.34229	1.34325	1.34421	1.34517	1.34612	1.34631	1.34651	1.34669
20.0	1.34021	1.34116	1.34211	1.34307	1.34402	1.34497	1.34593	1.34612	1.34631	1.34650
22.0	1.34002	1.34097	1.34192	1.34287	1.34382	1.34477	1.34571	1.34590	1.34610	1.34628
24.0	1.33981	1.34076	1.34171	1.34265	1.34360	1.34454	1.34549	1.34568	1.34587	1.34606
26.0	1.33960	1.34054	1.34148	1.34243	1.34337	1.34431	1.34525	1.34544	1.34563	1.34582
28.0	1.33937	1.34031	1.34125	1.34219	1.34313	1.34407	1.34501	1.34520	1.34538	1.34557
30.0	1.33913	1.34007	1.34100	1.34194	1.34288	1.34381	1.34475	1.34494	1.34513	1.34531

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34814	1.34835	1.34855	1.34876	1.34896	1.34916	1.34937	1.34957	1.34978	1.34998
2.0	1.34806	1.34826	1.34847	1.34867	1.34887	1.34907	1.34927	1.34947	1.34968	1.34988
4.0	1.34796	1.34816	1.34836	1.34856	1.34876	1.34896	1.34916	1.34936	1.34956	1.34976
6.0	1.34785	1.34805	1.34825	1.34845	1.34864	1.34884	1.34904	1.34924	1.34944	1.34964
8.0	1.34773	1.34792	1.34812	1.34831	1.34851	1.34871	1.34891	1.34910	1.34930	1.34949
10.0	1.34758	1.34778	1.34797	1.34817	1.34837	1.34856	1.34876	1.34895	1.34915	1.34934
12.0	1.34742	1.34762	1.34781	1.34801	1.34820	1.34839	1.34859	1.34878	1.34898	1.34917
14.0	1.34725	1.34745	1.34764	1.34783	1.34803	1.34822	1.34841	1.34861	1.34880	1.34899
16.0	1.34707	1.34727	1.34746	1.34765	1.34784	1.34803	1.34823	1.34842	1.34861	1.34881
18.0	1.34689	1.34708	1.34727	1.34746	1.34765	1.34784	1.34804	1.34823	1.34842	1.34861
20.0	1.34669	1.34688	1.34707	1.34726	1.34745	1.34764	1.34783	1.34802	1.34821	1.34840
22.0	1.34647	1.34666	1.34685	1.34704	1.34723	1.34742	1.34761	1.34780	1.34799	1.34818
24.0	1.34625	1.34644	1.34662	1.34682	1.34700	1.34719	1.34738	1.34757	1.34776	1.34795
26.0	1.34601	1.34620	1.34638	1.34658	1.34676	1.34695	1.34714	1.34733	1.34752	1.34771
28.0	1.34576	1.34595	1.34614	1.34632	1.34651	1.34670	1.34689	1.34707	1.34726	1.34745
30.0	1.34550	1.34569	1.34588	1.34606	1.34625	1.34644	1.34663	1.34681	1.34700	1.34719

Table A-3. (cont)

(c)

[Cd] λ = 467.8 nm

TEMP °C	SALINITY (0/00)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33913	1.34014	1.34115	1.34215	1.34316	1.34417	1.34517	1.34538	1.34558	1.34578
2.0	1.33912	1.34012	1.34111	1.34211	1.34311	1.34411	1.34511	1.34531	1.34551	1.34571
4.0	1.33908	1.34007	1.34106	1.34205	1.34304	1.34403	1.34502	1.34522	1.34542	1.34562
6.0	1.33903	1.34001	1.34099	1.34197	1.34295	1.34394	1.34492	1.34512	1.34531	1.34551
8.0	1.33895	1.33993	1.34090	1.34188	1.34285	1.34383	1.34480	1.34499	1.34519	1.34538
10.0	1.33886	1.33983	1.34079	1.34176	1.34273	1.34369	1.34466	1.34485	1.34505	1.34524
12.0	1.33874	1.33970	1.34066	1.34162	1.34258	1.34354	1.34451	1.34470	1.34489	1.34508
14.0	1.33861	1.33957	1.34052	1.34147	1.34243	1.34338	1.34434	1.34453	1.34472	1.34491
16.0	1.33846	1.33941	1.34036	1.34131	1.34226	1.34321	1.34416	1.34435	1.34453	1.34472
18.0	1.33830	1.33924	1.34019	1.34113	1.34208	1.34302	1.34397	1.34416	1.34434	1.34453
20.0	1.33813	1.33907	1.34001	1.34095	1.34189	1.34283	1.34377	1.34396	1.34414	1.34433
22.0	1.33794	1.33888	1.33982	1.34075	1.34169	1.34262	1.34356	1.34375	1.34393	1.34412
24.0	1.33774	1.33868	1.33961	1.34054	1.34147	1.34241	1.34334	1.34353	1.34371	1.34390
26.0	1.33753	1.33846	1.33939	1.34032	1.34125	1.34218	1.34311	1.34330	1.34348	1.34367
28.0	1.33730	1.33823	1.33916	1.34009	1.34102	1.34194	1.34287	1.34306	1.34324	1.34343
30.0	1.33706	1.33799	1.33891	1.33984	1.34077	1.34169	1.34262	1.34281	1.34299	1.34318
	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34598	1.34618	1.34639	1.34659	1.34679	1.34699	1.34719	1.34739	1.34759	1.34780
2.0	1.34591	1.34611	1.34631	1.34651	1.34671	1.34691	1.34711	1.34731	1.34750	1.34770
4.0	1.34581	1.34601	1.34621	1.34641	1.34661	1.34680	1.34700	1.34720	1.34740	1.34760
6.0	1.34570	1.34590	1.34610	1.34629	1.34649	1.34668	1.34688	1.34708	1.34728	1.34747
8.0	1.34558	1.34577	1.34597	1.34616	1.34636	1.34655	1.34675	1.34694	1.34714	1.34733
10.0	1.34543	1.34563	1.34582	1.34602	1.34621	1.34640	1.34660	1.34679	1.34698	1.34718
12.0	1.34527	1.34547	1.34566	1.34585	1.34604	1.34623	1.34643	1.34662	1.34681	1.34700
14.0	1.34510	1.34529	1.34548	1.34567	1.34586	1.34605	1.34624	1.34643	1.34663	1.34682
16.0	1.34492	1.34510	1.34529	1.34548	1.34567	1.34586	1.34605	1.34624	1.34643	1.34662
18.0	1.34472	1.34491	1.34510	1.34529	1.34548	1.34567	1.34585	1.34604	1.34623	1.34642
20.0	1.34452	1.34471	1.34490	1.34508	1.34527	1.34546	1.34565	1.34584	1.34602	1.34621
22.0	1.34431	1.34449	1.34468	1.34487	1.34506	1.34524	1.34543	1.34562	1.34581	1.34599
24.0	1.34409	1.34427	1.34446	1.34464	1.34483	1.34502	1.34521	1.34539	1.34558	1.34577
26.0	1.34385	1.34404	1.34423	1.34441	1.34460	1.34479	1.34497	1.34516	1.34534	1.34553
28.0	1.34361	1.34380	1.34398	1.34417	1.34436	1.34454	1.34473	1.34491	1.34510	1.34529
30.0	1.34336	1.34355	1.34373	1.34392	1.34411	1.34429	1.34448	1.34466	1.34485	1.34503

(d)

[Cd] λ = 508.6 nm

TEMP °C	SALINITY (0/00)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33701	1.33801	1.33901	1.34001	1.34100	1.34201	1.34301	1.34320	1.34340	1.34361
2.0	1.33700	1.33799	1.33898	1.33997	1.34096	1.34195	1.34294	1.34314	1.34333	1.34353
4.0	1.33697	1.33794	1.33893	1.33991	1.34089	1.34187	1.34285	1.34305	1.34324	1.34344
6.0	1.33691	1.33788	1.33885	1.33982	1.34080	1.34177	1.34274	1.34294	1.34313	1.34333
8.0	1.33683	1.33779	1.33876	1.33972	1.34069	1.34165	1.34262	1.34281	1.34301	1.34320
10.0	1.33674	1.33769	1.33865	1.33961	1.34057	1.34152	1.34248	1.34267	1.34286	1.34306
12.0	1.33663	1.33758	1.33853	1.33948	1.34043	1.34138	1.34233	1.34252	1.34271	1.34290
14.0	1.33651	1.33745	1.33839	1.33934	1.34028	1.34122	1.34216	1.34235	1.34254	1.34273
16.0	1.33636	1.33730	1.33824	1.33917	1.34011	1.34105	1.34199	1.34217	1.34236	1.34255
18.0	1.33620	1.33714	1.33807	1.33900	1.33993	1.34087	1.34180	1.34198	1.34217	1.34236
20.0	1.33603	1.33696	1.33789	1.33881	1.33974	1.34067	1.34160	1.34178	1.34197	1.34216
22.0	1.33584	1.33677	1.33769	1.33862	1.33954	1.34047	1.34139	1.34158	1.34176	1.34195
24.0	1.33564	1.33656	1.33749	1.33841	1.33933	1.34025	1.34118	1.34136	1.34155	1.34173
26.0	1.33543	1.33635	1.33727	1.33819	1.33911	1.34003	1.34095	1.34114	1.34132	1.34150
28.0	1.33521	1.33612	1.33704	1.33796	1.33888	1.33979	1.34071	1.34090	1.34108	1.34126
30.0	1.33497	1.33588	1.33680	1.33771	1.33863	1.33955	1.34046	1.34065	1.34083	1.34101
	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34380	1.34400	1.34420	1.34440	1.34460	1.34480	1.34500	1.34520	1.34540	1.34560
2.0	1.34373	1.34393	1.34413	1.34432	1.34452	1.34472	1.34492	1.34512	1.34531	1.34551
4.0	1.34364	1.34383	1.34403	1.34423	1.34442	1.34462	1.34481	1.34501	1.34521	1.34540
6.0	1.34352	1.34372	1.34391	1.34411	1.34430	1.34450	1.34469	1.34488	1.34508	1.34527
8.0	1.34339	1.34359	1.34378	1.34397	1.34416	1.34436	1.34455	1.34474	1.34493	1.34513
10.0	1.34325	1.34344	1.34363	1.34382	1.34401	1.34420	1.34440	1.34459	1.34478	1.34497
12.0	1.34309	1.34328	1.34347	1.34366	1.34385	1.34404	1.34423	1.34442	1.34461	1.34480
14.0	1.34292	1.34311	1.34330	1.34348	1.34367	1.34386	1.34405	1.34424	1.34443	1.34462
16.0	1.34274	1.34292	1.34311	1.34330	1.34348	1.34367	1.34386	1.34405	1.34424	1.34442
18.0	1.34254	1.34273	1.34292	1.34310	1.34329	1.34348	1.34366	1.34385	1.34404	1.34422
20.0	1.34234	1.34253	1.34271	1.34290	1.34308	1.34327	1.34346	1.34364	1.34383	1.34401
22.0	1.34213	1.34232	1.34250	1.34269	1.34287	1.34306	1.34324	1.34343	1.34361	1.34380
24.0	1.34192	1.34210	1.34229	1.34247	1.34266	1.34284	1.34302	1.34321	1.34339	1.34358
26.0	1.34169	1.34187	1.34206	1.34224	1.34243	1.34261	1.34279	1.34298	1.34316	1.34335
28.0	1.34145	1.34163	1.34181	1.34200	1.34218	1.34237	1.34255	1.34273	1.34292	1.34310
30.0	1.34119	1.34138	1.34156	1.34174	1.34193	1.34211	1.34229	1.34248	1.34266	1.34284

Table A-3. (cont)

(e)

[Hg] λ = 546.1 nm

TEMP	SALINITY (0/00)									
°C	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33545	1.33644	1.33743	1.33842	1.33941	1.34041	1.34140	1.34159	1.34179	1.34199
2.0	1.33543	1.33641	1.33739	1.33838	1.33936	1.34034	1.34132	1.34152	1.34171	1.34191
4.0	1.33539	1.33636	1.33734	1.33831	1.33928	1.34026	1.34123	1.34142	1.34162	1.34181
6.0	1.33534	1.33630	1.33727	1.33823	1.33920	1.34016	1.34113	1.34132	1.34151	1.34171
8.0	1.33527	1.33622	1.33718	1.33814	1.33910	1.34006	1.34101	1.34120	1.34139	1.34159
10.0	1.33518	1.33613	1.33708	1.33803	1.33898	1.33993	1.34088	1.34107	1.34126	1.34145
12.0	1.33507	1.33601	1.33695	1.33789	1.33884	1.33978	1.34072	1.34091	1.34110	1.34129
14.0	1.33494	1.33587	1.33681	1.33775	1.33868	1.33962	1.34055	1.34074	1.34093	1.34111
16.0	1.33479	1.33572	1.33666	1.33758	1.33851	1.33945	1.34037	1.34056	1.34075	1.34093
18.0	1.33464	1.33556	1.33649	1.33742	1.33834	1.33926	1.34019	1.34038	1.34056	1.34074
20.0	1.33447	1.33539	1.33631	1.33723	1.33815	1.33907	1.34000	1.34018	1.34036	1.34055
22.0	1.33428	1.33520	1.33612	1.33704	1.33795	1.33887	1.33979	1.33997	1.34015	1.34034
24.0	1.33408	1.33500	1.33591	1.33683	1.33774	1.33865	1.33957	1.33975	1.33994	1.34012
26.0	1.33387	1.33478	1.33569	1.33661	1.33751	1.33843	1.33934	1.33952	1.33971	1.33989
28.0	1.33365	1.33455	1.33547	1.33638	1.33728	1.33819	1.33910	1.33929	1.33947	1.33965
30.0	1.33341	1.33432	1.33522	1.33613	1.33704	1.33795	1.33886	1.33904	1.33922	1.33940

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34219	1.34239	1.34259	1.34279	1.34298	1.34318	1.34338	1.34358	1.34378	1.34398
2.0	1.34211	1.34230	1.34250	1.34270	1.34289	1.34309	1.34328	1.34348	1.34368	1.34387
4.0	1.34201	1.34220	1.34240	1.34259	1.34279	1.34298	1.34318	1.34337	1.34357	1.34376
6.0	1.34190	1.34209	1.34228	1.34248	1.34267	1.34286	1.34306	1.34325	1.34344	1.34364
8.0	1.34178	1.34197	1.34216	1.34235	1.34255	1.34273	1.34293	1.34312	1.34331	1.34350
10.0	1.34164	1.34183	1.34202	1.34221	1.34240	1.34259	1.34278	1.34297	1.34316	1.34335
12.0	1.34148	1.34166	1.34185	1.34204	1.34223	1.34242	1.34261	1.34280	1.34299	1.34317
14.0	1.34130	1.34149	1.34167	1.34186	1.34205	1.34224	1.34243	1.34261	1.34280	1.34299
16.0	1.34112	1.34130	1.34149	1.34168	1.34186	1.34205	1.34224	1.34242	1.34261	1.34280
18.0	1.34093	1.34112	1.34130	1.34149	1.34167	1.34186	1.34204	1.34223	1.34241	1.34260
20.0	1.34073	1.34092	1.34110	1.34129	1.34147	1.34166	1.34184	1.34202	1.34221	1.34239
22.0	1.34052	1.34071	1.34089	1.34107	1.34126	1.34144	1.34162	1.34181	1.34199	1.34217
24.0	1.34030	1.34048	1.34066	1.34085	1.34103	1.34122	1.34140	1.34158	1.34176	1.34194
26.0	1.34007	1.34025	1.34043	1.34062	1.34080	1.34098	1.34116	1.34134	1.34153	1.34171
28.0	1.33983	1.34001	1.34019	1.34038	1.34056	1.34074	1.34092	1.34110	1.34129	1.34147
30.0	1.33959	1.33977	1.33995	1.34013	1.34031	1.34049	1.34068	1.34086	1.34104	1.34122

(f)

[Kr] λ = 577.0 nm

TEMP	SALINITY (0/00)									
°C	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33435	1.33534	1.33632	1.33731	1.33829	1.33928	1.34027	1.34046	1.34066	1.34086
2.0	1.33434	1.33532	1.33629	1.33727	1.33825	1.33923	1.34021	1.34040	1.34060	1.34079
4.0	1.33430	1.33527	1.33624	1.33721	1.33818	1.33915	1.34012	1.34032	1.34051	1.34070
6.0	1.33425	1.33521	1.33617	1.33713	1.33809	1.33906	1.34002	1.34021	1.34040	1.34059
8.0	1.33417	1.33512	1.33608	1.33703	1.33798	1.33894	1.33989	1.34008	1.34027	1.34046
10.0	1.33408	1.33502	1.33597	1.33692	1.33786	1.33881	1.33975	1.33994	1.34013	1.34032
12.0	1.33397	1.33491	1.33585	1.33679	1.33772	1.33866	1.33960	1.33979	1.33998	1.34016
14.0	1.33385	1.33478	1.33571	1.33664	1.33757	1.33850	1.33944	1.33962	1.33981	1.34000
16.0	1.33370	1.33463	1.33556	1.33648	1.33741	1.33833	1.33926	1.33945	1.33963	1.33982
18.0	1.33355	1.33447	1.33539	1.33631	1.33723	1.33815	1.33907	1.33926	1.33944	1.33962
20.0	1.33338	1.33429	1.33521	1.33612	1.33704	1.33796	1.33887	1.33906	1.33924	1.33942
22.0	1.33319	1.33410	1.33502	1.33593	1.33684	1.33775	1.33866	1.33884	1.33903	1.33921
24.0	1.33299	1.33390	1.33481	1.33572	1.33663	1.33753	1.33844	1.33862	1.33881	1.33899
26.0	1.33278	1.33369	1.33459	1.33550	1.33640	1.33731	1.33822	1.33840	1.33858	1.33876
28.0	1.33256	1.33346	1.33437	1.33527	1.33617	1.33708	1.33798	1.33816	1.33835	1.33853
30.0	1.33233	1.33323	1.33413	1.33504	1.33594	1.33684	1.33775	1.33793	1.33811	1.33829

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34105	1.34125	1.34145	1.34165	1.34184	1.34204	1.34223	1.34243	1.34263	1.34283
2.0	1.34099	1.34118	1.34138	1.34157	1.34177	1.34196	1.34216	1.34236	1.34255	1.34275
4.0	1.34090	1.34109	1.34129	1.34148	1.34167	1.34187	1.34206	1.34226	1.34245	1.34265
6.0	1.34078	1.34098	1.34117	1.34136	1.34156	1.34175	1.34194	1.34213	1.34233	1.34252
8.0	1.34065	1.34085	1.34103	1.34123	1.34142	1.34161	1.34180	1.34199	1.34218	1.34237
10.0	1.34051	1.34070	1.34089	1.34108	1.34127	1.34145	1.34164	1.34183	1.34202	1.34221
12.0	1.34035	1.34054	1.34073	1.34091	1.34110	1.34129	1.34148	1.34166	1.34185	1.34204
14.0	1.34018	1.34037	1.34056	1.34074	1.34093	1.34111	1.34130	1.34149	1.34167	1.34186
16.0	1.34000	1.34019	1.34037	1.34056	1.34074	1.34093	1.34111	1.34130	1.34148	1.34167
18.0	1.33981	1.33999	1.34018	1.34036	1.34055	1.34073	1.34091	1.34110	1.34128	1.34146
20.0	1.33960	1.33979	1.33997	1.34016	1.34034	1.34052	1.34070	1.34089	1.34107	1.34125
22.0	1.33939	1.33957	1.33976	1.33994	1.34012	1.34030	1.34048	1.34067	1.34085	1.34103
24.0	1.33917	1.33935	1.33953	1.33972	1.33990	1.34008	1.34026	1.34044	1.34062	1.34081
26.0	1.33894	1.33912	1.33930	1.33949	1.33967	1.33985	1.34003	1.34021	1.34039	1.34057
28.0	1.33871	1.33889	1.33907	1.33925	1.33943	1.33961	1.33979	1.33997	1.34015	1.34034
30.0	1.33847	1.33865	1.33883	1.33901	1.33919	1.33937	1.33955	1.33973	1.33991	1.34009

Table A-3. (cont)

(g)

[Hg] λ = 579.1 nm

TEMP °C	SALINITY (0/00)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33428	1.33527	1.33625	1.33724	1.33822	1.33921	1.34020	1.34039	1.34059	1.34078
2.0	1.33427	1.33525	1.33622	1.33720	1.33818	1.33916	1.34013	1.34033	1.34052	1.34072
4.0	1.33423	1.33520	1.33617	1.33714	1.33811	1.33908	1.34005	1.34025	1.34044	1.34063
6.0	1.33418	1.33514	1.33610	1.33706	1.33803	1.33899	1.33995	1.34014	1.34033	1.34053
8.0	1.33411	1.33506	1.33602	1.33697	1.33792	1.33888	1.33983	1.34002	1.34021	1.34040
10.0	1.33402	1.33496	1.33591	1.33686	1.33780	1.33875	1.33969	1.33988	1.34007	1.34026
12.0	1.33391	1.33485	1.33578	1.33672	1.33766	1.33860	1.33954	1.33972	1.33991	1.34010
14.0	1.33378	1.33471	1.33564	1.33657	1.33751	1.33844	1.33937	1.33955	1.33974	1.33993
16.0	1.33364	1.33456	1.33549	1.33641	1.33734	1.33826	1.33919	1.33937	1.33956	1.33974
18.0	1.33348	1.33440	1.33532	1.33624	1.33716	1.33808	1.33900	1.33918	1.33937	1.33955
20.0	1.33331	1.33422	1.33514	1.33606	1.33697	1.33789	1.33880	1.33899	1.33917	1.33935
22.0	1.33312	1.33403	1.33494	1.33586	1.33677	1.33768	1.33859	1.33877	1.33896	1.33914
24.0	1.33292	1.33383	1.33474	1.33565	1.33656	1.33747	1.33837	1.33856	1.33874	1.33892
26.0	1.33271	1.33362	1.33452	1.33543	1.33634	1.33724	1.33815	1.33833	1.33851	1.33869
28.0	1.33249	1.33339	1.33430	1.33520	1.33611	1.33701	1.33791	1.33809	1.33828	1.33846
30.0	1.33226	1.33316	1.33406	1.33497	1.33587	1.33677	1.33767	1.33785	1.33804	1.33822
	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34098	1.34118	1.34138	1.34157	1.34177	1.34197	1.34217	1.34236	1.34256	1.34276
2.0	1.34092	1.34111	1.34131	1.34150	1.34170	1.34189	1.34209	1.34228	1.34248	1.34267
4.0	1.34083	1.34102	1.34122	1.34141	1.34160	1.34180	1.34199	1.34219	1.34238	1.34257
6.0	1.34072	1.34091	1.34110	1.34129	1.34149	1.34168	1.34187	1.34206	1.34226	1.34245
8.0	1.34059	1.34078	1.34097	1.34116	1.34136	1.34155	1.34173	1.34193	1.34212	1.34231
10.0	1.34045	1.34064	1.34083	1.34102	1.34121	1.34139	1.34158	1.34177	1.34196	1.34215
12.0	1.34029	1.34048	1.34066	1.34085	1.34104	1.34123	1.34141	1.34160	1.34179	1.34198
14.0	1.34011	1.34030	1.34049	1.34067	1.34086	1.34105	1.34123	1.34142	1.34161	1.34179
16.0	1.33993	1.34012	1.34030	1.34049	1.34067	1.34086	1.34104	1.34123	1.34141	1.34160
18.0	1.33974	1.33992	1.34011	1.34029	1.34047	1.34066	1.34084	1.34103	1.34121	1.34140
20.0	1.33954	1.33972	1.33990	1.34009	1.34027	1.34045	1.34063	1.34082	1.34100	1.34118
22.0	1.33932	1.33951	1.33969	1.33987	1.34005	1.34023	1.34041	1.34060	1.34078	1.34096
24.0	1.33910	1.33928	1.33946	1.33965	1.33983	1.34001	1.34019	1.34037	1.34056	1.34074
26.0	1.33887	1.33905	1.33923	1.33942	1.33960	1.33978	1.33996	1.34014	1.34032	1.34050
28.0	1.33864	1.33882	1.33900	1.33918	1.33936	1.33954	1.33972	1.33990	1.34009	1.34027
30.0	1.33840	1.33858	1.33876	1.33894	1.33912	1.33930	1.33948	1.33966	1.33984	1.34002

(h)

[Na] λ = 589.3 nm

TEMP °C	SALINITY (0/00)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33395	1.33494	1.33592	1.33690	1.33789	1.33887	1.33986	1.34006	1.34025	1.34045
2.0	1.33394	1.33491	1.33589	1.33687	1.33784	1.33882	1.33979	1.33999	1.34019	1.34038
4.0	1.33390	1.33487	1.33584	1.33681	1.33778	1.33874	1.33971	1.33991	1.34010	1.34029
6.0	1.33385	1.33481	1.33577	1.33673	1.33769	1.33865	1.33961	1.33980	1.34000	1.34019
8.0	1.33378	1.33473	1.33568	1.33663	1.33759	1.33854	1.33949	1.33968	1.33987	1.34006
10.0	1.33369	1.33463	1.33558	1.33652	1.33746	1.33841	1.33935	1.33954	1.33973	1.33992
12.0	1.33358	1.33452	1.33545	1.33639	1.33733	1.33826	1.33920	1.33939	1.33957	1.33976
14.0	1.33346	1.33438	1.33531	1.33624	1.33717	1.33810	1.33903	1.33922	1.33940	1.33959
16.0	1.33331	1.33424	1.33516	1.33608	1.33700	1.33793	1.33885	1.33904	1.33922	1.33941
18.0	1.33316	1.33408	1.33499	1.33591	1.33683	1.33774	1.33866	1.33885	1.33903	1.33921
20.0	1.33299	1.33390	1.33481	1.33573	1.33664	1.33755	1.33847	1.33865	1.33883	1.33901
22.0	1.33280	1.33371	1.33462	1.33553	1.33644	1.33735	1.33826	1.33844	1.33862	1.33880
24.0	1.33260	1.33351	1.33441	1.33532	1.33623	1.33713	1.33804	1.33822	1.33840	1.33858
26.0	1.33239	1.33329	1.33420	1.33510	1.33601	1.33691	1.33781	1.33799	1.33817	1.33835
28.0	1.33217	1.33307	1.33397	1.33487	1.33578	1.33668	1.33758	1.33776	1.33794	1.33812
30.0	1.33194	1.33284	1.33374	1.33464	1.33554	1.33644	1.33734	1.33752	1.33770	1.33788
	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.34064	1.34084	1.34104	1.34124	1.34143	1.34163	1.34182	1.34202	1.34222	1.34241
2.0	1.34058	1.34077	1.34097	1.34116	1.34136	1.34155	1.34175	1.34194	1.34214	1.34233
4.0	1.34049	1.34068	1.34087	1.34107	1.34126	1.34146	1.34165	1.34184	1.34204	1.34223
6.0	1.34038	1.34057	1.34076	1.34095	1.34115	1.34134	1.34153	1.34172	1.34192	1.34211
8.0	1.34025	1.34045	1.34063	1.34082	1.34101	1.34121	1.34140	1.34159	1.34178	1.34197
10.0	1.34011	1.34030	1.34049	1.34068	1.34086	1.34105	1.34124	1.34143	1.34162	1.34181
12.0	1.33995	1.34014	1.34032	1.34051	1.34070	1.34089	1.34107	1.34126	1.34145	1.34163
14.0	1.33978	1.33996	1.34015	1.34033	1.34052	1.34070	1.34089	1.34108	1.34126	1.34145
16.0	1.33959	1.33977	1.33996	1.34014	1.34033	1.34051	1.34070	1.34088	1.34107	1.34125
18.0	1.33940	1.33958	1.33976	1.33995	1.34013	1.34032	1.34050	1.34068	1.34087	1.34105
20.0	1.33919	1.33938	1.33956	1.33974	1.33993	1.34011	1.34029	1.34047	1.34066	1.34084
22.0	1.33898	1.33916	1.33934	1.33953	1.33971	1.33989	1.34007	1.34025	1.34044	1.34062
24.0	1.33876	1.33894	1.33912	1.33930	1.33949	1.33967	1.33985	1.34003	1.34021	1.34039
26.0	1.33853	1.33871	1.33889	1.33907	1.33926	1.33944	1.33961	1.33980	1.33998	1.34016
28.0	1.33830	1.33848	1.33866	1.33884	1.33902	1.33920	1.33938	1.33956	1.33974	1.33992
30.0	1.33806	1.33824	1.33842	1.33860	1.33878	1.33896	1.33914	1.33932	1.33950	1.33968

Table A-3. (cont)

(i)

[Cd] λ = 643.8 nm

TEMP °C	SALINITY (‰)									
	0.0	5.0	10.0	15.0	20.0	25.0	30.0	31.0	32.0	33.0
0.0	1.33242	1.33339	1.33437	1.33535	1.33633	1.33732	1.33829	1.33849	1.33869	1.33888
2.0	1.33240	1.33337	1.33434	1.33531	1.33628	1.33726	1.33823	1.33842	1.33861	1.33881
4.0	1.33236	1.33333	1.33429	1.33525	1.33621	1.33718	1.33814	1.33833	1.33852	1.33872
6.0	1.33231	1.33326	1.33422	1.33517	1.33612	1.33708	1.33804	1.33823	1.33842	1.33861
8.0	1.33224	1.33318	1.33413	1.33508	1.33602	1.33697	1.33792	1.33811	1.33829	1.33848
10.0	1.33215	1.33309	1.33402	1.33496	1.33590	1.33684	1.33778	1.33797	1.33816	1.33834
12.0	1.33205	1.33298	1.33391	1.33484	1.33577	1.33670	1.33763	1.33782	1.33800	1.33819
14.0	1.33193	1.33285	1.33377	1.33470	1.33562	1.33654	1.33747	1.33765	1.33784	1.33802
16.0	1.33179	1.33270	1.33362	1.33454	1.33545	1.33637	1.33729	1.33747	1.33766	1.33784
18.0	1.33163	1.33254	1.33345	1.33437	1.33528	1.33619	1.33710	1.33728	1.33746	1.33765
20.0	1.33146	1.33237	1.33327	1.33418	1.33509	1.33599	1.33690	1.33708	1.33726	1.33744
22.0	1.33127	1.33218	1.33308	1.33398	1.33489	1.33579	1.33669	1.33687	1.33705	1.33723
24.0	1.33108	1.33198	1.33288	1.33378	1.33467	1.33557	1.33647	1.33665	1.33683	1.33701
26.0	1.33087	1.33177	1.33266	1.33356	1.33445	1.33535	1.33625	1.33642	1.33660	1.33679
28.0	1.33065	1.33154	1.33244	1.33333	1.33422	1.33512	1.33601	1.33619	1.33637	1.33655
30.0	1.33042	1.33131	1.33220	1.33309	1.33398	1.33487	1.33577	1.33594	1.33612	1.33630

	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0
0.0	1.33908	1.33927	1.33947	1.33966	1.33986	1.34006	1.34025	1.34045	1.34065	1.34084
2.0	1.33900	1.33920	1.33939	1.33959	1.33978	1.33997	1.34017	1.34036	1.34056	1.34075
4.0	1.33891	1.33910	1.33929	1.33949	1.33968	1.33987	1.34007	1.34026	1.34045	1.34064
6.0	1.33880	1.33899	1.33918	1.33937	1.33956	1.33975	1.33994	1.34013	1.34033	1.34052
8.0	1.33867	1.33886	1.33905	1.33924	1.33943	1.33962	1.33981	1.34000	1.34019	1.34038
10.0	1.33853	1.33872	1.33891	1.33909	1.33928	1.33947	1.33966	1.33985	1.34003	1.34022
12.0	1.33837	1.33856	1.33875	1.33893	1.33912	1.33931	1.33949	1.33968	1.33986	1.34005
14.0	1.33821	1.33839	1.33857	1.33876	1.33894	1.33913	1.33931	1.33950	1.33968	1.33986
16.0	1.33802	1.33821	1.33839	1.33857	1.33876	1.33894	1.33912	1.33930	1.33949	1.33967
18.0	1.33783	1.33801	1.33820	1.33838	1.33856	1.33874	1.33892	1.33911	1.33929	1.33947
20.0	1.33763	1.33781	1.33799	1.33817	1.33835	1.33853	1.33872	1.33890	1.33908	1.33926
22.0	1.33741	1.33759	1.33778	1.33796	1.33813	1.33832	1.33850	1.33868	1.33886	1.33904
24.0	1.33719	1.33737	1.33755	1.33773	1.33791	1.33809	1.33827	1.33845	1.33863	1.33881
26.0	1.33696	1.33714	1.33732	1.33750	1.33768	1.33786	1.33804	1.33822	1.33839	1.33858
28.0	1.33672	1.33690	1.33708	1.33726	1.33744	1.33762	1.33780	1.33798	1.33815	1.33833
30.0	1.33648	1.33666	1.33684	1.33701	1.33719	1.33737	1.33755	1.33773	1.33791	1.33808

TABLE A-4

Atmospheric Pressure

This table holds for exactly the same values of salinity and temperature given for Tables A-1 through A-3. It contains the same data given in Table A-1 but in a different form and with some additional wavelengths. It gives the dependence of index of refraction of seawater (with respect to air) on temperature and wavelength at atmospheric pressure, for individual values of salinity.

The salinities have been chosen every 5‰ between 0 and 30‰, and every 1‰ between 30 and 43‰ for oceanographic considerations. The temperatures are every 2°C between 0 and 30°C. The wavelengths have been chosen equispaced every 10 nm between 400 and 700 nm, giving an advantage over Table A-1.

The accuracy is "within" 3×10^{-5} in index in the interpolated wavelength range (404.7 to 643.8 nm) and possibly slightly less accurate outside this range.

Table A-4. INDEX OF REFRACTION OF SEAWATER
Selected Salinities – Atmospheric Pressure

(a)

(PURE WATER)

S = 0‰

TEMP °C	WAVELENGTH (nm)									
	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.34419	1.34328	1.34243	1.34164	1.34092	1.34024	1.33960	1.33900	1.33844	1.33791
2.0	1.34417	1.34327	1.34242	1.34162	1.34091	1.34023	1.33959	1.33899	1.33843	1.33790
4.0	1.34413	1.34323	1.34238	1.34159	1.34087	1.34020	1.33956	1.33895	1.33839	1.33787
6.0	1.34408	1.34318	1.34232	1.34153	1.34082	1.34014	1.33950	1.33890	1.33834	1.33781
8.0	1.34400	1.34310	1.34225	1.34146	1.34074	1.34007	1.33943	1.33883	1.33826	1.33773
10.0	1.34390	1.34300	1.34215	1.34136	1.34064	1.33997	1.33933	1.33873	1.33817	1.33764
12.0	1.34379	1.34289	1.34204	1.34125	1.34053	1.33985	1.33921	1.33861	1.33805	1.33753
14.0	1.34366	1.34276	1.34191	1.34112	1.34040	1.33972	1.33908	1.33848	1.33793	1.33741
16.0	1.34351	1.34261	1.34176	1.34097	1.34025	1.33957	1.33893	1.33833	1.33778	1.33726
18.0	1.34334	1.34245	1.34160	1.34081	1.34009	1.33941	1.33877	1.33817	1.33762	1.33710
20.0	1.34317	1.34227	1.34142	1.34063	1.33992	1.33924	1.33860	1.33800	1.33745	1.33693
22.0	1.34298	1.34208	1.34123	1.34044	1.33972	1.33905	1.33841	1.33782	1.33726	1.33674
24.0	1.34277	1.34187	1.34102	1.34024	1.33952	1.33885	1.33821	1.33762	1.33706	1.33654
26.0	1.34255	1.34166	1.34081	1.34002	1.33931	1.33864	1.33800	1.33740	1.33684	1.33632
28.0	1.34232	1.34143	1.34058	1.33979	1.33908	1.33841	1.33777	1.33717	1.33662	1.33610
30.0	1.34208	1.34119	1.34034	1.33955	1.33884	1.33816	1.33753	1.33693	1.33638	1.33586

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.33741	1.33694	1.33649	1.33607	1.33567	1.33530	1.33494	1.33459	1.33424	1.33393
2.0	1.33740	1.33693	1.33648	1.33606	1.33566	1.33529	1.33493	1.33457	1.33423	1.33392
4.0	1.33737	1.33690	1.33645	1.33603	1.33563	1.33525	1.33489	1.33454	1.33420	1.33388
6.0	1.33731	1.33684	1.33640	1.33597	1.33557	1.33520	1.33483	1.33448	1.33415	1.33383
8.0	1.33723	1.33676	1.33632	1.33590	1.33550	1.33512	1.33475	1.33440	1.33408	1.33376
10.0	1.33714	1.33667	1.33623	1.33581	1.33541	1.33503	1.33466	1.33431	1.33399	1.33367
12.0	1.33703	1.33656	1.33612	1.33569	1.33529	1.33492	1.33455	1.33420	1.33388	1.33356
14.0	1.33691	1.33644	1.33599	1.33557	1.33517	1.33479	1.33443	1.33408	1.33375	1.33343
16.0	1.33676	1.33629	1.33585	1.33542	1.33502	1.33465	1.33430	1.33395	1.33361	1.33329
18.0	1.33660	1.33613	1.33569	1.33526	1.33486	1.33450	1.33414	1.33379	1.33345	1.33314
20.0	1.33643	1.33596	1.33551	1.33509	1.33469	1.33433	1.33397	1.33362	1.33328	1.33297
22.0	1.33624	1.33577	1.33533	1.33490	1.33451	1.33414	1.33379	1.33344	1.33309	1.33278
24.0	1.33604	1.33557	1.33513	1.33470	1.33431	1.33394	1.33359	1.33324	1.33289	1.33258
26.0	1.33583	1.33536	1.33492	1.33449	1.33409	1.33373	1.33338	1.33303	1.33268	1.33237
28.0	1.33560	1.33514	1.33469	1.33427	1.33387	1.33351	1.33316	1.33281	1.33246	1.33215
30.0	1.33537	1.33490	1.33445	1.33403	1.33363	1.33327	1.33292	1.33257	1.33223	1.33192

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.33362	1.33333	1.33305	1.33278	1.33251	1.33225	1.33200	1.33176	1.33153	1.33130	1.33108
2.0	1.33361	1.33332	1.33304	1.33276	1.33250	1.33224	1.33199	1.33175	1.33152	1.33129	1.33108
4.0	1.33358	1.33328	1.33300	1.33273	1.33246	1.33220	1.33195	1.33171	1.33148	1.33126	1.33105
6.0	1.33352	1.33323	1.33294	1.33267	1.33241	1.33215	1.33190	1.33166	1.33143	1.33121	1.33100
8.0	1.33345	1.33316	1.33288	1.33260	1.33234	1.33208	1.33183	1.33159	1.33136	1.33114	1.33093
10.0	1.33336	1.33307	1.33279	1.33251	1.33225	1.33199	1.33174	1.33150	1.33127	1.33105	1.33084
12.0	1.33325	1.33296	1.33268	1.33241	1.33214	1.33189	1.33164	1.33140	1.33117	1.33095	1.33074
14.0	1.33312	1.33283	1.33255	1.33229	1.33202	1.33177	1.33152	1.33128	1.33105	1.33083	1.33061
16.0	1.33299	1.33270	1.33242	1.33215	1.33189	1.33163	1.33138	1.33114	1.33091	1.33069	1.33047
18.0	1.33284	1.33255	1.33227	1.33200	1.33173	1.33147	1.33122	1.33098	1.33076	1.33053	1.33032
20.0	1.33267	1.33238	1.33210	1.33183	1.33156	1.33130	1.33105	1.33081	1.33059	1.33037	1.33016
22.0	1.33248	1.33220	1.33191	1.33164	1.33138	1.33112	1.33087	1.33063	1.33040	1.33018	1.32997
24.0	1.33229	1.33200	1.33172	1.33144	1.33118	1.33092	1.33067	1.33044	1.33021	1.32999	1.32978
26.0	1.33208	1.33179	1.33151	1.33124	1.33097	1.33071	1.33047	1.33023	1.33000	1.32979	1.32958
28.0	1.33186	1.33157	1.33129	1.33102	1.33075	1.33049	1.33025	1.33001	1.32978	1.32957	1.32936
30.0	1.33162	1.33134	1.33106	1.33078	1.33052	1.33026	1.33001	1.32978	1.32955	1.32934	1.32913

Table A-4. (cont)

(b)

S = 5 ‰

TEMP °C	WAVELENGTH (nm)									
	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.34522	1.34431	1.34345	1.34266	1.34194	1.34126	1.34061	1.34001	1.33944	1.33892
2.0	1.34519	1.34429	1.34343	1.34263	1.34191	1.34123	1.34059	1.33999	1.33942	1.33890
4.0	1.34515	1.34424	1.34338	1.34259	1.34187	1.34119	1.34055	1.33994	1.33938	1.33885
6.0	1.34508	1.34418	1.34332	1.34252	1.34180	1.34113	1.34048	1.33988	1.33932	1.33879
8.0	1.34499	1.34409	1.34323	1.34244	1.34172	1.34104	1.34040	1.33980	1.33923	1.33870
10.0	1.34489	1.34399	1.34313	1.34234	1.34162	1.34094	1.34030	1.33970	1.33913	1.33860
12.0	1.34477	1.34387	1.34301	1.34222	1.34150	1.34082	1.34018	1.33957	1.33901	1.33849
14.0	1.34464	1.34373	1.34288	1.34208	1.34136	1.34068	1.34004	1.33944	1.33888	1.33836
16.0	1.34448	1.34358	1.34273	1.34193	1.34121	1.34053	1.33988	1.33928	1.33873	1.33821
18.0	1.34431	1.34342	1.34256	1.34177	1.34104	1.34036	1.33972	1.33912	1.33856	1.33804
20.0	1.34413	1.34324	1.34238	1.34159	1.34087	1.34018	1.33954	1.33894	1.33838	1.33786
22.0	1.34394	1.34304	1.34219	1.34139	1.34067	1.33999	1.33935	1.33875	1.33819	1.33767
24.0	1.34373	1.34283	1.34198	1.34118	1.34047	1.33979	1.33915	1.33855	1.33799	1.33746
26.0	1.34351	1.34261	1.34176	1.34096	1.34025	1.33957	1.33893	1.33833	1.33777	1.33725
28.0	1.34328	1.34238	1.34152	1.34073	1.34002	1.33934	1.33870	1.33810	1.33754	1.33702
30.0	1.34303	1.34213	1.34128	1.34049	1.33977	1.33910	1.33846	1.33786	1.33730	1.33678

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.33841	1.33794	1.33749	1.33707	1.33666	1.33629	1.33592	1.33557	1.33523	1.33491
2.0	1.33839	1.33792	1.33747	1.33704	1.33664	1.33627	1.33590	1.33555	1.33521	1.33489
4.0	1.33835	1.33788	1.33743	1.33700	1.33660	1.33622	1.33586	1.33551	1.33517	1.33485
6.0	1.33828	1.33781	1.33736	1.33694	1.33654	1.33616	1.33579	1.33544	1.33511	1.33479
8.0	1.33820	1.33773	1.33728	1.33686	1.33646	1.33608	1.33571	1.33536	1.33503	1.33471
10.0	1.33810	1.33763	1.33718	1.33676	1.33636	1.33598	1.33561	1.33526	1.33494	1.33461
12.0	1.33798	1.33751	1.33706	1.33664	1.33624	1.33586	1.33549	1.33514	1.33482	1.33449
14.0	1.33785	1.33738	1.33693	1.33650	1.33610	1.33573	1.33537	1.33501	1.33468	1.33436
16.0	1.33770	1.33723	1.33678	1.33635	1.33595	1.33558	1.33522	1.33487	1.33453	1.33421
18.0	1.33754	1.33707	1.33662	1.33619	1.33579	1.33542	1.33506	1.33471	1.33437	1.33405
20.0	1.33736	1.33689	1.33644	1.33602	1.33562	1.33525	1.33488	1.33453	1.33420	1.33388
22.0	1.33717	1.33670	1.33625	1.33582	1.33543	1.33506	1.33470	1.33434	1.33400	1.33369
24.0	1.33697	1.33650	1.33605	1.33562	1.33522	1.33485	1.33450	1.33415	1.33380	1.33349
26.0	1.33675	1.33628	1.33583	1.33541	1.33501	1.33464	1.33428	1.33393	1.33359	1.33327
28.0	1.33652	1.33605	1.33561	1.33518	1.33478	1.33441	1.33406	1.33371	1.33336	1.33305
30.0	1.33628	1.33582	1.33537	1.33494	1.33454	1.33418	1.33383	1.33348	1.33313	1.33282

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.33460	1.33431	1.33403	1.33376	1.33349	1.33323	1.33298	1.33274	1.33250	1.33228	1.33206
2.0	1.33458	1.33429	1.33401	1.33373	1.33347	1.33321	1.33296	1.33272	1.33249	1.33226	1.33205
4.0	1.33454	1.33425	1.33396	1.33369	1.33343	1.33317	1.33292	1.33267	1.33244	1.33222	1.33201
6.0	1.33448	1.33418	1.33390	1.33363	1.33336	1.33310	1.33285	1.33261	1.33238	1.33216	1.33195
8.0	1.33440	1.33411	1.33383	1.33355	1.33328	1.33302	1.33277	1.33253	1.33230	1.33208	1.33187
10.0	1.33431	1.33401	1.33373	1.33345	1.33319	1.33293	1.33268	1.33244	1.33221	1.33199	1.33178
12.0	1.33419	1.33389	1.33361	1.33334	1.33308	1.33282	1.33257	1.33233	1.33210	1.33187	1.33166
14.0	1.33405	1.33376	1.33348	1.33321	1.33295	1.33269	1.33244	1.33220	1.33197	1.33175	1.33153
16.0	1.33391	1.33362	1.33334	1.33307	1.33280	1.33254	1.33229	1.33205	1.33182	1.33160	1.33139
18.0	1.33375	1.33346	1.33318	1.33291	1.33264	1.33238	1.33213	1.33189	1.33166	1.33144	1.33123
20.0	1.33357	1.33328	1.33300	1.33273	1.33247	1.33221	1.33196	1.33172	1.33149	1.33127	1.33105
22.0	1.33339	1.33310	1.33282	1.33254	1.33228	1.33202	1.33177	1.33153	1.33130	1.33108	1.33087
24.0	1.33319	1.33290	1.33262	1.33235	1.33208	1.33182	1.33157	1.33133	1.33110	1.33088	1.33067
26.0	1.33298	1.33269	1.33241	1.33213	1.33187	1.33161	1.33136	1.33112	1.33090	1.33068	1.33046
28.0	1.33275	1.33247	1.33218	1.33191	1.33164	1.33139	1.33114	1.33090	1.33067	1.33045	1.33024
30.0	1.33252	1.33223	1.33195	1.33167	1.33141	1.33115	1.33090	1.33067	1.33044	1.33022	1.33001

Table A-4. (cont)

(c)

S = 10 ‰

TEMP °C	WAVELENGTH (nm)									
	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.34625	1.34534	1.34448	1.34368	1.34295	1.34227	1.34162	1.34102	1.34045	1.33992
2.0	1.34621	1.34531	1.34444	1.34365	1.34292	1.34224	1.34159	1.34099	1.34042	1.33989
4.0	1.34616	1.34525	1.34439	1.34359	1.34287	1.34219	1.34154	1.34093	1.34037	1.33984
6.0	1.34608	1.34517	1.34432	1.34352	1.34279	1.34211	1.34147	1.34086	1.34029	1.33977
8.0	1.34599	1.34508	1.34422	1.34343	1.34270	1.34202	1.34138	1.34077	1.34020	1.33967
10.0	1.34588	1.34498	1.34412	1.34332	1.34260	1.34192	1.34127	1.34066	1.34010	1.33957
12.0	1.34576	1.34485	1.34399	1.34319	1.34247	1.34178	1.34114	1.34053	1.33997	1.33944
14.0	1.34562	1.34471	1.34385	1.34305	1.34232	1.34164	1.34099	1.34039	1.33983	1.33930
16.0	1.34546	1.34455	1.34369	1.34290	1.34217	1.34148	1.34083	1.34023	1.33967	1.33915
18.0	1.34529	1.34438	1.34352	1.34273	1.34200	1.34131	1.34066	1.34006	1.33950	1.33898
20.0	1.34510	1.34420	1.34334	1.34254	1.34182	1.34113	1.34048	1.33988	1.33932	1.33880
22.0	1.34490	1.34400	1.34314	1.34235	1.34162	1.34094	1.34029	1.33969	1.33912	1.33860
24.0	1.34469	1.34379	1.34293	1.34213	1.34141	1.34073	1.34008	1.33948	1.33892	1.33839
26.0	1.34447	1.34356	1.34271	1.34191	1.34119	1.34051	1.33986	1.33926	1.33870	1.33817
28.0	1.34423	1.34333	1.34247	1.34167	1.34095	1.34027	1.33963	1.33903	1.33846	1.33794
30.0	1.34398	1.34308	1.34222	1.34143	1.34071	1.34003	1.33939	1.33878	1.33822	1.33770

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.33942	1.33894	1.33849	1.33806	1.33766	1.33728	1.33691	1.33656	1.33622	1.33589
2.0	1.33939	1.33891	1.33846	1.33803	1.33763	1.33725	1.33688	1.33653	1.33619	1.33587
4.0	1.33933	1.33886	1.33841	1.33798	1.33757	1.33720	1.33683	1.33648	1.33614	1.33582
6.0	1.33926	1.33878	1.33834	1.33791	1.33750	1.33712	1.33675	1.33640	1.33607	1.33575
8.0	1.33917	1.33869	1.33824	1.33782	1.33742	1.33703	1.33666	1.33631	1.33599	1.33566
10.0	1.33906	1.33858	1.33814	1.33771	1.33731	1.33693	1.33655	1.33620	1.33588	1.33556
12.0	1.33894	1.33846	1.33801	1.33759	1.33718	1.33680	1.33643	1.33608	1.33576	1.33543
14.0	1.33880	1.33832	1.33787	1.33744	1.33704	1.33666	1.33630	1.33595	1.33561	1.33529
16.0	1.33864	1.33817	1.33772	1.33729	1.33688	1.33651	1.33615	1.33580	1.33546	1.33514
18.0	1.33848	1.33800	1.33755	1.33712	1.33672	1.33635	1.33599	1.33563	1.33529	1.33497
20.0	1.33829	1.33782	1.33737	1.33694	1.33654	1.33617	1.33581	1.33545	1.33511	1.33479
22.0	1.33809	1.33762	1.33717	1.33674	1.33634	1.33597	1.33561	1.33526	1.33491	1.33460
24.0	1.33789	1.33742	1.33697	1.33654	1.33614	1.33577	1.33541	1.33506	1.33471	1.33439
26.0	1.33767	1.33720	1.33675	1.33632	1.33592	1.33555	1.33519	1.33484	1.33449	1.33418
28.0	1.33744	1.33697	1.33652	1.33609	1.33569	1.33532	1.33496	1.33461	1.33427	1.33395
30.0	1.33720	1.33673	1.33628	1.33585	1.33545	1.33508	1.33473	1.33438	1.33403	1.33372

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.33558	1.33529	1.33501	1.33474	1.33447	1.33421	1.33396	1.33372	1.33348	1.33325	1.33303
2.0	1.33556	1.33526	1.33498	1.33471	1.33444	1.33418	1.33393	1.33369	1.33345	1.33323	1.33301
4.0	1.33551	1.33521	1.33493	1.33466	1.33439	1.33413	1.33388	1.33363	1.33340	1.33318	1.33297
6.0	1.33544	1.33514	1.33486	1.33459	1.33432	1.33406	1.33380	1.33356	1.33333	1.33311	1.33290
8.0	1.33536	1.33506	1.33477	1.33450	1.33423	1.33397	1.33372	1.33348	1.33325	1.33302	1.33281
10.0	1.33525	1.33496	1.33467	1.33439	1.33413	1.33386	1.33361	1.33337	1.33314	1.33292	1.33271
12.0	1.33512	1.33483	1.33455	1.33427	1.33401	1.33375	1.33350	1.33325	1.33302	1.33280	1.33259
14.0	1.33498	1.33469	1.33441	1.33414	1.33387	1.33361	1.33336	1.33312	1.33289	1.33267	1.33245
16.0	1.33483	1.33454	1.33426	1.33398	1.33372	1.33346	1.33321	1.33297	1.33274	1.33251	1.33230
18.0	1.33467	1.33437	1.33409	1.33382	1.33355	1.33329	1.33304	1.33280	1.33257	1.33235	1.33213
20.0	1.33449	1.33420	1.33391	1.33364	1.33337	1.33311	1.33286	1.33262	1.33239	1.33217	1.33195
22.0	1.33430	1.33400	1.33372	1.33345	1.33318	1.33292	1.33267	1.33243	1.33220	1.33198	1.33176
24.0	1.33409	1.33380	1.33352	1.33325	1.33298	1.33272	1.33247	1.33223	1.33200	1.33178	1.33156
26.0	1.33388	1.33359	1.33330	1.33303	1.33276	1.33250	1.33225	1.33202	1.33179	1.33157	1.33136
28.0	1.33365	1.33336	1.33308	1.33280	1.33254	1.33228	1.33203	1.33179	1.33156	1.33134	1.33113
30.0	1.33342	1.33312	1.33284	1.33257	1.33230	1.33204	1.33179	1.33156	1.33133	1.33111	1.33090

Table A-4 (cont)

(d)

S = 15 ‰

TEMP °C	WAVELENGTH (nm)									
	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.34728	1.34637	1.34551	1.34470	1.34397	1.34328	1.34263	1.34202	1.34145	1.34092
2.0	1.34723	1.34632	1.34546	1.34466	1.34393	1.34324	1.34259	1.34198	1.34141	1.34088
4.0	1.34717	1.34626	1.34540	1.34460	1.34387	1.34318	1.34253	1.34192	1.34135	1.34082
6.0	1.34709	1.34618	1.34531	1.34451	1.34378	1.34310	1.34245	1.34184	1.34127	1.34074
8.0	1.34699	1.34608	1.34521	1.34441	1.34369	1.34300	1.34235	1.34175	1.34118	1.34064
10.0	1.34688	1.34596	1.34510	1.34430	1.34357	1.34289	1.34224	1.34163	1.34106	1.34053
12.0	1.34675	1.34583	1.34497	1.34417	1.34344	1.34275	1.34210	1.34149	1.34093	1.34040
14.0	1.34660	1.34569	1.34482	1.34402	1.34329	1.34260	1.34195	1.34134	1.34078	1.34025
16.0	1.34643	1.34552	1.34466	1.34386	1.34313	1.34243	1.34178	1.34118	1.34062	1.34009
18.0	1.34626	1.34535	1.34449	1.34369	1.34295	1.34226	1.34161	1.34100	1.34045	1.33992
20.0	1.34607	1.34516	1.34430	1.34350	1.34277	1.34207	1.34142	1.34082	1.34026	1.33973
22.0	1.34587	1.34496	1.34410	1.34330	1.34257	1.34188	1.34123	1.34062	1.34006	1.33953
24.0	1.34565	1.34474	1.34388	1.34308	1.34235	1.34167	1.34102	1.34041	1.33985	1.33932
26.0	1.34543	1.34452	1.34366	1.34286	1.34213	1.34144	1.34080	1.34019	1.33962	1.33910
28.0	1.34519	1.34428	1.34342	1.34262	1.34189	1.34121	1.34056	1.33996	1.33939	1.33887
30.0	1.34494	1.34403	1.34317	1.34237	1.34164	1.34096	1.34032	1.33971	1.33915	1.33862

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34042	1.33994	1.33949	1.33906	1.33865	1.33827	1.33790	1.33755	1.33720	1.33688
2.0	1.34038	1.33990	1.33945	1.33901	1.33861	1.33823	1.33786	1.33751	1.33717	1.33684
4.0	1.34032	1.33984	1.33939	1.33895	1.33855	1.33817	1.33780	1.33745	1.33711	1.33679
6.0	1.34023	1.33976	1.33930	1.33887	1.33847	1.33809	1.33772	1.33736	1.33704	1.33671
8.0	1.34013	1.33965	1.33921	1.33878	1.33838	1.33799	1.33762	1.33727	1.33694	1.33661
10.0	1.34002	1.33954	1.33909	1.33867	1.33826	1.33788	1.33750	1.33715	1.33683	1.33650
12.0	1.33989	1.33941	1.33896	1.33853	1.33813	1.33774	1.33737	1.33702	1.33669	1.33637
14.0	1.33975	1.33927	1.33881	1.33838	1.33798	1.33760	1.33723	1.33688	1.33654	1.33622
16.0	1.33958	1.33910	1.33865	1.33822	1.33782	1.33744	1.33708	1.33672	1.33638	1.33606
18.0	1.33941	1.33893	1.33848	1.33805	1.33765	1.33727	1.33690	1.33655	1.33621	1.33589
20.0	1.33922	1.33875	1.33829	1.33787	1.33747	1.33709	1.33672	1.33636	1.33603	1.33570
22.0	1.33902	1.33855	1.33810	1.33767	1.33727	1.33689	1.33652	1.33616	1.33583	1.33551
24.0	1.33882	1.33834	1.33789	1.33746	1.33706	1.33668	1.33632	1.33596	1.33562	1.33530
26.0	1.33860	1.33812	1.33767	1.33724	1.33684	1.33646	1.33610	1.33574	1.33540	1.33508
28.0	1.33836	1.33789	1.33744	1.33701	1.33661	1.33623	1.33587	1.33551	1.33517	1.33485
30.0	1.33812	1.33765	1.33720	1.33677	1.33637	1.33599	1.33563	1.33527	1.33494	1.33462

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.33657	1.33628	1.33599	1.33572	1.33545	1.33519	1.33494	1.33470	1.33446	1.33423	1.33401
2.0	1.33653	1.33624	1.33595	1.33568	1.33541	1.33515	1.33490	1.33466	1.33442	1.33420	1.33398
4.0	1.33648	1.33618	1.33589	1.33562	1.33535	1.33509	1.33484	1.33460	1.33436	1.33414	1.33393
6.0	1.33640	1.33610	1.33582	1.33554	1.33527	1.33501	1.33476	1.33452	1.33429	1.33406	1.33385
8.0	1.33631	1.33601	1.33572	1.33545	1.33518	1.33492	1.33466	1.33442	1.33419	1.33397	1.33376
10.0	1.33619	1.33590	1.33561	1.33533	1.33506	1.33480	1.33455	1.33431	1.33408	1.33386	1.33364
12.0	1.33606	1.33576	1.33548	1.33520	1.33494	1.33468	1.33443	1.33418	1.33395	1.33373	1.33352
14.0	1.33591	1.33561	1.33533	1.33506	1.33480	1.33454	1.33429	1.33404	1.33381	1.33359	1.33337
16.0	1.33575	1.33546	1.33518	1.33490	1.33464	1.33438	1.33413	1.33388	1.33365	1.33342	1.33321
18.0	1.33558	1.33529	1.33500	1.33473	1.33447	1.33420	1.33395	1.33371	1.33348	1.33325	1.33303
20.0	1.33539	1.33510	1.33482	1.33455	1.33428	1.33402	1.33377	1.33353	1.33329	1.33307	1.33285
22.0	1.33520	1.33490	1.33462	1.33435	1.33408	1.33382	1.33357	1.33333	1.33310	1.33287	1.33266
24.0	1.33499	1.33470	1.33442	1.33414	1.33388	1.33362	1.33337	1.33313	1.33289	1.33267	1.33246
26.0	1.33478	1.33448	1.33420	1.33393	1.33366	1.33340	1.33315	1.33291	1.33268	1.33246	1.33224
28.0	1.33455	1.33426	1.33397	1.33370	1.33343	1.33317	1.33292	1.33268	1.33245	1.33223	1.33202
30.0	1.33431	1.33402	1.33373	1.33346	1.33319	1.33293	1.33268	1.33244	1.33221	1.33199	1.33178

Table A-4. (cont)

(e)

S = 20 ‰

TEMP °C	WAVELENGTH (nm)										
	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0	
0.0	1.34832	1.34740	1.34653	1.34572	1.34499	1.34430	1.34364	1.34303	1.34246	1.34193	
2.0	1.34826	1.34734	1.34647	1.34567	1.34494	1.34425	1.34359	1.34298	1.34241	1.34188	
4.0	1.34818	1.34727	1.34640	1.34560	1.34486	1.34418	1.34352	1.34291	1.34234	1.34181	
6.0	1.34809	1.34718	1.34631	1.34550	1.34477	1.34409	1.34343	1.34282	1.34225	1.34172	
8.0	1.34798	1.34707	1.34620	1.34540	1.34467	1.34398	1.34333	1.34272	1.34215	1.34161	
10.0	1.34787	1.34695	1.34608	1.34528	1.34455	1.34386	1.34321	1.34260	1.34203	1.34149	
12.0	1.34773	1.34681	1.34595	1.34514	1.34441	1.34371	1.34306	1.34245	1.34189	1.34135	
14.0	1.34758	1.34666	1.34579	1.34499	1.34425	1.34356	1.34291	1.34230	1.34173	1.34120	
16.0	1.34741	1.34649	1.34563	1.34482	1.34408	1.34339	1.34273	1.34213	1.34157	1.34104	
18.0	1.34723	1.34632	1.34545	1.34465	1.34391	1.34321	1.34256	1.34195	1.34139	1.34086	
20.0	1.34704	1.34612	1.34526	1.34446	1.34372	1.34302	1.34237	1.34176	1.34120	1.34066	
22.0	1.34683	1.34592	1.34505	1.34425	1.34351	1.34282	1.34217	1.34156	1.34099	1.34046	
24.0	1.34661	1.34570	1.34484	1.34403	1.34330	1.34261	1.34195	1.34134	1.34078	1.34025	
26.0	1.34638	1.34547	1.34460	1.34380	1.34307	1.34238	1.34173	1.34112	1.34055	1.34002	
28.0	1.34614	1.34523	1.34436	1.34356	1.34283	1.34214	1.34149	1.34088	1.34031	1.33979	
30.0	1.34589	1.34498	1.34411	1.34331	1.34258	1.34189	1.34124	1.34064	1.34007	1.33954	
	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0	
0.0	1.34142	1.34094	1.34048	1.34005	1.33965	1.33926	1.33889	1.33853	1.33819	1.33786	
2.0	1.34137	1.34089	1.34043	1.34000	1.33959	1.33921	1.33884	1.33848	1.33815	1.33782	
4.0	1.34130	1.34082	1.34036	1.33993	1.33952	1.33914	1.33877	1.33842	1.33808	1.33775	
6.0	1.34121	1.34073	1.34027	1.33984	1.33943	1.33905	1.33868	1.33833	1.33800	1.33767	
8.0	1.34110	1.34062	1.34017	1.33974	1.33934	1.33895	1.33857	1.33822	1.33789	1.33757	
10.0	1.34098	1.34050	1.34005	1.33962	1.33922	1.33883	1.33845	1.33809	1.33777	1.33744	
12.0	1.34084	1.34036	1.33991	1.33948	1.33907	1.33869	1.33831	1.33796	1.33763	1.33730	
14.0	1.34069	1.34021	1.33975	1.33932	1.33891	1.33854	1.33817	1.33781	1.33747	1.33715	
16.0	1.34052	1.34004	1.33958	1.33915	1.33875	1.33837	1.33801	1.33765	1.33731	1.33698	
18.0	1.34035	1.33986	1.33941	1.33898	1.33857	1.33820	1.33783	1.33747	1.33713	1.33680	
20.0	1.34015	1.33967	1.33922	1.33879	1.33839	1.33801	1.33764	1.33728	1.33694	1.33662	
22.0	1.33995	1.33947	1.33902	1.33859	1.33819	1.33780	1.33743	1.33708	1.33674	1.33641	
24.0	1.33974	1.33926	1.33881	1.33838	1.33797	1.33759	1.33723	1.33687	1.33653	1.33620	
26.0	1.33952	1.33904	1.33859	1.33816	1.33775	1.33737	1.33700	1.33664	1.33631	1.33598	
28.0	1.33928	1.33881	1.33836	1.33792	1.33752	1.33714	1.33677	1.33642	1.33608	1.33575	
30.0	1.33904	1.33856	1.33811	1.33768	1.33728	1.33690	1.33653	1.33618	1.33584	1.33552	
	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.33755	1.33725	1.33697	1.33670	1.33643	1.33617	1.33592	1.33567	1.33543	1.33520	1.33498
2.0	1.33751	1.33721	1.33693	1.33665	1.33638	1.33612	1.33587	1.33562	1.33539	1.33516	1.33494
4.0	1.33744	1.33714	1.33686	1.33658	1.33631	1.33605	1.33580	1.33556	1.33532	1.33510	1.33488
6.0	1.33736	1.33706	1.33677	1.33650	1.33623	1.33596	1.33571	1.33547	1.33524	1.33501	1.33480
8.0	1.33726	1.33696	1.33667	1.33639	1.33612	1.33586	1.33561	1.33537	1.33513	1.33491	1.33470
10.0	1.33714	1.33684	1.33655	1.33627	1.33600	1.33574	1.33549	1.33525	1.33502	1.33479	1.33458
12.0	1.33700	1.33670	1.33641	1.33614	1.33587	1.33561	1.33535	1.33511	1.33488	1.33466	1.33444
14.0	1.33684	1.33654	1.33626	1.33599	1.33572	1.33546	1.33521	1.33497	1.33473	1.33451	1.33429
16.0	1.33667	1.33638	1.33609	1.33582	1.33555	1.33529	1.33504	1.33480	1.33456	1.33434	1.33412
18.0	1.33650	1.33620	1.33592	1.33564	1.33538	1.33512	1.33486	1.33462	1.33438	1.33416	1.33394
20.0	1.33631	1.33601	1.33573	1.33545	1.33519	1.33493	1.33467	1.33443	1.33419	1.33397	1.33375
22.0	1.33610	1.33581	1.33553	1.33525	1.33499	1.33473	1.33447	1.33423	1.33399	1.33377	1.33355
24.0	1.33590	1.33560	1.33532	1.33504	1.33478	1.33451	1.33426	1.33402	1.33379	1.33356	1.33335
26.0	1.33567	1.33538	1.33510	1.33482	1.33455	1.33429	1.33404	1.33380	1.33357	1.33335	1.33313
28.0	1.33545	1.33515	1.33487	1.33459	1.33432	1.33406	1.33381	1.33357	1.33334	1.33312	1.33290
30.0	1.33521	1.33491	1.33463	1.33435	1.33408	1.33382	1.33357	1.33333	1.33310	1.33288	1.33266

Table A-4. (cont)

(f)

S = 25 ‰

TEMP	SALINITY (‰)									
°C	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.34935	1.34843	1.34756	1.34675	1.34601	1.34531	1.34465	1.34404	1.34346	1.34293
2.0	1.34928	1.34836	1.34749	1.34668	1.34594	1.34525	1.34459	1.34398	1.34341	1.34287
4.0	1.34919	1.34827	1.34741	1.34660	1.34586	1.34517	1.34452	1.34390	1.34333	1.34279
6.0	1.34909	1.34818	1.34731	1.34650	1.34577	1.34507	1.34442	1.34380	1.34323	1.34270
8.0	1.34898	1.34806	1.34719	1.34639	1.34565	1.34496	1.34431	1.34369	1.34312	1.34258
10.0	1.34886	1.34794	1.34707	1.34626	1.34552	1.34483	1.34418	1.34356	1.34299	1.34245
12.0	1.34872	1.34780	1.34692	1.34611	1.34537	1.34468	1.34403	1.34341	1.34284	1.34231
14.0	1.34856	1.34764	1.34677	1.34595	1.34521	1.34452	1.34386	1.34325	1.34269	1.34215
16.0	1.34839	1.34747	1.34659	1.34578	1.34504	1.34434	1.34369	1.34308	1.34251	1.34198
18.0	1.34820	1.34728	1.34641	1.34560	1.34486	1.34416	1.34350	1.34289	1.34233	1.34179
20.0	1.34800	1.34709	1.34622	1.34541	1.34467	1.34397	1.34331	1.34270	1.34213	1.34160
22.0	1.34779	1.34688	1.34601	1.34520	1.34446	1.34376	1.34311	1.34249	1.34192	1.34139
24.0	1.34758	1.34666	1.34579	1.34498	1.34424	1.34355	1.34289	1.34228	1.34171	1.34117
26.0	1.34734	1.34643	1.34555	1.34475	1.34401	1.34332	1.34266	1.34205	1.34148	1.34095
28.0	1.34710	1.34618	1.34531	1.34450	1.34377	1.34308	1.34243	1.34181	1.34124	1.34071
30.0	1.34684	1.34593	1.34506	1.34425	1.34352	1.34283	1.34218	1.34156	1.34099	1.34046

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34242	1.34194	1.34148	1.34105	1.34064	1.34025	1.33987	1.33951	1.33918	1.33885
2.0	1.34236	1.34188	1.34142	1.34098	1.34057	1.34019	1.33982	1.33947	1.33912	1.33880
4.0	1.34228	1.34180	1.34134	1.34090	1.34049	1.34011	1.33975	1.33940	1.33905	1.33872
6.0	1.34218	1.34170	1.34124	1.34081	1.34040	1.34001	1.33964	1.33929	1.33896	1.33863
8.0	1.34207	1.34158	1.34113	1.34070	1.34029	1.33990	1.33953	1.33917	1.33885	1.33852
10.0	1.34194	1.34145	1.34100	1.34058	1.34017	1.33978	1.33940	1.33904	1.33872	1.33839
12.0	1.34179	1.34131	1.34085	1.34043	1.34002	1.33963	1.33925	1.33890	1.33857	1.33824
14.0	1.34164	1.34115	1.34069	1.34026	1.33985	1.33947	1.33910	1.33874	1.33841	1.33808
16.0	1.34146	1.34098	1.34052	1.34008	1.33968	1.33930	1.33894	1.33858	1.33823	1.33790
18.0	1.34128	1.34079	1.34034	1.33990	1.33950	1.33912	1.33875	1.33839	1.33805	1.33772
20.0	1.34108	1.34060	1.34015	1.33972	1.33931	1.33893	1.33855	1.33819	1.33786	1.33753
22.0	1.34088	1.34040	1.33994	1.33951	1.33911	1.33872	1.33835	1.33799	1.33765	1.33732
24.0	1.34066	1.34018	1.33973	1.33930	1.33889	1.33851	1.33814	1.33778	1.33743	1.33711
26.0	1.34044	1.33996	1.33951	1.33907	1.33866	1.33828	1.33791	1.33755	1.33721	1.33689
28.0	1.34020	1.33972	1.33927	1.33884	1.33843	1.33805	1.33768	1.33733	1.33698	1.33665
30.0	1.33995	1.33948	1.33902	1.33859	1.33819	1.33781	1.33744	1.33708	1.33674	1.33642

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.33854	1.33824	1.33796	1.33768	1.33742	1.33715	1.33690	1.33665	1.33641	1.33618	1.33596
2.0	1.33848	1.33818	1.33790	1.33762	1.33736	1.33709	1.33684	1.33659	1.33636	1.33613	1.33591
4.0	1.33841	1.33811	1.33782	1.33755	1.33728	1.33701	1.33676	1.33652	1.33628	1.33606	1.33584
6.0	1.33832	1.33802	1.33773	1.33745	1.33718	1.33692	1.33667	1.33642	1.33619	1.33596	1.33575
8.0	1.33821	1.33791	1.33762	1.33734	1.33707	1.33681	1.33655	1.33631	1.33608	1.33585	1.33564
10.0	1.33808	1.33778	1.33749	1.33721	1.33694	1.33668	1.33643	1.33618	1.33595	1.33573	1.33551
12.0	1.33793	1.33763	1.33735	1.33707	1.33680	1.33654	1.33628	1.33604	1.33581	1.33558	1.33537
14.0	1.33776	1.33747	1.33718	1.33691	1.33664	1.33638	1.33613	1.33589	1.33565	1.33543	1.33521
16.0	1.33760	1.33730	1.33702	1.33674	1.33647	1.33621	1.33596	1.33571	1.33547	1.33525	1.33503
18.0	1.33741	1.33711	1.33683	1.33656	1.33629	1.33603	1.33577	1.33553	1.33529	1.33506	1.33484
20.0	1.33721	1.33692	1.33663	1.33636	1.33609	1.33583	1.33558	1.33533	1.33509	1.33486	1.33464
22.0	1.33701	1.33671	1.33643	1.33615	1.33589	1.33563	1.33537	1.33513	1.33489	1.33466	1.33444
24.0	1.33680	1.33650	1.33622	1.33594	1.33567	1.33541	1.33516	1.33492	1.33468	1.33445	1.33424
26.0	1.33657	1.33628	1.33599	1.33572	1.33545	1.33519	1.33494	1.33469	1.33446	1.33424	1.33402
28.0	1.33635	1.33605	1.33576	1.33549	1.33522	1.33495	1.33470	1.33446	1.33423	1.33401	1.33379
30.0	1.33610	1.33580	1.33552	1.33524	1.33498	1.33471	1.33446	1.33422	1.33399	1.33376	1.33355

Table A-4. (cont)

(g)

S = 30 ‰

TEMP	WAVELENGTH (nm)									
°C	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.35038	1.34946	1.34858	1.34777	1.34702	1.34632	1.34566	1.34504	1.34447	1.34393
2.0	1.35030	1.34938	1.34850	1.34769	1.34695	1.34625	1.34559	1.34498	1.34440	1.34387
4.0	1.35020	1.34928	1.34841	1.34760	1.34686	1.34617	1.34551	1.34489	1.34432	1.34378
6.0	1.35009	1.34918	1.34830	1.34749	1.34676	1.34606	1.34540	1.34479	1.34421	1.34367
8.0	1.34998	1.34906	1.34818	1.34737	1.34664	1.34594	1.34528	1.34467	1.34409	1.34355
10.0	1.34985	1.34893	1.34805	1.34724	1.34650	1.34580	1.34515	1.34453	1.34395	1.34341
12.0	1.34970	1.34878	1.34790	1.34708	1.34634	1.34565	1.34499	1.34437	1.34380	1.34326
14.0	1.34954	1.34861	1.34774	1.34692	1.34618	1.34548	1.34482	1.34421	1.34364	1.34310
16.0	1.34936	1.34844	1.34756	1.34675	1.34600	1.34530	1.34464	1.34402	1.34346	1.34292
18.0	1.34917	1.34825	1.34738	1.34656	1.34581	1.34511	1.34445	1.34384	1.34327	1.34274
20.0	1.34897	1.34805	1.34718	1.34637	1.34562	1.34491	1.34425	1.34364	1.34307	1.34254
22.0	1.34876	1.34784	1.34697	1.34615	1.34541	1.34470	1.34404	1.34343	1.34286	1.34232
24.0	1.34854	1.34762	1.34674	1.34593	1.34519	1.34448	1.34382	1.34321	1.34264	1.34210
26.0	1.34830	1.34738	1.34650	1.34569	1.34495	1.34425	1.34359	1.34298	1.34240	1.34187
28.0	1.34805	1.34713	1.34626	1.34544	1.34471	1.34401	1.34336	1.34274	1.34216	1.34163
30.0	1.34780	1.34687	1.34600	1.34519	1.34445	1.34376	1.34311	1.34249	1.34192	1.34138

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34342	1.34293	1.34248	1.34204	1.34163	1.34125	1.34087	1.34051	1.34016	1.33983
2.0	1.34335	1.34287	1.34241	1.34197	1.34155	1.34118	1.34081	1.34045	1.34010	1.33977
4.0	1.34327	1.34278	1.34232	1.34187	1.34146	1.34109	1.34073	1.34037	1.34002	1.33969
6.0	1.34316	1.34267	1.34221	1.34178	1.34137	1.34098	1.34061	1.34025	1.33992	1.33959
8.0	1.34303	1.34255	1.34209	1.34166	1.34125	1.34086	1.34048	1.34012	1.33980	1.33947
10.0	1.34290	1.34241	1.34196	1.34153	1.34112	1.34072	1.34034	1.33998	1.33966	1.33933
12.0	1.34274	1.34226	1.34180	1.34137	1.34096	1.34057	1.34019	1.33983	1.33951	1.33918
14.0	1.34258	1.34209	1.34163	1.34120	1.34079	1.34040	1.34003	1.33967	1.33934	1.33901
16.0	1.34241	1.34192	1.34145	1.34102	1.34061	1.34023	1.33986	1.33950	1.33916	1.33883
18.0	1.34222	1.34173	1.34126	1.34083	1.34042	1.34004	1.33968	1.33932	1.33897	1.33864
20.0	1.34202	1.34153	1.34107	1.34064	1.34023	1.33985	1.33948	1.33912	1.33877	1.33844
22.0	1.34181	1.34132	1.34087	1.34043	1.34002	1.33964	1.33926	1.33890	1.33856	1.33823
24.0	1.34159	1.34111	1.34065	1.34022	1.33981	1.33942	1.33904	1.33868	1.33834	1.33801
26.0	1.34136	1.34088	1.34043	1.33999	1.33958	1.33919	1.33881	1.33845	1.33812	1.33779
28.0	1.34112	1.34064	1.34019	1.33975	1.33934	1.33896	1.33859	1.33823	1.33788	1.33756
30.0	1.34087	1.34039	1.33994	1.33950	1.33909	1.33871	1.33835	1.33799	1.33764	1.33732

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.33952	1.33922	1.33894	1.33866	1.33840	1.33813	1.33788	1.33763	1.33739	1.33715	1.33693
2.0	1.33946	1.33916	1.33887	1.33860	1.33833	1.33806	1.33781	1.33756	1.33733	1.33710	1.33688
4.0	1.33938	1.33908	1.33879	1.33851	1.33824	1.33798	1.33772	1.33748	1.33724	1.33702	1.33680
6.0	1.33927	1.33897	1.33869	1.33841	1.33814	1.33787	1.33762	1.33738	1.33714	1.33692	1.33670
8.0	1.33916	1.33886	1.33857	1.33829	1.33802	1.33775	1.33750	1.33726	1.33702	1.33680	1.33658
10.0	1.33902	1.33873	1.33844	1.33815	1.33788	1.33762	1.33736	1.33712	1.33689	1.33666	1.33645
12.0	1.33887	1.33857	1.33828	1.33800	1.33773	1.33747	1.33721	1.33697	1.33674	1.33651	1.33630
14.0	1.33869	1.33839	1.33811	1.33783	1.33757	1.33730	1.33705	1.33681	1.33657	1.33635	1.33613
16.0	1.33851	1.33822	1.33793	1.33766	1.33739	1.33713	1.33687	1.33663	1.33639	1.33616	1.33594
18.0	1.33833	1.33803	1.33774	1.33747	1.33720	1.33694	1.33668	1.33644	1.33620	1.33597	1.33574
20.0	1.33813	1.33783	1.33754	1.33727	1.33700	1.33674	1.33648	1.33624	1.33600	1.33576	1.33554
22.0	1.33792	1.33762	1.33733	1.33706	1.33679	1.33653	1.33628	1.33603	1.33579	1.33556	1.33534
24.0	1.33770	1.33740	1.33712	1.33684	1.33657	1.33631	1.33606	1.33581	1.33558	1.33535	1.33513
26.0	1.33747	1.33717	1.33689	1.33661	1.33635	1.33608	1.33583	1.33559	1.33535	1.33513	1.33491
28.0	1.33724	1.33694	1.33666	1.33638	1.33611	1.33585	1.33560	1.33535	1.33512	1.33489	1.33468
30.0	1.33700	1.33670	1.33642	1.33614	1.33587	1.33560	1.33535	1.33511	1.33487	1.33465	1.33443

Table A-4. (cont)

(h)

S = 31 ‰

TEMP	WAVELENGTH (nm)									
°C	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.35059	1.34966	1.34879	1.34797	1.34723	1.34653	1.34586	1.34525	1.34467	1.34413
2.0	1.35050	1.34958	1.34871	1.34789	1.34715	1.34646	1.34579	1.34518	1.34460	1.34406
4.0	1.35040	1.34948	1.34861	1.34780	1.34706	1.34637	1.34571	1.34509	1.34451	1.34398
6.0	1.35030	1.34938	1.34850	1.34769	1.34695	1.34626	1.34560	1.34498	1.34441	1.34387
8.0	1.35018	1.34926	1.34838	1.34757	1.34683	1.34614	1.34548	1.34486	1.34429	1.34374
10.0	1.35005	1.34912	1.34825	1.34743	1.34669	1.34600	1.34534	1.34472	1.34415	1.34361
12.0	1.34990	1.34897	1.34809	1.34728	1.34654	1.34584	1.34518	1.34457	1.34399	1.34345
14.0	1.34974	1.34881	1.34793	1.34711	1.34637	1.34567	1.34501	1.34440	1.34383	1.34329
16.0	1.34956	1.34863	1.34776	1.34694	1.34619	1.34549	1.34483	1.34422	1.34365	1.34311
18.0	1.34937	1.34844	1.34757	1.34675	1.34601	1.34530	1.34464	1.34403	1.34346	1.34292
20.0	1.34916	1.34824	1.34737	1.34656	1.34581	1.34510	1.34444	1.34383	1.34326	1.34272
22.0	1.34895	1.34803	1.34716	1.34634	1.34560	1.34489	1.34423	1.34361	1.34305	1.34251
24.0	1.34873	1.34781	1.34693	1.34612	1.34538	1.34467	1.34401	1.34339	1.34282	1.34229
26.0	1.34849	1.34757	1.34669	1.34588	1.34514	1.34444	1.34378	1.34316	1.34259	1.34205
28.0	1.34824	1.34732	1.34645	1.34563	1.34489	1.34420	1.34354	1.34292	1.34235	1.34181
30.0	1.34799	1.34706	1.34619	1.34537	1.34464	1.34395	1.34329	1.34268	1.34210	1.34157

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34362	1.34313	1.34268	1.34224	1.34183	1.34144	1.34106	1.34070	1.34036	1.34003
2.0	1.34355	1.34307	1.34260	1.34217	1.34175	1.34137	1.34100	1.34064	1.34030	1.33997
4.0	1.34346	1.34298	1.34251	1.34207	1.34166	1.34128	1.34091	1.34056	1.34022	1.33988
6.0	1.34335	1.34287	1.34241	1.34197	1.34156	1.34117	1.34080	1.34044	1.34011	1.33978
8.0	1.34323	1.34274	1.34229	1.34186	1.34144	1.34105	1.34067	1.34032	1.33999	1.33966
10.0	1.34309	1.34260	1.34215	1.34172	1.34131	1.34091	1.34053	1.34017	1.33985	1.33952
12.0	1.34294	1.34245	1.34199	1.34156	1.34115	1.34076	1.34038	1.34002	1.33970	1.33936
14.0	1.34277	1.34228	1.34182	1.34139	1.34098	1.34059	1.34022	1.33986	1.33953	1.33919
16.0	1.34259	1.34210	1.34164	1.34120	1.34079	1.34042	1.34005	1.33969	1.33934	1.33901
18.0	1.34240	1.34191	1.34145	1.34102	1.34061	1.34023	1.33986	1.33950	1.33916	1.33882
20.0	1.34220	1.34171	1.34126	1.34082	1.34042	1.34003	1.33966	1.33930	1.33896	1.33863
22.0	1.34199	1.34151	1.34105	1.34062	1.34021	1.33982	1.33944	1.33908	1.33875	1.33842
24.0	1.34177	1.34129	1.34084	1.34040	1.33999	1.33960	1.33922	1.33886	1.33853	1.33820
26.0	1.34155	1.34107	1.34061	1.34017	1.33976	1.33937	1.33900	1.33864	1.33830	1.33797
28.0	1.34131	1.34083	1.34037	1.33994	1.33952	1.33914	1.33876	1.33840	1.33807	1.33774
30.0	1.34106	1.34058	1.34012	1.33968	1.33928	1.33890	1.33853	1.33817	1.33782	1.33750

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.33972	1.33942	1.33913	1.33886	1.33859	1.33833	1.33807	1.33782	1.33758	1.33735	1.33713
2.0	1.33965	1.33935	1.33906	1.33879	1.33852	1.33826	1.33800	1.33776	1.33752	1.33729	1.33707
4.0	1.33956	1.33926	1.33898	1.33870	1.33843	1.33817	1.33792	1.33767	1.33744	1.33721	1.33699
6.0	1.33947	1.33916	1.33888	1.33860	1.33833	1.33806	1.33781	1.33757	1.33733	1.33711	1.33689
8.0	1.33935	1.33905	1.33876	1.33848	1.33821	1.33794	1.33769	1.33744	1.33721	1.33699	1.33677
10.0	1.33921	1.33891	1.33862	1.33834	1.33807	1.33780	1.33755	1.33731	1.33707	1.33685	1.33663
12.0	1.33905	1.33876	1.33847	1.33819	1.33792	1.33765	1.33740	1.33716	1.33692	1.33670	1.33648
14.0	1.33888	1.33858	1.33829	1.33802	1.33775	1.33749	1.33724	1.33699	1.33676	1.33653	1.33631
16.0	1.33870	1.33840	1.33812	1.33784	1.33757	1.33731	1.33706	1.33681	1.33657	1.33634	1.33612
18.0	1.33851	1.33821	1.33793	1.33765	1.33738	1.33712	1.33687	1.33662	1.33638	1.33615	1.33592
20.0	1.33831	1.33801	1.33773	1.33745	1.33718	1.33692	1.33666	1.33642	1.33618	1.33594	1.33572
22.0	1.33810	1.33780	1.33751	1.33724	1.33697	1.33671	1.33645	1.33621	1.33597	1.33574	1.33551
24.0	1.33788	1.33758	1.33730	1.33702	1.33675	1.33649	1.33624	1.33599	1.33575	1.33552	1.33531
26.0	1.33765	1.33735	1.33707	1.33679	1.33652	1.33626	1.33601	1.33577	1.33553	1.33531	1.33509
28.0	1.33742	1.33712	1.33683	1.33656	1.33629	1.33603	1.33577	1.33553	1.33529	1.33507	1.33486
30.0	1.33718	1.33689	1.33660	1.33632	1.33605	1.33578	1.33553	1.33528	1.33505	1.33482	1.33461

Table A-4. (cont)

(i)

S = 32 ‰

TEMP °C	SALINITY (0/00)									
	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.35079	1.34987	1.34899	1.34818	1.34743	1.34673	1.34607	1.34545	1.34487	1.34433
2.0	1.35071	1.34978	1.34891	1.34809	1.34735	1.34666	1.34600	1.34538	1.34480	1.34426
4.0	1.35061	1.34969	1.34881	1.34800	1.34726	1.34656	1.34590	1.34529	1.34471	1.34417
6.0	1.35050	1.34958	1.34870	1.34789	1.34715	1.34645	1.34580	1.34518	1.34460	1.34406
8.0	1.35038	1.34945	1.34858	1.34777	1.34703	1.34633	1.34567	1.34506	1.34448	1.34394
10.0	1.35025	1.34932	1.34844	1.34763	1.34689	1.34619	1.34553	1.34492	1.34434	1.34380
12.0	1.35010	1.34917	1.34829	1.34748	1.34673	1.34603	1.34537	1.34476	1.34418	1.34364
14.0	1.34993	1.34900	1.34813	1.34731	1.34656	1.34586	1.34520	1.34459	1.34402	1.34348
16.0	1.34975	1.34883	1.34795	1.34713	1.34638	1.34568	1.34502	1.34440	1.34384	1.34330
18.0	1.34956	1.34864	1.34776	1.34695	1.34620	1.34549	1.34483	1.34421	1.34365	1.34311
20.0	1.34936	1.34844	1.34756	1.34675	1.34600	1.34529	1.34463	1.34401	1.34345	1.34291
22.0	1.34914	1.34822	1.34735	1.34653	1.34579	1.34508	1.34442	1.34380	1.34323	1.34270
24.0	1.34892	1.34800	1.34712	1.34631	1.34556	1.34486	1.34420	1.34358	1.34301	1.34247
26.0	1.34869	1.34776	1.34688	1.34607	1.34533	1.34463	1.34397	1.34335	1.34277	1.34224
28.0	1.34844	1.34751	1.34663	1.34582	1.34508	1.34439	1.34373	1.34311	1.34253	1.34200
30.0	1.34818	1.34725	1.34637	1.34556	1.34482	1.34413	1.34348	1.34286	1.34228	1.34175

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34382	1.34333	1.34288	1.34244	1.34203	1.34164	1.34126	1.34090	1.34056	1.34023
2.0	1.34375	1.34326	1.34280	1.34236	1.34195	1.34157	1.34120	1.34084	1.34049	1.34016
4.0	1.34366	1.34317	1.34271	1.34227	1.34185	1.34148	1.34111	1.34076	1.34041	1.34008
6.0	1.34355	1.34306	1.34260	1.34216	1.34175	1.34137	1.34099	1.34064	1.34030	1.33997
8.0	1.34342	1.34294	1.34248	1.34205	1.34164	1.34124	1.34086	1.34051	1.34018	1.33985
10.0	1.34328	1.34279	1.34234	1.34191	1.34150	1.34110	1.34072	1.34036	1.34004	1.33971
12.0	1.34313	1.34264	1.34218	1.34175	1.34134	1.34095	1.34057	1.34021	1.33988	1.33955
14.0	1.34296	1.34247	1.34201	1.34157	1.34116	1.34078	1.34041	1.34005	1.33971	1.33938
16.0	1.34278	1.34229	1.34183	1.34139	1.34098	1.34060	1.34023	1.33987	1.33953	1.33920
18.0	1.34259	1.34210	1.34164	1.34120	1.34080	1.34041	1.34004	1.33968	1.33934	1.33901
20.0	1.34239	1.34190	1.34144	1.34101	1.34060	1.34022	1.33984	1.33948	1.33914	1.33881
22.0	1.34218	1.34169	1.34124	1.34080	1.34039	1.34001	1.33963	1.33926	1.33893	1.33860
24.0	1.34196	1.34148	1.34102	1.34058	1.34017	1.33978	1.33941	1.33905	1.33871	1.33838
26.0	1.34173	1.34125	1.34079	1.34036	1.33994	1.33955	1.33918	1.33882	1.33848	1.33815
28.0	1.34149	1.34101	1.34055	1.34012	1.33971	1.33932	1.33894	1.33858	1.33825	1.33791
30.0	1.34124	1.34076	1.34030	1.33987	1.33946	1.33908	1.33871	1.33835	1.33801	1.33768

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.33991	1.33961	1.33933	1.33905	1.33879	1.33852	1.33827	1.33802	1.33778	1.33755	1.33732
2.0	1.33985	1.33955	1.33926	1.33898	1.33872	1.33845	1.33820	1.33795	1.33771	1.33748	1.33726
4.0	1.33976	1.33947	1.33918	1.33890	1.33863	1.33836	1.33811	1.33786	1.33763	1.33740	1.33718
6.0	1.33965	1.33935	1.33907	1.33879	1.33852	1.33825	1.33800	1.33776	1.33752	1.33730	1.33708
8.0	1.33954	1.33924	1.33895	1.33867	1.33840	1.33813	1.33788	1.33763	1.33740	1.33717	1.33696
10.0	1.33940	1.33910	1.33881	1.33853	1.33826	1.33799	1.33774	1.33749	1.33726	1.33704	1.33682
12.0	1.33924	1.33894	1.33865	1.33837	1.33810	1.33784	1.33759	1.33734	1.33711	1.33688	1.33667
14.0	1.33906	1.33876	1.33848	1.33820	1.33794	1.33767	1.33742	1.33718	1.33694	1.33672	1.33650
16.0	1.33888	1.33858	1.33830	1.33802	1.33776	1.33749	1.33724	1.33699	1.33675	1.33652	1.33630
18.0	1.33869	1.33839	1.33811	1.33783	1.33757	1.33730	1.33705	1.33680	1.33656	1.33633	1.33610
20.0	1.33849	1.33819	1.33790	1.33763	1.33736	1.33710	1.33684	1.33660	1.33636	1.33612	1.33590
22.0	1.33828	1.33798	1.33770	1.33742	1.33715	1.33689	1.33663	1.33639	1.33615	1.33592	1.33569
24.0	1.33806	1.33776	1.33747	1.33720	1.33693	1.33667	1.33642	1.33617	1.33593	1.33570	1.33548
26.0	1.33783	1.33753	1.33725	1.33697	1.33670	1.33644	1.33619	1.33595	1.33571	1.33549	1.33527
28.0	1.33760	1.33730	1.33701	1.33674	1.33647	1.33621	1.33595	1.33571	1.33547	1.33525	1.33503
30.0	1.33736	1.33706	1.33677	1.33650	1.33622	1.33596	1.33571	1.33546	1.33523	1.33500	1.33478

Table A-4. (cont)

(j)

S = 33 ‰

TEMP	WAVELENGTH (nm)									
°C	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.35100	1.35007	1.34920	1.34838	1.34763	1.34693	1.34627	1.34565	1.34507	1.34453
2.0	1.35091	1.34999	1.34911	1.34830	1.34756	1.34686	1.34620	1.34558	1.34500	1.34446
4.0	1.35081	1.34989	1.34901	1.34820	1.34746	1.34676	1.34610	1.34548	1.34491	1.34437
6.0	1.35070	1.34978	1.34890	1.34809	1.34735	1.34665	1.34599	1.34538	1.34480	1.34426
8.0	1.35058	1.34965	1.34878	1.34796	1.34722	1.34653	1.34587	1.34525	1.34467	1.34413
10.0	1.35044	1.34952	1.34864	1.34782	1.34708	1.34639	1.34573	1.34511	1.34453	1.34399
12.0	1.35030	1.34937	1.34849	1.34767	1.34692	1.34622	1.34556	1.34495	1.34438	1.34384
14.0	1.35013	1.34920	1.34832	1.34750	1.34676	1.34605	1.34539	1.34478	1.34421	1.34367
16.0	1.34995	1.34902	1.34814	1.34732	1.34657	1.34587	1.34521	1.34459	1.34403	1.34349
18.0	1.34976	1.34883	1.34795	1.34714	1.34639	1.34568	1.34502	1.34440	1.34384	1.34330
20.0	1.34955	1.34863	1.34775	1.34694	1.34619	1.34548	1.34482	1.34420	1.34363	1.34309
22.0	1.34934	1.34841	1.34754	1.34673	1.34598	1.34527	1.34461	1.34399	1.34342	1.34288
24.0	1.34911	1.34819	1.34731	1.34650	1.34575	1.34505	1.34439	1.34377	1.34319	1.34266
26.0	1.34888	1.34795	1.34707	1.34626	1.34552	1.34482	1.34415	1.34353	1.34296	1.34243
28.0	1.34863	1.34770	1.34682	1.34601	1.34527	1.34457	1.34391	1.34329	1.34272	1.34218
30.0	1.34837	1.34744	1.34656	1.34575	1.34501	1.34432	1.34366	1.34305	1.34247	1.34193

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34402	1.34353	1.34308	1.34264	1.34223	1.34184	1.34147	1.34110	1.34075	1.34043
2.0	1.34395	1.34346	1.34300	1.34256	1.34215	1.34176	1.34139	1.34103	1.34069	1.34036
4.0	1.34386	1.34337	1.34291	1.34246	1.34205	1.34167	1.34130	1.34095	1.34060	1.34027
6.0	1.34374	1.34326	1.34280	1.34236	1.34195	1.34156	1.34118	1.34083	1.34050	1.34016
8.0	1.34361	1.34313	1.34267	1.34224	1.34183	1.34143	1.34105	1.34070	1.34037	1.34004
10.0	1.34347	1.34299	1.34253	1.34210	1.34169	1.34130	1.34091	1.34055	1.34023	1.33990
12.0	1.34332	1.34283	1.34237	1.34194	1.34153	1.34114	1.34076	1.34040	1.34007	1.33974
14.0	1.34315	1.34266	1.34220	1.34176	1.34135	1.34097	1.34059	1.34023	1.33990	1.33957
16.0	1.34297	1.34248	1.34202	1.34158	1.34117	1.34079	1.34042	1.34006	1.33971	1.33938
18.0	1.34278	1.34229	1.34182	1.34139	1.34098	1.34060	1.34022	1.33986	1.33952	1.33919
20.0	1.34257	1.34208	1.34163	1.34119	1.34079	1.34040	1.34002	1.33966	1.33932	1.33899
22.0	1.34236	1.34188	1.34142	1.34099	1.34058	1.34019	1.33981	1.33945	1.33911	1.33878
24.0	1.34214	1.34166	1.34120	1.34077	1.34035	1.33997	1.33959	1.33923	1.33889	1.33856
26.0	1.34192	1.34143	1.34097	1.34054	1.34012	1.33974	1.33937	1.33901	1.33866	1.33833
28.0	1.34167	1.34119	1.34074	1.34030	1.33989	1.33950	1.33913	1.33877	1.33843	1.33810
30.0	1.34142	1.34094	1.34049	1.34005	1.33964	1.33926	1.33888	1.33853	1.33819	1.33785

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.34011	1.33982	1.33953	1.33925	1.33898	1.33872	1.33846	1.33821	1.33797	1.33774	1.33752
2.0	1.34004	1.33974	1.33946	1.33918	1.33891	1.33865	1.33839	1.33814	1.33791	1.33768	1.33746
4.0	1.33995	1.33965	1.33937	1.33909	1.33882	1.33856	1.33830	1.33805	1.33782	1.33759	1.33737
6.0	1.33985	1.33955	1.33926	1.33898	1.33871	1.33845	1.33819	1.33795	1.33771	1.33749	1.33727
8.0	1.33973	1.33943	1.33914	1.33886	1.33858	1.33832	1.33807	1.33782	1.33759	1.33736	1.33715
10.0	1.33959	1.33929	1.33900	1.33872	1.33844	1.33818	1.33793	1.33768	1.33745	1.33722	1.33701
12.0	1.33943	1.33913	1.33884	1.33856	1.33829	1.33803	1.33777	1.33753	1.33729	1.33707	1.33685
14.0	1.33925	1.33895	1.33866	1.33839	1.33812	1.33786	1.33760	1.33736	1.33712	1.33690	1.33668
16.0	1.33906	1.33877	1.33848	1.33821	1.33794	1.33768	1.33742	1.33718	1.33694	1.33671	1.33649
18.0	1.33887	1.33857	1.33829	1.33801	1.33775	1.33748	1.33723	1.33698	1.33674	1.33651	1.33628
20.0	1.33867	1.33837	1.33809	1.33781	1.33755	1.33728	1.33703	1.33678	1.33654	1.33630	1.33608
22.0	1.33846	1.33816	1.33788	1.33760	1.33733	1.33707	1.33681	1.33657	1.33633	1.33609	1.33587
24.0	1.33824	1.33794	1.33766	1.33738	1.33711	1.33685	1.33660	1.33635	1.33611	1.33588	1.33566
26.0	1.33802	1.33772	1.33743	1.33715	1.33688	1.33662	1.33637	1.33612	1.33589	1.33566	1.33545
28.0	1.33778	1.33748	1.33720	1.33692	1.33665	1.33638	1.33613	1.33589	1.33565	1.33543	1.33521
30.0	1.33753	1.33723	1.33695	1.33667	1.33640	1.33614	1.33589	1.33564	1.33541	1.33518	1.33496

Table A-4. (cont)

(k)

S = 34 ‰

TEMP	WAVELENGTH (nm)									
°C	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.35121	1.35028	1.34940	1.34858	1.34784	1.34713	1.34647	1.34585	1.34527	1.34473
2.0	1.35111	1.35019	1.34932	1.34850	1.34776	1.34706	1.34639	1.34577	1.34520	1.34466
4.0	1.35101	1.35009	1.34921	1.34840	1.34766	1.34696	1.34630	1.34568	1.34511	1.34457
6.0	1.35090	1.34998	1.34910	1.34829	1.34755	1.34685	1.34619	1.34557	1.34499	1.34445
8.0	1.35077	1.34985	1.34898	1.34816	1.34742	1.34672	1.34606	1.34545	1.34487	1.34433
10.0	1.35064	1.34972	1.34884	1.34802	1.34728	1.34658	1.34592	1.34530	1.34473	1.34418
12.0	1.35049	1.34956	1.34868	1.34786	1.34712	1.34642	1.34576	1.34514	1.34457	1.34403
14.0	1.35032	1.34939	1.34851	1.34770	1.34695	1.34624	1.34558	1.34497	1.34440	1.34386
16.0	1.35014	1.34921	1.34833	1.34752	1.34677	1.34606	1.34540	1.34478	1.34422	1.34368
18.0	1.34995	1.34902	1.34815	1.34733	1.34658	1.34587	1.34521	1.34459	1.34403	1.34349
20.0	1.34974	1.34882	1.34795	1.34713	1.34638	1.34567	1.34501	1.34439	1.34382	1.34328
22.0	1.34953	1.34861	1.34773	1.34691	1.34617	1.34546	1.34479	1.34418	1.34361	1.34307
24.0	1.34930	1.34838	1.34750	1.34669	1.34594	1.34524	1.34457	1.34395	1.34338	1.34284
26.0	1.34907	1.34814	1.34726	1.34645	1.34570	1.34500	1.34434	1.34372	1.34314	1.34261
28.0	1.34882	1.34789	1.34701	1.34620	1.34546	1.34476	1.34410	1.34348	1.34290	1.34237
30.0	1.34856	1.34763	1.34675	1.34594	1.34520	1.34451	1.34385	1.34323	1.34265	1.34212

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34422	1.34373	1.34328	1.34284	1.34243	1.34204	1.34166	1.34129	1.34095	1.34062
2.0	1.34414	1.34366	1.34320	1.34276	1.34234	1.34196	1.34159	1.34123	1.34089	1.34055
4.0	1.34405	1.34357	1.34310	1.34266	1.34224	1.34186	1.34150	1.34114	1.34079	1.34047
6.0	1.34394	1.34345	1.34299	1.34255	1.34214	1.34175	1.34138	1.34102	1.34069	1.34036
8.0	1.34381	1.34332	1.34286	1.34243	1.34202	1.34163	1.34125	1.34089	1.34056	1.34023
10.0	1.34366	1.34317	1.34272	1.34229	1.34188	1.34149	1.34110	1.34074	1.34042	1.34009
12.0	1.34351	1.34302	1.34256	1.34213	1.34172	1.34132	1.34094	1.34058	1.34026	1.33993
14.0	1.34334	1.34285	1.34239	1.34195	1.34154	1.34115	1.34078	1.34042	1.34009	1.33975
16.0	1.34316	1.34267	1.34220	1.34176	1.34135	1.34097	1.34060	1.34024	1.33990	1.33957
18.0	1.34296	1.34247	1.34201	1.34158	1.34117	1.34078	1.34041	1.34005	1.33971	1.33937
20.0	1.34276	1.34227	1.34181	1.34138	1.34097	1.34058	1.34021	1.33984	1.33951	1.33917
22.0	1.34255	1.34206	1.34160	1.34117	1.34076	1.34037	1.33999	1.33963	1.33929	1.33896
24.0	1.34233	1.34185	1.34139	1.34095	1.34054	1.34015	1.33977	1.33941	1.33907	1.33874
26.0	1.34210	1.34162	1.34116	1.34072	1.34031	1.33992	1.33954	1.33918	1.33884	1.33851
28.0	1.34186	1.34138	1.34092	1.34048	1.34007	1.33968	1.33931	1.33895	1.33861	1.33828
30.0	1.34161	1.34112	1.34067	1.34023	1.33982	1.33944	1.33907	1.33871	1.33837	1.33804

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.34030	1.34000	1.33972	1.33945	1.33918	1.33891	1.33866	1.33841	1.33817	1.33794	1.33771
2.0	1.34023	1.33993	1.33965	1.33937	1.33910	1.33884	1.33858	1.33834	1.33810	1.33787	1.33765
4.0	1.34015	1.33985	1.33956	1.33928	1.33901	1.33875	1.33849	1.33825	1.33801	1.33778	1.33757
6.0	1.34004	1.33974	1.33945	1.33917	1.33890	1.33864	1.33838	1.33814	1.33790	1.33768	1.33746
8.0	1.33992	1.33962	1.33933	1.33905	1.33877	1.33851	1.33825	1.33801	1.33778	1.33755	1.33733
10.0	1.33978	1.33948	1.33919	1.33891	1.33863	1.33837	1.33811	1.33787	1.33763	1.33741	1.33719
12.0	1.33962	1.33932	1.33903	1.33875	1.33848	1.33821	1.33796	1.33771	1.33748	1.33725	1.33704
14.0	1.33944	1.33914	1.33885	1.33857	1.33831	1.33804	1.33779	1.33754	1.33731	1.33708	1.33686
16.0	1.33925	1.33895	1.33866	1.33839	1.33812	1.33786	1.33760	1.33736	1.33712	1.33689	1.33667
18.0	1.33906	1.33876	1.33847	1.33820	1.33793	1.33767	1.33741	1.33716	1.33692	1.33669	1.33646
20.0	1.33886	1.33856	1.33827	1.33800	1.33773	1.33746	1.33721	1.33696	1.33672	1.33648	1.33626
22.0	1.33864	1.33834	1.33806	1.33778	1.33751	1.33725	1.33699	1.33675	1.33651	1.33627	1.33605
24.0	1.33842	1.33812	1.33783	1.33756	1.33729	1.33703	1.33677	1.33653	1.33629	1.33606	1.33584
26.0	1.33819	1.33789	1.33761	1.33733	1.33706	1.33680	1.33655	1.33630	1.33607	1.33584	1.33562
28.0	1.33796	1.33766	1.33737	1.33710	1.33683	1.33656	1.33631	1.33606	1.33583	1.33560	1.33539
30.0	1.33772	1.33742	1.33713	1.33685	1.33658	1.33632	1.33606	1.33582	1.33558	1.33535	1.33514

Table A-4. (cont)

(I)

S = 35 ‰

TEMP °C	WAVELENGTH (nm)									
	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.35141	1.35049	1.34961	1.34879	1.34804	1.34734	1.34667	1.34605	1.34548	1.34494
2.0	1.35132	1.35040	1.34952	1.34870	1.34796	1.34726	1.34659	1.34597	1.34540	1.34486
4.0	1.35121	1.35029	1.34941	1.34860	1.34786	1.34716	1.34650	1.34588	1.34530	1.34476
6.0	1.35110	1.35018	1.34930	1.34849	1.34775	1.34705	1.34639	1.34577	1.34519	1.34465
8.0	1.35098	1.35005	1.34917	1.34836	1.34762	1.34692	1.34626	1.34564	1.34506	1.34452
10.0	1.35084	1.34991	1.34903	1.34822	1.34747	1.34678	1.34612	1.34550	1.34492	1.34437
12.0	1.35069	1.34976	1.34888	1.34806	1.34731	1.34661	1.34595	1.34533	1.34476	1.34422
14.0	1.35052	1.34959	1.34871	1.34789	1.34714	1.34644	1.34577	1.34516	1.34459	1.34405
16.0	1.35034	1.34941	1.34853	1.34771	1.34696	1.34625	1.34559	1.34497	1.34441	1.34387
18.0	1.35014	1.34922	1.34834	1.34752	1.34677	1.34606	1.34539	1.34478	1.34421	1.34367
20.0	1.34994	1.34902	1.34814	1.34732	1.34657	1.34586	1.34519	1.34458	1.34401	1.34347
22.0	1.34972	1.34880	1.34792	1.34711	1.34636	1.34565	1.34498	1.34436	1.34379	1.34325
24.0	1.34950	1.34857	1.34769	1.34688	1.34613	1.34542	1.34476	1.34414	1.34357	1.34303
26.0	1.34926	1.34833	1.34745	1.34664	1.34589	1.34519	1.34453	1.34391	1.34333	1.34280
28.0	1.34901	1.34808	1.34720	1.34639	1.34564	1.34495	1.34429	1.34367	1.34309	1.34255
30.0	1.34875	1.34782	1.34694	1.34613	1.34539	1.34469	1.34404	1.34342	1.34284	1.34230

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34442	1.34393	1.34347	1.34304	1.34263	1.34224	1.34186	1.34149	1.34115	1.34082
2.0	1.34434	1.34386	1.34339	1.34295	1.34254	1.34216	1.34179	1.34143	1.34108	1.34075
4.0	1.34425	1.34376	1.34330	1.34285	1.34243	1.34206	1.34170	1.34134	1.34099	1.34066
6.0	1.34413	1.34365	1.34318	1.34274	1.34233	1.34194	1.34157	1.34122	1.34088	1.34055
8.0	1.34400	1.34351	1.34306	1.34262	1.34221	1.34182	1.34144	1.34108	1.34075	1.34042
10.0	1.34385	1.34337	1.34291	1.34248	1.34207	1.34167	1.34129	1.34093	1.34061	1.34028
12.0	1.34370	1.34321	1.34275	1.34232	1.34191	1.34151	1.34113	1.34077	1.34045	1.34011
14.0	1.34353	1.34304	1.34257	1.34214	1.34173	1.34134	1.34096	1.34061	1.34027	1.33994
16.0	1.34334	1.34285	1.34239	1.34195	1.34154	1.34116	1.34079	1.34043	1.34009	1.33975
18.0	1.34315	1.34266	1.34220	1.34176	1.34135	1.34097	1.34060	1.34023	1.33989	1.33956
20.0	1.34295	1.34246	1.34200	1.34157	1.34116	1.34077	1.34039	1.34003	1.33969	1.33936
22.0	1.34273	1.34225	1.34179	1.34136	1.34095	1.34055	1.34017	1.33981	1.33947	1.33914
24.0	1.34251	1.34203	1.34157	1.34114	1.34072	1.34033	1.33995	1.33959	1.33925	1.33892
26.0	1.34228	1.34180	1.34134	1.34091	1.34049	1.34010	1.33972	1.33936	1.33902	1.33869
28.0	1.34204	1.34156	1.34110	1.34066	1.34025	1.33986	1.33949	1.33913	1.33879	1.33846
30.0	1.34179	1.34131	1.34085	1.34041	1.34000	1.33962	1.33925	1.33889	1.33855	1.33822

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.34050	1.34020	1.33992	1.33964	1.33937	1.33911	1.33885	1.33860	1.33836	1.33813	1.33791
2.0	1.34044	1.34014	1.33985	1.33957	1.33930	1.33903	1.33878	1.33853	1.33829	1.33806	1.33784
4.0	1.34035	1.34005	1.33976	1.33948	1.33920	1.33894	1.33868	1.33844	1.33820	1.33798	1.33776
6.0	1.34023	1.33993	1.33964	1.33936	1.33909	1.33883	1.33857	1.33833	1.33809	1.33787	1.33765
8.0	1.34011	1.33981	1.33952	1.33924	1.33896	1.33870	1.33844	1.33820	1.33796	1.33774	1.33752
10.0	1.33997	1.33967	1.33938	1.33910	1.33882	1.33855	1.33830	1.33806	1.33782	1.33760	1.33738
12.0	1.33980	1.33950	1.33921	1.33893	1.33866	1.33840	1.33814	1.33790	1.33766	1.33744	1.33722
14.0	1.33962	1.33932	1.33904	1.33876	1.33849	1.33823	1.33797	1.33773	1.33749	1.33727	1.33705
16.0	1.33943	1.33913	1.33885	1.33857	1.33831	1.33804	1.33779	1.33754	1.33730	1.33707	1.33685
18.0	1.33924	1.33894	1.33865	1.33838	1.33811	1.33785	1.33759	1.33735	1.33710	1.33687	1.33664
20.0	1.33904	1.33874	1.33845	1.33818	1.33791	1.33765	1.33739	1.33714	1.33690	1.33666	1.33644
22.0	1.33883	1.33853	1.33824	1.33797	1.33770	1.33743	1.33718	1.33693	1.33669	1.33645	1.33623
24.0	1.33860	1.33830	1.33802	1.33774	1.33747	1.33721	1.33695	1.33671	1.33647	1.33624	1.33602
26.0	1.33837	1.33807	1.33778	1.33751	1.33724	1.33698	1.33672	1.33648	1.33625	1.33602	1.33580
28.0	1.33814	1.33784	1.33755	1.33727	1.33700	1.33674	1.33649	1.33624	1.33601	1.33578	1.33557
30.0	1.33790	1.33760	1.33731	1.33703	1.33676	1.33649	1.33624	1.33599	1.33576	1.33553	1.33532

Table A-4. (cont)

(m)

S = 36 ‰

TEMP °C	WAVELENGTH (nm)									
	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.35162	1.35069	1.34981	1.34900	1.34825	1.34754	1.34688	1.34625	1.34568	1.34513
2.0	1.35152	1.35060	1.34972	1.34891	1.34816	1.34746	1.34680	1.34617	1.34560	1.34506
4.0	1.35142	1.35049	1.34962	1.34880	1.34806	1.34736	1.34670	1.34608	1.34550	1.34496
6.0	1.35130	1.35038	1.34950	1.34869	1.34794	1.34725	1.34658	1.34596	1.34539	1.34485
8.0	1.35117	1.35025	1.34937	1.34856	1.34782	1.34712	1.34646	1.34584	1.34526	1.34471
10.0	1.35104	1.35011	1.34923	1.34841	1.34767	1.34697	1.34631	1.34569	1.34511	1.34457
12.0	1.35089	1.34995	1.34907	1.34825	1.34751	1.34680	1.34614	1.34552	1.34495	1.34441
14.0	1.35072	1.34979	1.34890	1.34808	1.34733	1.34663	1.34596	1.34535	1.34478	1.34424
16.0	1.35053	1.34960	1.34872	1.34790	1.34715	1.34644	1.34578	1.34516	1.34459	1.34405
18.0	1.35034	1.34941	1.34853	1.34771	1.34696	1.34625	1.34558	1.34497	1.34440	1.34386
20.0	1.35013	1.34921	1.34833	1.34751	1.34676	1.34605	1.34538	1.34476	1.34420	1.34365
22.0	1.34991	1.34899	1.34811	1.34730	1.34655	1.34584	1.34517	1.34455	1.34398	1.34344
24.0	1.34969	1.34876	1.34789	1.34707	1.34632	1.34561	1.34495	1.34433	1.34375	1.34321
26.0	1.34945	1.34852	1.34764	1.34682	1.34608	1.34538	1.34471	1.34409	1.34352	1.34298
28.0	1.34920	1.34827	1.34739	1.34657	1.34583	1.34513	1.34447	1.34385	1.34327	1.34274
30.0	1.34894	1.34801	1.34713	1.34631	1.34557	1.34488	1.34422	1.34360	1.34302	1.34248

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34462	1.34413	1.34368	1.34324	1.34283	1.34244	1.34205	1.34169	1.34135	1.34101
2.0	1.34454	1.34406	1.34359	1.34315	1.34274	1.34235	1.34198	1.34162	1.34128	1.34094
4.0	1.34445	1.34396	1.34349	1.34305	1.34263	1.34225	1.34189	1.34153	1.34118	1.34085
6.0	1.34433	1.34384	1.34338	1.34294	1.34252	1.34213	1.34176	1.34140	1.34107	1.34074
8.0	1.34419	1.34371	1.34325	1.34282	1.34240	1.34201	1.34163	1.34127	1.34095	1.34061
10.0	1.34405	1.34356	1.34310	1.34267	1.34226	1.34186	1.34148	1.34112	1.34080	1.34047
12.0	1.34389	1.34340	1.34294	1.34251	1.34210	1.34170	1.34132	1.34096	1.34063	1.34030
14.0	1.34372	1.34322	1.34276	1.34233	1.34191	1.34153	1.34115	1.34079	1.34046	1.34012
16.0	1.34353	1.34304	1.34258	1.34214	1.34173	1.34134	1.34097	1.34061	1.34027	1.33994
18.0	1.34334	1.34284	1.34238	1.34195	1.34154	1.34116	1.34078	1.34042	1.34008	1.33974
20.0	1.34313	1.34264	1.34218	1.34175	1.34134	1.34095	1.34057	1.34021	1.33987	1.33954
22.0	1.34292	1.34243	1.34197	1.34154	1.34113	1.34074	1.34036	1.33999	1.33966	1.33932
24.0	1.34270	1.34222	1.34176	1.34132	1.34091	1.34052	1.34013	1.33977	1.33943	1.33910
26.0	1.34247	1.34199	1.34153	1.34109	1.34067	1.34028	1.33990	1.33954	1.33920	1.33887
28.0	1.34223	1.34174	1.34129	1.34085	1.34044	1.34005	1.33967	1.33931	1.33897	1.33864
30.0	1.34197	1.34149	1.34103	1.34060	1.34019	1.33980	1.33943	1.33907	1.33873	1.33840

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.34070	1.34040	1.34011	1.33984	1.33957	1.33931	1.33905	1.33880	1.33856	1.33833	1.33810
2.0	1.34062	1.34032	1.34004	1.33976	1.33949	1.33923	1.33897	1.33873	1.33849	1.33826	1.33804
4.0	1.34053	1.34023	1.33994	1.33967	1.33940	1.33913	1.33888	1.33863	1.33839	1.33817	1.33795
6.0	1.34042	1.34012	1.33983	1.33955	1.33928	1.33902	1.33876	1.33852	1.33828	1.33805	1.33784
8.0	1.34030	1.34000	1.33971	1.33943	1.33915	1.33889	1.33863	1.33839	1.33815	1.33793	1.33771
10.0	1.34016	1.33986	1.33957	1.33928	1.33901	1.33874	1.33849	1.33824	1.33801	1.33778	1.33757
12.0	1.33999	1.33969	1.33940	1.33912	1.33885	1.33858	1.33833	1.33809	1.33785	1.33762	1.33741
14.0	1.33981	1.33951	1.33922	1.33894	1.33867	1.33841	1.33816	1.33791	1.33768	1.33745	1.33723
16.0	1.33961	1.33932	1.33903	1.33876	1.33849	1.33823	1.33797	1.33772	1.33748	1.33725	1.33703
18.0	1.33942	1.33912	1.33883	1.33856	1.33829	1.33803	1.33777	1.33753	1.33728	1.33705	1.33682
20.0	1.33922	1.33892	1.33864	1.33836	1.33809	1.33783	1.33757	1.33732	1.33708	1.33684	1.33662
22.0	1.33901	1.33871	1.33842	1.33815	1.33788	1.33761	1.33736	1.33711	1.33687	1.33663	1.33641
24.0	1.33878	1.33848	1.33820	1.33792	1.33765	1.33739	1.33713	1.33689	1.33665	1.33642	1.33620
26.0	1.33855	1.33825	1.33796	1.33769	1.33742	1.33716	1.33690	1.33666	1.33642	1.33620	1.33598
28.0	1.33832	1.33801	1.33773	1.33745	1.33718	1.33692	1.33667	1.33642	1.33619	1.33596	1.33574
30.0	1.33808	1.33778	1.33749	1.33721	1.33694	1.33667	1.33642	1.33617	1.33594	1.33571	1.33549

Table A-4. (cont)

(n)

S = 37 ‰

TEMP	WAVELENGTH (nm)									
°C	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.35183	1.35090	1.35002	1.34920	1.34845	1.34774	1.34708	1.34646	1.34588	1.34534
2.0	1.35173	1.35080	1.34992	1.34911	1.34836	1.34766	1.34700	1.34637	1.34580	1.34526
4.0	1.35162	1.35069	1.34982	1.34900	1.34826	1.34756	1.34690	1.34628	1.34570	1.34516
6.0	1.35150	1.35058	1.34970	1.34888	1.34814	1.34744	1.34678	1.34616	1.34558	1.34504
8.0	1.35137	1.35045	1.34957	1.34875	1.34801	1.34731	1.34665	1.34603	1.34545	1.34491
10.0	1.35124	1.35031	1.34943	1.34861	1.34787	1.34717	1.34650	1.34588	1.34530	1.34476
12.0	1.35108	1.35015	1.34927	1.34845	1.34770	1.34700	1.34634	1.34572	1.34514	1.34460
14.0	1.35091	1.34998	1.34910	1.34828	1.34753	1.34682	1.34616	1.34554	1.34497	1.34443
16.0	1.35073	1.34980	1.34892	1.34810	1.34734	1.34663	1.34597	1.34535	1.34478	1.34424
18.0	1.35053	1.34961	1.34873	1.34791	1.34715	1.34644	1.34577	1.34516	1.34459	1.34405
20.0	1.35033	1.34940	1.34852	1.34770	1.34695	1.34624	1.34557	1.34495	1.34438	1.34384
22.0	1.35011	1.34918	1.34831	1.34749	1.34673	1.34602	1.34536	1.34474	1.34416	1.34363
24.0	1.34988	1.34895	1.34807	1.34726	1.34651	1.34580	1.34513	1.34451	1.34394	1.34340
26.0	1.34964	1.34871	1.34783	1.34702	1.34627	1.34556	1.34490	1.34428	1.34370	1.34317
28.0	1.34939	1.34846	1.34758	1.34676	1.34602	1.34532	1.34466	1.34404	1.34346	1.34292
30.0	1.34913	1.34820	1.34732	1.34650	1.34576	1.34507	1.34441	1.34379	1.34321	1.34267

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34482	1.34433	1.34387	1.34344	1.34303	1.34264	1.34225	1.34189	1.34155	1.34121
2.0	1.34474	1.34425	1.34379	1.34335	1.34293	1.34255	1.34218	1.34182	1.34147	1.34114
4.0	1.34464	1.34416	1.34369	1.34324	1.34282	1.34245	1.34209	1.34173	1.34138	1.34105
6.0	1.34452	1.34404	1.34357	1.34313	1.34272	1.34233	1.34196	1.34160	1.34126	1.34093
8.0	1.34439	1.34390	1.34344	1.34301	1.34260	1.34220	1.34182	1.34146	1.34114	1.34080
10.0	1.34424	1.34375	1.34330	1.34286	1.34245	1.34206	1.34167	1.34131	1.34099	1.34065
12.0	1.34408	1.34359	1.34313	1.34270	1.34229	1.34189	1.34151	1.34115	1.34082	1.34049
14.0	1.34391	1.34341	1.34295	1.34251	1.34210	1.34171	1.34134	1.34098	1.34064	1.34031
16.0	1.34372	1.34323	1.34276	1.34232	1.34191	1.34153	1.34116	1.34080	1.34046	1.34012
18.0	1.34352	1.34303	1.34257	1.34213	1.34172	1.34134	1.34096	1.34060	1.34026	1.33993
20.0	1.34332	1.34283	1.34237	1.34193	1.34153	1.34114	1.34076	1.34040	1.34006	1.33972
22.0	1.34311	1.34262	1.34216	1.34172	1.34131	1.34092	1.34054	1.34018	1.33984	1.33950
24.0	1.34288	1.34240	1.34194	1.34150	1.34109	1.34070	1.34032	1.33996	1.33962	1.33928
26.0	1.34265	1.34217	1.34171	1.34127	1.34086	1.34047	1.34009	1.33972	1.33939	1.33905
28.0	1.34241	1.34193	1.34147	1.34103	1.34062	1.34023	1.33985	1.33949	1.33915	1.33881
30.0	1.34216	1.34167	1.34122	1.34078	1.34037	1.33998	1.33961	1.33925	1.33891	1.33857

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.34089	1.34059	1.34031	1.34003	1.33977	1.33950	1.33924	1.33900	1.33875	1.33852	1.33830
2.0	1.34083	1.34052	1.34024	1.33996	1.33969	1.33942	1.33917	1.33892	1.33868	1.33845	1.33823
4.0	1.34073	1.34043	1.34014	1.33986	1.33959	1.33932	1.33907	1.33882	1.33859	1.33836	1.33814
6.0	1.34062	1.34031	1.34002	1.33974	1.33947	1.33921	1.33895	1.33871	1.33847	1.33825	1.33803
8.0	1.34049	1.34019	1.33990	1.33962	1.33934	1.33908	1.33882	1.33858	1.33834	1.33812	1.33790
10.0	1.34035	1.34004	1.33975	1.33947	1.33920	1.33893	1.33868	1.33843	1.33820	1.33797	1.33775
12.0	1.34018	1.33988	1.33959	1.33931	1.33903	1.33877	1.33852	1.33827	1.33804	1.33781	1.33759
14.0	1.33999	1.33969	1.33941	1.33913	1.33886	1.33860	1.33834	1.33810	1.33786	1.33764	1.33742
16.0	1.33980	1.33950	1.33921	1.33894	1.33867	1.33841	1.33815	1.33791	1.33767	1.33744	1.33721
18.0	1.33961	1.33931	1.33902	1.33875	1.33848	1.33821	1.33796	1.33771	1.33747	1.33723	1.33701
20.0	1.33940	1.33910	1.33882	1.33854	1.33827	1.33801	1.33775	1.33750	1.33726	1.33702	1.33680
22.0	1.33919	1.33889	1.33860	1.33832	1.33806	1.33779	1.33753	1.33729	1.33704	1.33681	1.33659
24.0	1.33896	1.33866	1.33838	1.33810	1.33783	1.33757	1.33731	1.33707	1.33683	1.33660	1.33637
26.0	1.33873	1.33843	1.33814	1.33787	1.33760	1.33734	1.33708	1.33684	1.33660	1.33638	1.33616
28.0	1.33850	1.33820	1.33791	1.33763	1.33736	1.33710	1.33684	1.33660	1.33636	1.33614	1.33592
30.0	1.33826	1.33795	1.33767	1.33739	1.33712	1.33685	1.33660	1.33635	1.33611	1.33589	1.33567

Table A-4. (cont)

(o)

S = 38 ‰

TEMP °C	WAVELENGTH (nm)									
	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.35203	1.35110	1.35022	1.34940	1.34865	1.34795	1.34728	1.34665	1.34608	1.34554
2.0	1.35193	1.35101	1.35013	1.34931	1.34856	1.34786	1.34720	1.34657	1.34600	1.34546
4.0	1.35182	1.35089	1.35002	1.34920	1.34846	1.34776	1.34710	1.34647	1.34589	1.34536
6.0	1.35170	1.35078	1.34990	1.34908	1.34834	1.34764	1.34698	1.34636	1.34578	1.34524
8.0	1.35157	1.35065	1.34977	1.34895	1.34821	1.34751	1.34685	1.34622	1.34564	1.34510
10.0	1.35143	1.35050	1.34962	1.34880	1.34806	1.34736	1.34670	1.34608	1.34550	1.34495
12.0	1.35128	1.35035	1.34946	1.34864	1.34790	1.34719	1.34653	1.34591	1.34534	1.34479
14.0	1.35111	1.35018	1.34929	1.34847	1.34772	1.34701	1.34635	1.34573	1.34516	1.34462
16.0	1.35092	1.34999	1.34911	1.34829	1.34753	1.34682	1.34616	1.34554	1.34497	1.34443
18.0	1.35073	1.34980	1.34892	1.34810	1.34734	1.34663	1.34596	1.34535	1.34478	1.34424
20.0	1.35052	1.34959	1.34871	1.34789	1.34714	1.34643	1.34576	1.34514	1.34457	1.34403
22.0	1.35030	1.34937	1.34850	1.34768	1.34692	1.34621	1.34554	1.34492	1.34435	1.34381
24.0	1.35007	1.34914	1.34827	1.34745	1.34670	1.34599	1.34532	1.34470	1.34412	1.34359
26.0	1.34983	1.34890	1.34802	1.34720	1.34646	1.34575	1.34509	1.34447	1.34389	1.34335
28.0	1.34958	1.34865	1.34777	1.34695	1.34621	1.34551	1.34485	1.34422	1.34364	1.34311
30.0	1.34932	1.34839	1.34751	1.34669	1.34595	1.34525	1.34459	1.34397	1.34339	1.34285

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34502	1.34453	1.34407	1.34364	1.34323	1.34283	1.34245	1.34208	1.34174	1.34141
2.0	1.34494	1.34445	1.34399	1.34355	1.34313	1.34274	1.34237	1.34201	1.34167	1.34133
4.0	1.34484	1.34435	1.34388	1.34344	1.34302	1.34264	1.34228	1.34192	1.34157	1.34124
6.0	1.34472	1.34423	1.34377	1.34333	1.34291	1.34252	1.34215	1.34179	1.34146	1.34112
8.0	1.34458	1.34409	1.34363	1.34320	1.34279	1.34239	1.34201	1.34165	1.34133	1.34099
10.0	1.34443	1.34394	1.34349	1.34305	1.34264	1.34225	1.34186	1.34150	1.34118	1.34084
12.0	1.34427	1.34378	1.34332	1.34289	1.34247	1.34208	1.34170	1.34134	1.34101	1.34067
14.0	1.34410	1.34360	1.34314	1.34270	1.34229	1.34190	1.34153	1.34117	1.34083	1.34050
16.0	1.34391	1.34341	1.34295	1.34251	1.34210	1.34172	1.34134	1.34098	1.34064	1.34030
18.0	1.34371	1.34322	1.34275	1.34232	1.34191	1.34153	1.34115	1.34079	1.34044	1.34011
20.0	1.34351	1.34301	1.34255	1.34212	1.34171	1.34132	1.34095	1.34058	1.34024	1.33990
22.0	1.34329	1.34280	1.34234	1.34191	1.34150	1.34111	1.34073	1.34036	1.34002	1.33969
24.0	1.34307	1.34258	1.34212	1.34169	1.34127	1.34088	1.34050	1.34014	1.33980	1.33946
26.0	1.34284	1.34236	1.34190	1.34146	1.34104	1.34065	1.34027	1.33991	1.33957	1.33923
28.0	1.34259	1.34211	1.34165	1.34122	1.34080	1.34041	1.34003	1.33967	1.33933	1.33900
30.0	1.34234	1.34186	1.34140	1.34096	1.34055	1.34017	1.33979	1.33943	1.33909	1.33875

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.34110	1.34080	1.34051	1.34023	1.33996	1.33970	1.33944	1.33919	1.33895	1.33872	1.33849
2.0	1.34101	1.34071	1.34043	1.34015	1.33988	1.33962	1.33936	1.33911	1.33887	1.33864	1.33842
4.0	1.34092	1.34062	1.34033	1.34005	1.33978	1.33952	1.33926	1.33902	1.33878	1.33855	1.33833
6.0	1.34081	1.34051	1.34022	1.33994	1.33966	1.33940	1.33914	1.33890	1.33866	1.33844	1.33822
8.0	1.34068	1.34038	1.34009	1.33981	1.33953	1.33926	1.33901	1.33876	1.33853	1.33830	1.33809
10.0	1.34053	1.34023	1.33994	1.33966	1.33938	1.33912	1.33886	1.33862	1.33838	1.33816	1.33794
12.0	1.34036	1.34006	1.33977	1.33949	1.33922	1.33895	1.33870	1.33846	1.33822	1.33799	1.33778
14.0	1.34018	1.33988	1.33959	1.33931	1.33904	1.33878	1.33853	1.33828	1.33805	1.33782	1.33760
16.0	1.33998	1.33968	1.33940	1.33912	1.33886	1.33859	1.33834	1.33809	1.33785	1.33762	1.33740
18.0	1.33979	1.33949	1.33920	1.33893	1.33866	1.33840	1.33814	1.33789	1.33765	1.33741	1.33719
20.0	1.33958	1.33928	1.33900	1.33872	1.33845	1.33819	1.33793	1.33768	1.33744	1.33720	1.33698
22.0	1.33937	1.33907	1.33878	1.33851	1.33824	1.33797	1.33771	1.33746	1.33722	1.33699	1.33676
24.0	1.33914	1.33884	1.33856	1.33828	1.33801	1.33775	1.33749	1.33724	1.33700	1.33677	1.33655
26.0	1.33891	1.33861	1.33832	1.33805	1.33778	1.33752	1.33726	1.33702	1.33678	1.33655	1.33634
28.0	1.33868	1.33837	1.33809	1.33781	1.33754	1.33728	1.33702	1.33678	1.33654	1.33632	1.33610
30.0	1.33843	1.33813	1.33784	1.33757	1.33729	1.33703	1.33677	1.33653	1.33629	1.33606	1.33585

Table A-4. (cont)

(p)

S = 39 ‰

TEMP	WAVELENGTH (nm)									
°C	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.35224	1.35131	1.35043	1.34961	1.34886	1.34815	1.34748	1.34686	1.34628	1.34574
2.0	1.35214	1.35121	1.35033	1.34951	1.34876	1.34806	1.34739	1.34677	1.34619	1.34566
4.0	1.35202	1.35110	1.35022	1.34940	1.34866	1.34796	1.34729	1.34667	1.34609	1.34555
6.0	1.35190	1.35098	1.35010	1.34928	1.34854	1.34784	1.34717	1.34655	1.34597	1.34543
8.0	1.35177	1.35085	1.34997	1.34915	1.34840	1.34770	1.34704	1.34642	1.34584	1.34530
10.0	1.35163	1.35070	1.34982	1.34900	1.34825	1.34755	1.34689	1.34627	1.34569	1.34515
12.0	1.35148	1.35054	1.34966	1.34884	1.34809	1.34738	1.34672	1.34610	1.34553	1.34498
14.0	1.35131	1.35037	1.34949	1.34866	1.34791	1.34720	1.34654	1.34592	1.34535	1.34481
16.0	1.35112	1.35019	1.34930	1.34848	1.34772	1.34702	1.34635	1.34573	1.34516	1.34462
18.0	1.35092	1.34999	1.34911	1.34829	1.34753	1.34682	1.34615	1.34554	1.34497	1.34442
20.0	1.35071	1.34979	1.34891	1.34809	1.34733	1.34662	1.34595	1.34533	1.34476	1.34422
22.0	1.35049	1.34957	1.34869	1.34787	1.34711	1.34640	1.34573	1.34511	1.34454	1.34400
24.0	1.35027	1.34934	1.34846	1.34764	1.34688	1.34618	1.34551	1.34489	1.34431	1.34377
26.0	1.35003	1.34910	1.34821	1.34739	1.34665	1.34594	1.34528	1.34465	1.34407	1.34354
28.0	1.34977	1.34884	1.34796	1.34714	1.34640	1.34569	1.34503	1.34441	1.34383	1.34329
30.0	1.34951	1.34858	1.34770	1.34688	1.34614	1.34544	1.34478	1.34416	1.34358	1.34304

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34522	1.34473	1.34427	1.34384	1.34342	1.34303	1.34265	1.34228	1.34194	1.34161
2.0	1.34514	1.34465	1.34418	1.34374	1.34333	1.34294	1.34257	1.34221	1.34186	1.34153
4.0	1.34504	1.34455	1.34408	1.34363	1.34322	1.34283	1.34247	1.34211	1.34177	1.34143
6.0	1.34491	1.34443	1.34396	1.34352	1.34310	1.34271	1.34234	1.34198	1.34165	1.34132
8.0	1.34478	1.34429	1.34383	1.34339	1.34298	1.34258	1.34220	1.34184	1.34152	1.34118
10.0	1.34462	1.34413	1.34368	1.34324	1.34283	1.34243	1.34205	1.34169	1.34136	1.34103
12.0	1.34446	1.34397	1.34351	1.34307	1.34266	1.34227	1.34188	1.34152	1.34120	1.34086
14.0	1.34429	1.34379	1.34333	1.34289	1.34248	1.34209	1.34171	1.34135	1.34102	1.34068
16.0	1.34410	1.34360	1.34314	1.34270	1.34229	1.34190	1.34153	1.34117	1.34083	1.34049
18.0	1.34390	1.34340	1.34294	1.34250	1.34209	1.34171	1.34134	1.34097	1.34063	1.34029
20.0	1.34369	1.34320	1.34274	1.34230	1.34189	1.34151	1.34113	1.34076	1.34042	1.34009
22.0	1.34348	1.34299	1.34253	1.34209	1.34168	1.34129	1.34091	1.34055	1.34020	1.33987
24.0	1.34325	1.34277	1.34231	1.34187	1.34146	1.34106	1.34068	1.34032	1.33998	1.33964
26.0	1.34302	1.34254	1.34208	1.34164	1.34122	1.34083	1.34045	1.34009	1.33975	1.33941
28.0	1.34278	1.34230	1.34184	1.34140	1.34098	1.34059	1.34022	1.33985	1.33951	1.33918
30.0	1.34252	1.34204	1.34158	1.34114	1.34073	1.34035	1.33998	1.33961	1.33927	1.33894

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.34129	1.34099	1.34070	1.34043	1.34016	1.33989	1.33964	1.33939	1.33915	1.33891	1.33869
2.0	1.34121	1.34091	1.34062	1.34035	1.34008	1.33981	1.33955	1.33931	1.33907	1.33884	1.33862
4.0	1.34111	1.34081	1.34052	1.34024	1.33997	1.33971	1.33945	1.33921	1.33897	1.33874	1.33852
6.0	1.34100	1.34070	1.34041	1.34013	1.33985	1.33959	1.33933	1.33909	1.33885	1.33863	1.33841
8.0	1.34087	1.34057	1.34028	1.34000	1.33972	1.33946	1.33920	1.33895	1.33872	1.33849	1.33828
10.0	1.34072	1.34042	1.34013	1.33985	1.33957	1.33931	1.33905	1.33881	1.33857	1.33834	1.33813
12.0	1.34055	1.34025	1.33996	1.33968	1.33941	1.33914	1.33889	1.33864	1.33841	1.33818	1.33796
14.0	1.34037	1.34007	1.33978	1.33950	1.33923	1.33897	1.33871	1.33847	1.33823	1.33800	1.33779
16.0	1.34017	1.33987	1.33958	1.33931	1.33904	1.33878	1.33852	1.33827	1.33803	1.33780	1.33758
18.0	1.33998	1.33967	1.33939	1.33911	1.33884	1.33858	1.33832	1.33807	1.33783	1.33759	1.33737
20.0	1.33977	1.33947	1.33918	1.33890	1.33864	1.33837	1.33811	1.33786	1.33762	1.33738	1.33716
22.0	1.33955	1.33925	1.33896	1.33869	1.33842	1.33815	1.33789	1.33764	1.33740	1.33717	1.33694
24.0	1.33932	1.33902	1.33874	1.33846	1.33819	1.33793	1.33767	1.33742	1.33718	1.33695	1.33673
26.0	1.33909	1.33879	1.33850	1.33823	1.33796	1.33769	1.33744	1.33719	1.33696	1.33673	1.33651
28.0	1.33886	1.33856	1.33827	1.33799	1.33772	1.33745	1.33720	1.33696	1.33672	1.33649	1.33628
30.0	1.33862	1.33832	1.33803	1.33775	1.33747	1.33721	1.33695	1.33671	1.33647	1.33624	1.33602

Table A-4. (cont)

(q)

S = 40 ‰

TEMP °C	WAVELENGTH (nm)									
	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.35245	1.35152	1.35063	1.34981	1.34906	1.34835	1.34768	1.34706	1.34648	1.34594
2.0	1.35234	1.35141	1.35053	1.34971	1.34897	1.34826	1.34760	1.34697	1.34639	1.34585
4.0	1.35223	1.35130	1.35042	1.34960	1.34886	1.34816	1.34749	1.34687	1.34629	1.34575
6.0	1.35210	1.35118	1.35030	1.34948	1.34874	1.34804	1.34737	1.34675	1.34617	1.34563
8.0	1.35197	1.35104	1.35016	1.34935	1.34860	1.34790	1.34724	1.34661	1.34603	1.34549
10.0	1.35183	1.35090	1.35002	1.34920	1.34845	1.34775	1.34708	1.34646	1.34588	1.34534
12.0	1.35168	1.35074	1.34985	1.34903	1.34828	1.34758	1.34691	1.34629	1.34572	1.34517
14.0	1.35150	1.35057	1.34968	1.34886	1.34810	1.34740	1.34673	1.34611	1.34554	1.34500
16.0	1.35131	1.35038	1.34950	1.34867	1.34792	1.34721	1.34654	1.34592	1.34535	1.34481
18.0	1.35112	1.35019	1.34930	1.34848	1.34772	1.34701	1.34634	1.34572	1.34516	1.34461
20.0	1.35091	1.34998	1.34910	1.34828	1.34752	1.34681	1.34614	1.34552	1.34495	1.34440
22.0	1.35069	1.34976	1.34888	1.34806	1.34730	1.34659	1.34592	1.34530	1.34473	1.34418
24.0	1.35046	1.34953	1.34865	1.34783	1.34707	1.34636	1.34570	1.34507	1.34450	1.34396
26.0	1.35022	1.34929	1.34840	1.34758	1.34683	1.34613	1.34546	1.34484	1.34426	1.34372
28.0	1.34997	1.34903	1.34815	1.34733	1.34658	1.34588	1.34522	1.34459	1.34401	1.34347
30.0	1.34970	1.34877	1.34788	1.34706	1.34632	1.34562	1.34496	1.34434	1.34376	1.34322

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34542	1.34493	1.34447	1.34404	1.34362	1.34323	1.34284	1.34247	1.34214	1.34180
2.0	1.34534	1.34485	1.34438	1.34394	1.34352	1.34314	1.34276	1.34240	1.34206	1.34172
4.0	1.34523	1.34474	1.34427	1.34382	1.34341	1.34303	1.34267	1.34231	1.34196	1.34163
6.0	1.34511	1.34462	1.34415	1.34371	1.34330	1.34291	1.34253	1.34218	1.34184	1.34151
8.0	1.34497	1.34448	1.34402	1.34359	1.34317	1.34277	1.34239	1.34203	1.34171	1.34137
10.0	1.34481	1.34432	1.34387	1.34344	1.34302	1.34262	1.34224	1.34188	1.34155	1.34122
12.0	1.34465	1.34416	1.34370	1.34326	1.34285	1.34245	1.34207	1.34171	1.34138	1.34105
14.0	1.34447	1.34398	1.34352	1.34308	1.34267	1.34227	1.34190	1.34154	1.34120	1.34087
16.0	1.34429	1.34379	1.34332	1.34289	1.34247	1.34209	1.34171	1.34135	1.34101	1.34067
18.0	1.34409	1.34359	1.34313	1.34269	1.34228	1.34189	1.34152	1.34116	1.34081	1.34048
20.0	1.34388	1.34338	1.34292	1.34249	1.34208	1.34169	1.34131	1.34095	1.34060	1.34027
22.0	1.34366	1.34317	1.34271	1.34228	1.34186	1.34147	1.34109	1.34073	1.34038	1.34005
24.0	1.34344	1.34295	1.34249	1.34205	1.34164	1.34125	1.34087	1.34050	1.34016	1.33982
26.0	1.34321	1.34272	1.34226	1.34182	1.34141	1.34101	1.34063	1.34027	1.33993	1.33959
28.0	1.34296	1.34248	1.34202	1.34158	1.34116	1.34077	1.34039	1.34003	1.33969	1.33936
30.0	1.34271	1.34222	1.34176	1.34133	1.34091	1.34053	1.34015	1.33979	1.33945	1.33912

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.34149	1.34119	1.34090	1.34063	1.34036	1.34009	1.33983	1.33958	1.33934	1.33911	1.33888
2.0	1.34140	1.34110	1.34082	1.34054	1.34027	1.34001	1.33975	1.33950	1.33926	1.33903	1.33881
4.0	1.34131	1.34101	1.34072	1.34044	1.34017	1.33990	1.33965	1.33940	1.33916	1.33893	1.33871
6.0	1.34119	1.34089	1.34060	1.34032	1.34005	1.33978	1.33952	1.33928	1.33904	1.33882	1.33860
8.0	1.34106	1.34076	1.34047	1.34019	1.33991	1.33964	1.33939	1.33914	1.33891	1.33868	1.33846
10.0	1.34091	1.34061	1.34032	1.34004	1.33976	1.33949	1.33924	1.33899	1.33876	1.33853	1.33831
12.0	1.34074	1.34044	1.34015	1.33987	1.33959	1.33933	1.33907	1.33883	1.33859	1.33837	1.33815
14.0	1.34055	1.34025	1.33996	1.33968	1.33941	1.33915	1.33889	1.33865	1.33841	1.33819	1.33797
16.0	1.34035	1.34005	1.33977	1.33949	1.33922	1.33896	1.33870	1.33846	1.33821	1.33798	1.33776
18.0	1.34015	1.33985	1.33957	1.33929	1.33903	1.33876	1.33850	1.33825	1.33801	1.33777	1.33755
20.0	1.33995	1.33965	1.33936	1.33909	1.33882	1.33855	1.33829	1.33804	1.33780	1.33756	1.33734
22.0	1.33973	1.33943	1.33914	1.33887	1.33860	1.33833	1.33808	1.33783	1.33758	1.33735	1.33712
24.0	1.33950	1.33920	1.33892	1.33864	1.33837	1.33811	1.33785	1.33760	1.33736	1.33713	1.33691
26.0	1.33928	1.33897	1.33869	1.33841	1.33814	1.33788	1.33762	1.33737	1.33714	1.33691	1.33669
28.0	1.33904	1.33874	1.33845	1.33817	1.33790	1.33763	1.33738	1.33713	1.33690	1.33667	1.33645
30.0	1.33879	1.33849	1.33820	1.33792	1.33765	1.33739	1.33713	1.33688	1.33665	1.33642	1.33620

Table A-4. (cont)

(r)

S = 41 ‰

TEMP °C	WAVELENGTH (nm)									
	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.35265	1.35172	1.35084	1.35001	1.34926	1.34855	1.34789	1.34726	1.34668	1.34614
2.0	1.35255	1.35162	1.35074	1.34992	1.34917	1.34846	1.34780	1.34717	1.34659	1.34605
4.0	1.35243	1.35150	1.35062	1.34980	1.34906	1.34835	1.34769	1.34707	1.34649	1.34595
6.0	1.35230	1.35138	1.35050	1.34968	1.34893	1.34823	1.34757	1.34694	1.34636	1.34582
8.0	1.35217	1.35124	1.35036	1.34954	1.34880	1.34810	1.34743	1.34681	1.34623	1.34568
10.0	1.35203	1.35110	1.35021	1.34939	1.34865	1.34794	1.34728	1.34666	1.34608	1.34553
12.0	1.35187	1.35094	1.35005	1.34923	1.34848	1.34777	1.34711	1.34649	1.34591	1.34536
14.0	1.35170	1.35076	1.34987	1.34905	1.34830	1.34759	1.34692	1.34630	1.34573	1.34519
16.0	1.35151	1.35057	1.34969	1.34887	1.34811	1.34740	1.34673	1.34611	1.34554	1.34500
18.0	1.35131	1.35038	1.34950	1.34867	1.34791	1.34720	1.34653	1.34591	1.34534	1.34480
20.0	1.35110	1.35017	1.34929	1.34847	1.34771	1.34700	1.34632	1.34571	1.34513	1.34459
22.0	1.35088	1.34995	1.34907	1.34825	1.34749	1.34678	1.34611	1.34549	1.34491	1.34437
24.0	1.35065	1.34972	1.34884	1.34801	1.34726	1.34655	1.34588	1.34526	1.34468	1.34414
26.0	1.35041	1.34948	1.34859	1.34777	1.34702	1.34632	1.34565	1.34502	1.34444	1.34390
28.0	1.35016	1.34922	1.34834	1.34752	1.34677	1.34607	1.34540	1.34478	1.34420	1.34366
30.0	1.34989	1.34896	1.34807	1.34725	1.34651	1.34581	1.34515	1.34453	1.34395	1.34340

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34562	1.34513	1.34467	1.34423	1.34382	1.34343	1.34305	1.34268	1.34233	1.34200
2.0	1.34553	1.34505	1.34458	1.34414	1.34372	1.34333	1.34296	1.34260	1.34225	1.34192
4.0	1.34543	1.34494	1.34447	1.34402	1.34360	1.34322	1.34286	1.34250	1.34215	1.34182
6.0	1.34530	1.34481	1.34435	1.34391	1.34349	1.34310	1.34272	1.34237	1.34203	1.34170
8.0	1.34516	1.34467	1.34421	1.34378	1.34336	1.34296	1.34258	1.34222	1.34190	1.34157
10.0	1.34501	1.34451	1.34406	1.34363	1.34321	1.34281	1.34243	1.34207	1.34174	1.34141
12.0	1.34484	1.34435	1.34389	1.34345	1.34304	1.34264	1.34226	1.34190	1.34157	1.34124
14.0	1.34466	1.34417	1.34370	1.34327	1.34285	1.34246	1.34208	1.34172	1.34139	1.34105
16.0	1.34447	1.34398	1.34351	1.34307	1.34266	1.34227	1.34190	1.34154	1.34120	1.34086
18.0	1.34427	1.34378	1.34331	1.34288	1.34247	1.34208	1.34170	1.34134	1.34100	1.34066
20.0	1.34406	1.34357	1.34311	1.34267	1.34226	1.34188	1.34149	1.34113	1.34079	1.34045
22.0	1.34385	1.34336	1.34290	1.34246	1.34205	1.34166	1.34127	1.34091	1.34057	1.34023
24.0	1.34362	1.34314	1.34268	1.34224	1.34182	1.34143	1.34105	1.34068	1.34034	1.34000
26.0	1.34339	1.34291	1.34245	1.34201	1.34159	1.34119	1.34081	1.34045	1.34011	1.33977
28.0	1.34315	1.34266	1.34220	1.34176	1.34135	1.34095	1.34058	1.34021	1.33987	1.33954
30.0	1.34289	1.34241	1.34195	1.34151	1.34110	1.34071	1.34033	1.33997	1.33963	1.33929

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.34168	1.34138	1.34110	1.34082	1.34055	1.34029	1.34003	1.33978	1.33954	1.33930	1.33908
2.0	1.34160	1.34130	1.34101	1.34073	1.34046	1.34020	1.33994	1.33969	1.33945	1.33922	1.33900
4.0	1.34150	1.34120	1.34091	1.34063	1.34036	1.34009	1.33984	1.33959	1.33935	1.33913	1.33891
6.0	1.34138	1.34108	1.34079	1.34051	1.34024	1.33997	1.33972	1.33947	1.33923	1.33901	1.33879
8.0	1.34126	1.34095	1.34066	1.34038	1.34010	1.33983	1.33958	1.33933	1.33910	1.33887	1.33865
10.0	1.34110	1.34080	1.34051	1.34022	1.33995	1.33968	1.33943	1.33918	1.33894	1.33872	1.33850
12.0	1.34093	1.34063	1.34033	1.34005	1.33978	1.33951	1.33926	1.33901	1.33878	1.33855	1.33834
14.0	1.34074	1.34044	1.34015	1.33987	1.33960	1.33933	1.33908	1.33883	1.33860	1.33837	1.33815
16.0	1.34054	1.34023	1.33995	1.33967	1.33941	1.33914	1.33889	1.33864	1.33840	1.33817	1.33794
18.0	1.34034	1.34004	1.33975	1.33948	1.33921	1.33894	1.33868	1.33843	1.33819	1.33796	1.33773
20.0	1.34013	1.33983	1.33954	1.33927	1.33900	1.33873	1.33847	1.33822	1.33798	1.33774	1.33751
22.0	1.33991	1.33961	1.33933	1.33905	1.33878	1.33851	1.33826	1.33801	1.33776	1.33753	1.33730
24.0	1.33969	1.33939	1.33910	1.33882	1.33855	1.33829	1.33803	1.33778	1.33754	1.33731	1.33709
26.0	1.33945	1.33915	1.33887	1.33859	1.33832	1.33805	1.33780	1.33755	1.33732	1.33709	1.33687
28.0	1.33922	1.33891	1.33862	1.33835	1.33808	1.33781	1.33756	1.33731	1.33708	1.33685	1.33663
30.0	1.33897	1.33867	1.33838	1.33810	1.33783	1.33756	1.33731	1.33706	1.33682	1.33659	1.33638

Table A-4. (cont)

(s)

S = 42 ‰

TEMP °C	WAVELENGTH (nm)										
	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0	
0.0	1.35286	1.35193	1.35105	1.35022	1.34947	1.34875	1.34808	1.34746	1.34688	1.34634	
2.0	1.35275	1.35182	1.35094	1.35012	1.34937	1.34866	1.34800	1.34737	1.34679	1.34625	
4.0	1.35263	1.35170	1.35082	1.35000	1.34926	1.34855	1.34789	1.34726	1.34668	1.34614	
6.0	1.35250	1.35158	1.35070	1.34988	1.34913	1.34843	1.34776	1.34714	1.34656	1.34602	
8.0	1.35237	1.35144	1.35056	1.34974	1.34899	1.34829	1.34763	1.34700	1.34642	1.34588	
10.0	1.35223	1.35130	1.35041	1.34959	1.34884	1.34814	1.34747	1.34685	1.34627	1.34572	
12.0	1.35207	1.35113	1.35025	1.34942	1.34867	1.34797	1.34730	1.34668	1.34610	1.34556	
14.0	1.35190	1.35096	1.35007	1.34924	1.34849	1.34778	1.34711	1.34649	1.34592	1.34538	
16.0	1.35171	1.35077	1.34988	1.34906	1.34830	1.34759	1.34692	1.34630	1.34573	1.34519	
18.0	1.35150	1.35057	1.34969	1.34886	1.34811	1.34739	1.34672	1.34610	1.34553	1.34499	
20.0	1.35129	1.35036	1.34948	1.34866	1.34790	1.34718	1.34651	1.34589	1.34532	1.34478	
22.0	1.35107	1.35014	1.34926	1.34844	1.34768	1.34697	1.34630	1.34567	1.34510	1.34456	
24.0	1.35084	1.34991	1.34903	1.34821	1.34745	1.34674	1.34607	1.34544	1.34487	1.34433	
26.0	1.35060	1.34967	1.34878	1.34796	1.34721	1.34650	1.34584	1.34521	1.34463	1.34409	
28.0	1.35035	1.34941	1.34853	1.34770	1.34696	1.34626	1.34559	1.34496	1.34438	1.34384	
30.0	1.35009	1.34915	1.34826	1.34744	1.34670	1.34600	1.34534	1.34471	1.34417	1.34359	
	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0	
0.0	1.34582	1.34533	1.34487	1.34444	1.34402	1.34363	1.34324	1.34287	1.34253	1.34220	
2.0	1.34573	1.34524	1.34478	1.34433	1.34392	1.34353	1.34316	1.34280	1.34245	1.34211	
4.0	1.34563	1.34514	1.34466	1.34422	1.34380	1.34342	1.34306	1.34270	1.34235	1.34201	
6.0	1.34550	1.34501	1.34454	1.34410	1.34368	1.34329	1.34292	1.34256	1.34223	1.34189	
8.0	1.34535	1.34486	1.34440	1.34397	1.34355	1.34316	1.34277	1.34241	1.34209	1.34175	
10.0	1.34520	1.34471	1.34425	1.34382	1.34340	1.34301	1.34262	1.34226	1.34193	1.34160	
12.0	1.34503	1.34454	1.34408	1.34364	1.34323	1.34283	1.34245	1.34209	1.34176	1.34142	
14.0	1.34485	1.34436	1.34389	1.34346	1.34304	1.34265	1.34227	1.34191	1.34157	1.34124	
16.0	1.34466	1.34416	1.34370	1.34326	1.34285	1.34246	1.34208	1.34172	1.34138	1.34104	
18.0	1.34446	1.34396	1.34350	1.34306	1.34265	1.34226	1.34189	1.34152	1.34118	1.34084	
20.0	1.34425	1.34376	1.34329	1.34286	1.34245	1.34206	1.34168	1.34131	1.34097	1.34063	
22.0	1.34403	1.34354	1.34308	1.34265	1.34223	1.34184	1.34146	1.34109	1.34075	1.34041	
24.0	1.34381	1.34332	1.34286	1.34242	1.34201	1.34161	1.34123	1.34086	1.34052	1.34019	
26.0	1.34358	1.34309	1.34263	1.34219	1.34177	1.34138	1.34099	1.34063	1.34029	1.33996	
28.0	1.34333	1.34285	1.34239	1.34195	1.34153	1.34114	1.34076	1.34039	1.34005	1.33972	
30.0	1.34307	1.34259	1.34213	1.34169	1.34128	1.34089	1.34052	1.34015	1.33981	1.33947	
	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.34188	1.34158	1.34129	1.34102	1.34075	1.34048	1.34023	1.33998	1.33973	1.33950	1.33927
2.0	1.34179	1.34149	1.34121	1.34093	1.34066	1.34039	1.34014	1.33989	1.33965	1.33942	1.33920
4.0	1.34170	1.34139	1.34110	1.34082	1.34055	1.34029	1.34003	1.33978	1.33955	1.33932	1.33910
6.0	1.34157	1.34127	1.34098	1.34070	1.34043	1.34016	1.33991	1.33966	1.33942	1.33920	1.33898
8.0	1.34144	1.34114	1.34085	1.34057	1.34029	1.34002	1.33977	1.33952	1.33929	1.33906	1.33884
10.0	1.34129	1.34099	1.34070	1.34041	1.34014	1.33987	1.33961	1.33937	1.33913	1.33891	1.33869
12.0	1.34111	1.34081	1.34052	1.34024	1.33996	1.33970	1.33945	1.33920	1.33896	1.33874	1.33852
14.0	1.34092	1.34062	1.34033	1.34005	1.33978	1.33952	1.33926	1.33902	1.33878	1.33855	1.33834
16.0	1.34072	1.34042	1.34013	1.33986	1.33959	1.33933	1.33907	1.33882	1.33858	1.33835	1.33813
18.0	1.34052	1.34022	1.33994	1.33966	1.33939	1.33913	1.33887	1.33862	1.33837	1.33814	1.33791
20.0	1.34032	1.34002	1.33973	1.33945	1.33918	1.33892	1.33866	1.33840	1.33816	1.33792	1.33769
22.0	1.34010	1.33980	1.33951	1.33923	1.33896	1.33869	1.33844	1.33819	1.33794	1.33771	1.33748
24.0	1.33987	1.33957	1.33928	1.33900	1.33873	1.33847	1.33821	1.33796	1.33772	1.33749	1.33727
26.0	1.33964	1.33934	1.33905	1.33877	1.33850	1.33823	1.33798	1.33773	1.33749	1.33727	1.33705
28.0	1.33940	1.33910	1.33881	1.33853	1.33826	1.33799	1.33774	1.33749	1.33725	1.33702	1.33681
30.0	1.33915	1.33885	1.33856	1.33828	1.33801	1.33774	1.33749	1.33724	1.33700	1.33677	1.33655

Table A-4. (cont)

(t)

S = 43 ‰

TEMP °C	WAVELENGTH (nm)									
	400.0	410.0	420.0	430.0	440.0	450.0	460.0	470.0	480.0	490.0
0.0	1.35307	1.35213	1.35125	1.35042	1.34967	1.34896	1.34829	1.34766	1.34708	1.34654
2.0	1.35295	1.35202	1.35114	1.35032	1.34957	1.34886	1.34820	1.34757	1.34699	1.34645
4.0	1.35283	1.35190	1.35102	1.35020	1.34946	1.34875	1.34809	1.34746	1.34688	1.34634
6.0	1.35270	1.35178	1.35089	1.35008	1.34933	1.34863	1.34796	1.34734	1.34676	1.34621
8.0	1.35257	1.35164	1.35076	1.34994	1.34919	1.34849	1.34782	1.34720	1.34662	1.34607
10.0	1.35243	1.35149	1.35061	1.34978	1.34904	1.34833	1.34767	1.34704	1.34646	1.34591
12.0	1.35227	1.35133	1.35044	1.34962	1.34886	1.34816	1.34749	1.34687	1.34629	1.34575
14.0	1.35209	1.35115	1.35026	1.34944	1.34868	1.34797	1.34730	1.34669	1.34611	1.34557
16.0	1.35190	1.35096	1.35008	1.34925	1.34849	1.34778	1.34711	1.34649	1.34592	1.34538
18.0	1.35170	1.35077	1.34988	1.34906	1.34830	1.34758	1.34691	1.34629	1.34572	1.34518
20.0	1.35149	1.35056	1.34968	1.34885	1.34809	1.34737	1.34670	1.34608	1.34551	1.34496
22.0	1.35126	1.35034	1.34945	1.34863	1.34787	1.34716	1.34648	1.34586	1.34529	1.34474
24.0	1.35103	1.35010	1.34922	1.34840	1.34764	1.34693	1.34626	1.34563	1.34505	1.34451
26.0	1.35079	1.34986	1.34897	1.34815	1.34740	1.34669	1.34602	1.34539	1.34481	1.34427
28.0	1.35054	1.34960	1.34872	1.34789	1.34715	1.34644	1.34578	1.34515	1.34457	1.34403
30.0	1.35028	1.34934	1.34845	1.34763	1.34688	1.34618	1.34552	1.34490	1.34432	1.34377

	500.0	510.0	520.0	530.0	540.0	550.0	560.0	570.0	580.0	590.0
0.0	1.34602	1.34553	1.34507	1.34464	1.34422	1.34382	1.34344	1.34307	1.34273	1.34239
2.0	1.34593	1.34544	1.34497	1.34453	1.34411	1.34373	1.34336	1.34299	1.34264	1.34231
4.0	1.34582	1.34533	1.34486	1.34441	1.34399	1.34362	1.34326	1.34290	1.34254	1.34221
6.0	1.34569	1.34520	1.34474	1.34429	1.34387	1.34349	1.34311	1.34275	1.34242	1.34208
8.0	1.34555	1.34506	1.34460	1.34416	1.34375	1.34335	1.34297	1.34260	1.34228	1.34194
10.0	1.34539	1.34490	1.34444	1.34401	1.34359	1.34319	1.34281	1.34245	1.34212	1.34179
12.0	1.34522	1.34473	1.34427	1.34383	1.34342	1.34302	1.34264	1.34227	1.34195	1.34161
14.0	1.34504	1.34455	1.34408	1.34364	1.34323	1.34284	1.34246	1.34210	1.34176	1.34142
16.0	1.34485	1.34435	1.34388	1.34344	1.34303	1.34264	1.34227	1.34191	1.34157	1.34123
18.0	1.34465	1.34415	1.34368	1.34325	1.34284	1.34245	1.34207	1.34171	1.34136	1.34103
20.0	1.34444	1.34394	1.34348	1.34304	1.34263	1.34224	1.34186	1.34149	1.34115	1.34082
22.0	1.34422	1.34373	1.34327	1.34283	1.34242	1.34202	1.34164	1.34127	1.34093	1.34059
24.0	1.34399	1.34351	1.34305	1.34261	1.34219	1.34179	1.34141	1.34105	1.34071	1.34037
26.0	1.34376	1.34327	1.34281	1.34237	1.34195	1.34156	1.34118	1.34081	1.34047	1.34013
28.0	1.34351	1.34303	1.34257	1.34213	1.34171	1.34132	1.34094	1.34057	1.34024	1.33990
30.0	1.34326	1.34277	1.34231	1.34188	1.34146	1.34107	1.34070	1.34033	1.33999	1.33966

	600.0	610.0	620.0	630.0	640.0	650.0	660.0	670.0	680.0	690.0	700.0
0.0	1.34208	1.34178	1.34149	1.34121	1.34094	1.34068	1.34042	1.34017	1.33993	1.33969	1.33947
2.0	1.34199	1.34169	1.34140	1.34112	1.34085	1.34059	1.34033	1.34008	1.33984	1.33961	1.33939
4.0	1.34189	1.34159	1.34130	1.34102	1.34075	1.34048	1.34022	1.33998	1.33974	1.33951	1.33929
6.0	1.34176	1.34146	1.34117	1.34089	1.34062	1.34035	1.34010	1.33985	1.33961	1.33939	1.33917
8.0	1.34163	1.34133	1.34104	1.34075	1.34048	1.34021	1.33996	1.33971	1.33947	1.33925	1.33903
10.0	1.34148	1.34118	1.34088	1.34060	1.34032	1.34006	1.33980	1.33955	1.33932	1.33909	1.33887
12.0	1.34130	1.34100	1.34071	1.34042	1.34015	1.33988	1.33963	1.33939	1.33915	1.33892	1.33871
14.0	1.34111	1.34081	1.34052	1.34024	1.33997	1.33970	1.33945	1.33920	1.33896	1.33874	1.33852
16.0	1.34091	1.34061	1.34032	1.34004	1.33977	1.33951	1.33925	1.33900	1.33876	1.33853	1.33831
18.0	1.34071	1.34041	1.34012	1.33984	1.33957	1.33931	1.33905	1.33880	1.33855	1.33832	1.33809
20.0	1.34050	1.34020	1.33991	1.33963	1.33936	1.33910	1.33884	1.33858	1.33834	1.33810	1.33787
22.0	1.34028	1.33998	1.33969	1.33941	1.33914	1.33887	1.33862	1.33836	1.33812	1.33789	1.33766
24.0	1.34005	1.33975	1.33946	1.33918	1.33891	1.33865	1.33839	1.33814	1.33790	1.33767	1.33745
26.0	1.33982	1.33951	1.33922	1.33895	1.33868	1.33841	1.33816	1.33791	1.33767	1.33744	1.33722
28.0	1.33958	1.33927	1.33899	1.33871	1.33843	1.33817	1.33791	1.33767	1.33743	1.33720	1.33698
30.0	1.33933	1.33903	1.33874	1.33846	1.33819	1.33792	1.33766	1.33741	1.33718	1.33695	1.33673

TABLE A-5 (a,b)

High Pressures S = 35‰ only

This table is based on the data of Stanley (1971). A detailed description of their modification is given in Subsection 4.3. The resulting table, shown in Table 4-7 in the text, replaces the original data and includes the following values of the variables:

Wavelength: 457.9, 488.0, 514.5, 632.8 nm

Pressure: 0, 352, 703, 1055 kg/cm^2(gage)

Temperature: 0.03, 15.02, 29.98°C

Note: The following values of the variables were excluded
$\lambda = 501.7$ nm and $p = 1406$ kg/cm^2 gage

Tables A-5(a,b) represent the increment of index with pressure, and are sequentially additive to Tables A-1 through A-4 giving the pressure, temperature, and wavelength dependence of the index of refraction (with respect to air) of Copenhagen Standard Seawater of 35‰ salinity. They are accurate to within $\pm 6 \times 10^{-5}$.

Table A-5(a): holds for any wavelength (it is exact only for 530 nm, see Figure 4-7 in Subsection 4.3) providing an additive index increment for various values of pressure and temperature.

Table A-5(b): holds for any temperature and gives additive increments for values of wavelength and pressure to provide wavelength corrections to Table A-5(a).

To use these tables, first read Tables A-1, A-2, A-3, or A-4(ℓ) for the desired wavelength and temperature (at atmospheric pressure) for S = 35‰; then, add the appropriate factor given in Table A-5(a), and then add the factor in Table A-5(b).

The pressures have been chosen every 50 kg/cm^2 between 0 and 1100 kg/cm^2 (gage). The temperatures are every 2°C between 0 and 30°C. The wavelengths are equispaced every 10 nm between 400 and 700 nm.

Table A-5. INDEX OF REFRACTION OF SEAWATER

Index Increments due to Pressure – Salinity = 35‰

Tables (a) and (b) are not independent. They are both additive to the atmospheric pressure index values.

(a) Index increase with pressure and temperature, applicable at all wavelengths.

All Wavelengths

TEMP °C	PRESSURES (kg/cm^2) 0.0	50.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0	550.0
0.0	0.00000	0.00077	0.00154	0.00230	0.00305	0.00379	0.00452	0.00525	0.00597	0.00669	0.00739	0.00809
2.0	0.00000	0.00077	0.00152	0.00227	0.00301	0.00375	0.00448	0.00520	0.00591	0.00662	0.00732	0.00801
4.0	0.00000	0.00076	0.00151	0.00225	0.00298	0.00371	0.00443	0.00515	0.00585	0.00655	0.00725	0.00793
6.0	0.00000	0.00075	0.00149	0.00223	0.00296	0.00368	0.00439	0.00510	0.00580	0.00649	0.00718	0.00786
8.0	0.00000	0.00074	0.00148	0.00221	0.00293	0.00364	0.00435	0.00505	0.00575	0.00643	0.00712	0.00779
10.0	0.00000	0.00074	0.00147	0.00219	0.00290	0.00361	0.00431	0.00501	0.00570	0.00638	0.00706	0.00772
12.0	0.00000	0.00073	0.00145	0.00217	0.00288	0.00358	0.00428	0.00497	0.00565	0.00633	0.00700	0.00766
14.0	0.00000	0.00073	0.00144	0.00215	0.00286	0.00355	0.00425	0.00493	0.00561	0.00628	0.00695	0.00761
16.0	0.00000	0.00072	0.00143	0.00214	0.00284	0.00353	0.00422	0.00490	0.00557	0.00624	0.00690	0.00755
18.0	0.00000	0.00072	0.00142	0.00212	0.00282	0.00351	0.00419	0.00486	0.00553	0.00620	0.00686	0.00751
20.0	0.00000	0.00071	0.00141	0.00211	0.00280	0.00349	0.00416	0.00484	0.00550	0.00616	0.00682	0.00746
22.0	0.00000	0.00071	0.00141	0.00210	0.00279	0.00347	0.00414	0.00481	0.00547	0.00613	0.00678	0.00742
24.0	0.00000	0.00070	0.00140	0.00209	0.00277	0.00345	0.00412	0.00479	0.00545	0.00610	0.00675	0.00739
26.0	0.00000	0.00070	0.00139	0.00208	0.00276	0.00343	0.00410	0.00477	0.00542	0.00607	0.00672	0.00736
28.0	0.00000	0.00070	0.00139	0.00207	0.00275	0.00342	0.00409	0.00475	0.00540	0.00605	0.00670	0.00733
30.0	0.00000	0.00069	0.00138	0.00206	0.00274	0.00341	0.00407	0.00473	0.00539	0.00603	0.00667	0.00731

TEMP °C	600.0	650.0	700.0	750.0	800.0	850.0	900.0	950.0	1000.0	1050.0	1100.0
0.0	0.00879	0.00947	0.01015	0.01082	0.01148	0.01214	0.01278	0.01343	0.01406	0.01468	0.01530
2.0	0.00870	0.00937	0.01005	0.01071	0.01137	0.01202	0.01266	0.01329	0.01392	0.01454	0.01516
4.0	0.00861	0.00928	0.00995	0.01061	0.01126	0.01190	0.01254	0.01317	0.01379	0.01441	0.01501
6.0	0.00853	0.00920	0.00986	0.01051	0.01116	0.01179	0.01243	0.01305	0.01367	0.01428	0.01488
8.0	0.00846	0.00912	0.00977	0.01042	0.01106	0.01169	0.01232	0.01294	0.01355	0.01416	0.01476
10.0	0.00839	0.00904	0.00969	0.01033	0.01097	0.01160	0.01222	0.01283	0.01344	0.01405	0.01464
12.0	0.00832	0.00897	0.00962	0.01025	0.01088	0.01151	0.01213	0.01274	0.01334	0.01394	0.01453
14.0	0.00826	0.00891	0.00955	0.01018	0.01081	0.01143	0.01204	0.01265	0.01325	0.01384	0.01443
16.0	0.00820	0.00885	0.00948	0.01011	0.01073	0.01135	0.01196	0.01257	0.01316	0.01375	0.01434
18.0	0.00815	0.00879	0.00942	0.01005	0.01067	0.01128	0.01189	0.01249	0.01308	0.01367	0.01425
20.0	0.00810	0.00874	0.00937	0.00999	0.01061	0.01122	0.01182	0.01242	0.01301	0.01360	0.01418
22.0	0.00806	0.00869	0.00932	0.00994	0.01055	0.01116	0.01176	0.01236	0.01295	0.01353	0.01411
24.0	0.00802	0.00865	0.00928	0.00990	0.01051	0.01111	0.01171	0.01230	0.01289	0.01347	0.01405
26.0	0.00799	0.00862	0.00924	0.00986	0.01047	0.01107	0.01167	0.01226	0.01284	0.01342	0.01400
28.0	0.00796	0.00859	0.00921	0.00982	0.01043	0.01103	0.01163	0.01222	0.01280	0.01338	0.01395
30.0	0.00794	0.00856	0.00918	0.00979	0.01040	0.01100	0.01160	0.01218	0.01277	0.01334	0.01392

(b) Index increase with pressure and wavelength, applicable at all temperatures.

All Temperatures

λ (nm)	PRESSURES (kg/cm^2) 0.0	50.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0	550.0
400	0.00000	0.00001	0.00002	0.00003	0.00003	0.00004	0.00005	0.00006	0.00007	0.00008	0.00009	0.00010
420	0.00000	0.00001	0.00002	0.00002	0.00003	0.00004	0.00004	0.00005	0.00006	0.00007	0.00007	0.00008
440	0.00000	0.00001	0.00001	0.00002	0.00002	0.00003	0.00004	0.00004	0.00005	0.00005	0.00006	0.00007
460	0.00000	0.00001	0.00001	0.00002	0.00002	0.00002	0.00003	0.00003	0.00004	0.00004	0.00005	0.00005
480	0.00000	0.00001	0.00001	0.00001	0.00001	0.00002	0.00002	0.00002	0.00003	0.00003	0.00003	0.00004
500	0.00000	0.00000	0.00000	0.00001	0.00001	0.00001	0.00001	0.00001	0.00002	0.00002	0.00002	0.00002
520	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00001	0.00001
540	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001
560	0.00000	0.00000	0.00000	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00002	-0.00002	-0.00002	-0.00002
580	0.00000	0.00000	-0.00001	-0.00001	-0.00001	-0.00002	-0.00002	-0.00002	-0.00003	-0.00003	-0.00003	-0.00004
600	0.00000	-0.00001	-0.00001	-0.00002	-0.00002	-0.00002	-0.00003	-0.00003	-0.00004	-0.00004	-0.00005	-0.00005
620	0.00000	-0.00001	-0.00001	-0.00002	-0.00003	-0.00003	-0.00004	-0.00004	-0.00005	-0.00005	-0.00006	-0.00006
640	0.00000	-0.00001	-0.00002	-0.00002	-0.00003	-0.00004	-0.00005	-0.00005	-0.00006	-0.00007	-0.00007	-0.00008
660	0.00000	-0.00001	-0.00002	-0.00003	-0.00004	-0.00005	-0.00005	-0.00006	-0.00007	-0.00008	-0.00009	-0.00009
680	0.00000	-0.00001	-0.00002	-0.00003	-0.00004	-0.00005	-0.00006	-0.00007	-0.00008	-0.00009	-0.00010	-0.00011
700	0.00000	-0.00001	-0.00002	-0.00003	-0.00005	-0.00006	-0.00007	-0.00008	-0.00009	-0.00010	-0.00011	-0.00012

λ (nm)	600.0	650.0	700.0	750.0	800.0	850.0	900.0	950.0	1000.0	1050.0	1100.0
400	0.00011	0.00011	0.00012	0.00013	0.00014	0.00015	0.00015	0.00016	0.00016	0.00017	0.00017
420	0.00009	0.00010	0.00010	0.00011	0.00012	0.00012	0.00013	0.00013	0.00014	0.00014	0.00014
440	0.00007	0.00008	0.00008	0.00009	0.00010	0.00010	0.00010	0.00011	0.00011	0.00011	0.00012
460	0.00006	0.00006	0.00007	0.00007	0.00007	0.00008	0.00008	0.00008	0.00009	0.00009	0.00009
480	0.00004	0.00004	0.00005	0.00005	0.00005	0.00005	0.00006	0.00006	0.00006	0.00006	0.00006
500	0.00002	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003	0.00003
520	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00000
540	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00002	-0.00002	-0.00002	-0.00002
560	-0.00002	-0.00002	-0.00003	-0.00003	-0.00003	-0.00003	-0.00004	-0.00004	-0.00004	-0.00005	-0.00005
580	-0.00004	-0.00004	-0.00004	-0.00005	-0.00005	-0.00006	-0.00006	-0.00007	-0.00007	-0.00008	-0.00008
600	-0.00005	-0.00006	-0.00006	-0.00007	-0.00007	-0.00008	-0.00008	-0.00009	-0.00010	-0.00010	-0.00011
620	-0.00007	-0.00008	-0.00008	-0.00009	-0.00009	-0.00010	-0.00011	-0.00011	-0.00012	-0.00013	-0.00014
640	-0.00009	-0.00009	-0.00010	-0.00011	-0.00011	-0.00012	-0.00013	-0.00014	-0.00015	-0.00016	-0.00017
660	-0.00010	-0.00011	-0.00012	-0.00013	-0.00014	-0.00014	-0.00015	-0.00016	-0.00017	-0.00018	-0.00019
680	-0.00012	-0.00013	-0.00014	-0.00015	-0.00016	-0.00017	-0.00018	-0.00019	-0.00020	-0.00021	-0.00022
700	-0.00013	-0.00014	-0.00016	-0.00017	-0.00018	-0.00019	-0.00020	-0.00021	-0.00022	-0.00023	-0.00025

TABLE A-6 (a,b)

High Pressures · S = 0‰ (pure water only)

This table is based on the data of Waxler, Weir and Schamp (1964). The analysis of this body of data was presented in Subsection 4.4, and the resulting table which we have adopted is given as Table 4-12 in the text. It includes the following values of the variables:

Wavelength: 467.8, 480.0, 492.2, 501.6, 587.6, 643.8, 667.8 nm

Pressure: 0, 250, 500, 750, 1100 kg/cm^2

Temperature: 1.56, 7.64, 24.80, 34.50, 54.34°C

Tables A-6(a,b) represent the increment of index with pressure and are sequentially additive to Tables A-1 through A-4 to provide the pressure, temperature, and wavelength dependence of the index of refraction (with respect to air) of pure water, S = 0‰. They are accurate to within $\pm 10 \times 10^{-5}$.

Table A-6(a):	holds for any wavelength (it is exact only for 540 nm) providing an additive increment for various values of pressure and temperature.
Table A-6(b):	holds for any temperature and provides additive increments for various wavelengths and pressures, thus offering a wavelength correction to Table A-6(a).

To use these tables, first read Tables A-1, A-2, A-3, or A-4(a) for the desired wavelength and temperature (at atmospheric pressure) for S = 0‰; then add the factor given in Table A-6(a) and then add algebraically that given in Table A-6(b).

The increments in pressure, temperature, and wavelength are identical to those in Tables A-5(a,b).

Table A-6. INDEX OF REFRACTION OF PURE WATER

Index increments due to Pressure – Salinity = 0‰

Tables (a) and (b) are not independent. They are both additive to the atmospheric pressure index values.

(a) Index increase with pressure and temperature, applicable at all wavelengths.

All Wavelengths

TEMP °C	PRESSURES (kg/cm^2) 0.0	50.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0	550.0
0.0	0.00000	0.00080	0.00159	0.00237	0.00314	0.00390	0.00466	0.00540	0.00614	0.00687	0.00758	0.00829
2.0	0.00000	0.00078	0.00156	0.00232	0.00308	0.00384	0.00459	0.00533	0.00606	0.00679	0.00751	0.00823
4.0	0.00000	0.00077	0.00152	0.00228	0.00303	0.00378	0.00452	0.00526	0.00599	0.00672	0.00744	0.00816
6.0	0.00000	0.00075	0.00150	0.00224	0.00298	0.00372	0.00446	0.00520	0.00593	0.00665	0.00738	0.00810
8.0	0.00000	0.00074	0.00148	0.00221	0.00295	0.00368	0.00441	0.00514	0.00587	0.00659	0.00732	0.00803
10.0	0.00000	0.00073	0.00146	0.00219	0.00291	0.00364	0.00437	0.00509	0.00581	0.00654	0.00726	0.00797
12.0	0.00000	0.00072	0.00144	0.00216	0.00288	0.00360	0.00432	0.00504	0.00576	0.00648	0.00720	0.00791
14.0	0.00000	0.00071	0.00143	0.00214	0.00285	0.00357	0.00428	0.00500	0.00571	0.00643	0.00714	0.00785
16.0	0.00000	0.00071	0.00141	0.00212	0.00283	0.00353	0.00424	0.00495	0.00567	0.00638	0.00709	0.00779
18.0	0.00000	0.00070	0.00140	0.00210	0.00280	0.00350	0.00421	0.00492	0.00563	0.00633	0.00704	0.00773
20.0	0.00000	0.00069	0.00139	0.00208	0.00278	0.00348	0.00418	0.00488	0.00559	0.00629	0.00699	0.00767
22.0	0.00000	0.00069	0.00138	0.00207	0.00276	0.00345	0.00415	0.00485	0.00555	0.00625	0.00694	0.00761
24.0	0.00000	0.00069	0.00137	0.00206	0.00275	0.00344	0.00413	0.00482	0.00551	0.00620	0.00689	0.00756
26.0	0.00000	0.00069	0.00137	0.00205	0.00274	0.00342	0.00411	0.00479	0.00548	0.00616	0.00685	0.00751
28.0	0.00000	0.00068	0.00137	0.00205	0.00273	0.00341	0.00409	0.00477	0.00545	0.00613	0.00681	0.00747
30.0	0.00000	0.00068	0.00136	0.00204	0.00272	0.00340	0.00408	0.00476	0.00543	0.00611	0.00677	0.00743

	600.0	650.0	700.0	750.0	800.0	850.0	900.0	950.0	1000.0	1050.0	1100.0
0.0	0.00900	0.00970	0.01038	0.01107	0.01174	0.01242	0.01309	0.01375	0.01441	0.01506	0.01571
2.0	0.00893	0.00963	0.01032	0.01100	0.01167	0.01233	0.01298	0.01362	0.01425	0.01488	0.01550
4.0	0.00887	0.00956	0.01025	0.01092	0.01158	0.01223	0.01287	0.01349	0.01410	0.01470	0.01529
6.0	0.00880	0.00949	0.01017	0.01084	0.01150	0.01214	0.01276	0.01337	0.01396	0.01455	0.01512
8.0	0.00873	0.00942	0.01010	0.01076	0.01142	0.01205	0.01267	0.01327	0.01386	0.01443	0.01500
10.0	0.00867	0.00935	0.01002	0.01068	0.01133	0.01196	0.01257	0.01317	0.01376	0.01433	0.01490
12.0	0.00860	0.00928	0.00994	0.01059	0.01124	0.01186	0.01248	0.01307	0.01366	0.01424	0.01480
14.0	0.00853	0.00920	0.00986	0.01050	0.01114	0.01176	0.01237	0.01297	0.01356	0.01414	0.01471
16.0	0.00846	0.00912	0.00977	0.01041	0.01104	0.01166	0.01227	0.01287	0.01346	0.01404	0.01462
18.0	0.00840	0.00905	0.00969	0.01032	0.01094	0.01156	0.01217	0.01277	0.01337	0.01395	0.01453
20.0	0.00833	0.00897	0.00960	0.01023	0.01085	0.01146	0.01207	0.01267	0.01327	0.01386	0.01444
22.0	0.00827	0.00890	0.00952	0.01014	0.01076	0.01137	0.01198	0.01258	0.01318	0.01377	0.01435
24.0	0.00821	0.00883	0.00945	0.01006	0.01067	0.01128	0.01189	0.01249	0.01309	0.01368	0.01427
26.0	0.00815	0.00877	0.00938	0.00999	0.01059	0.01120	0.01180	0.01240	0.01300	0.01360	0.01418
28.0	0.00810	0.00872	0.00932	0.00993	0.01053	0.01113	0.01173	0.01233	0.01293	0.01352	0.01410
30.0	0.00806	0.00867	0.00928	0.00988	0.01048	0.01108	0.01168	0.01227	0.01286	0.01344	0.01402

(b) Index increase with pressure and wavelength, applicable at all temperatures.

All Temperatures

λ (nm)	PRESSURES (kg/cm^2) 0.0	50.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0	550.0
400.0	0.00000	0.00001	0.00002	0.00003	0.00004	0.00005	0.00006	0.00006	0.00007	0.00008	0.00008	0.00009
420.0	0.00000	0.00001	0.00002	0.00002	0.00003	0.00004	0.00004	0.00005	0.00006	0.00006	0.00007	0.00008
440.0	0.00000	0.00000	0.00001	0.00001	0.00002	0.00003	0.00003	0.00004	0.00005	0.00005	0.00006	0.00007
460.0	0.00000	0.00000	0.00001	0.00001	0.00001	0.00002	0.00002	0.00003	0.00004	0.00004	0.00005	0.00005
480.0	0.00000	0.00000	0.00000	0.00001	0.00001	0.00001	0.00002	0.00002	0.00003	0.00003	0.00004	0.00004
500.0	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00001	0.00002	0.00002	0.00002	0.00003	0.00003
520.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00001	0.00001	0.00001	0.00002
540.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
560.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001
580.0	0.00000	0.00000	0.00000	0.00000	-0.00001	-0.00001	-0.00001	-0.00001	-0.00002	-0.00002	-0.00002	-0.00002
600.0	0.00000	0.00000	0.00000	-0.00001	-0.00001	-0.00001	-0.00002	-0.00002	-0.00002	-0.00003	-0.00003	-0.00004
620.0	0.00000	0.00000	0.00000	-0.00001	-0.00001	-0.00001	-0.00002	-0.00003	-0.00003	-0.00004	-0.00004	-0.00005
640.0	0.00000	0.00000	0.00000	-0.00001	-0.00001	-0.00002	-0.00003	-0.00003	-0.00004	-0.00005	-0.00006	-0.00006
660.0	0.00000	0.00000	-0.00001	-0.00001	-0.00002	-0.00002	-0.00003	-0.00004	-0.00005	-0.00006	-0.00007	-0.00007
680.0	0.00000	0.00000	-0.00001	-0.00001	-0.00002	-0.00003	-0.00004	-0.00005	-0.00006	-0.00007	-0.00008	-0.00009
700.0	0.00000	0.00000	-0.00001	-0.00002	-0.00002	-0.00003	-0.00004	-0.00006	-0.00007	-0.00008	-0.00009	-0.00010

	600.0	650.0	700.0	750.0	800.0	850.0	900.0	950.0	1000.0	1050.0	1100.0
400.0	0.00010	0.00010	0.00011	0.00012	0.00013	0.00013	0.00014	0.00015	0.00016	0.00017	0.00018
420.0	0.00008	0.00009	0.00010	0.00010	0.00011	0.00011	0.00012	0.00013	0.00014	0.00014	0.00015
440.0	0.00007	0.00007	0.00008	0.00008	0.00009	0.00010	0.00010	0.00011	0.00011	0.00012	0.00013
460.0	0.00006	0.00006	0.00006	0.00007	0.00007	0.00008	0.00008	0.00009	0.00009	0.00010	0.00010
480.0	0.00004	0.00005	0.00005	0.00005	0.00006	0.00006	0.00006	0.00007	0.00007	0.00007	0.00008
500.0	0.00003	0.00003	0.00003	0.00004	0.00004	0.00004	0.00004	0.00005	0.00005	0.00005	0.00005
520.0	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00003	0.00003	0.00003
540.0	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
560.0	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00002	-0.00002	-0.00002	-0.00002	-0.00002	-0.00002
580.0	-0.00002	-0.00003	-0.00003	-0.00003	-0.00003	-0.00003	-0.00004	-0.00004	-0.00004	-0.00004	-0.00004
600.0	-0.00004	-0.00004	-0.00004	-0.00005	-0.00005	-0.00005	-0.00006	-0.00006	-0.00006	-0.00007	-0.00007
620.0	-0.00005	-0.00006	-0.00006	-0.00006	-0.00007	-0.00007	-0.00008	-0.00008	-0.00008	-0.00009	-0.00009
640.0	-0.00007	-0.00007	-0.00007	-0.00008	-0.00008	-0.00009	-0.00010	-0.00010	-0.00011	-0.00011	-0.00012
660.0	-0.00008	-0.00008	-0.00009	-0.00010	-0.00010	-0.00011	-0.00012	-0.00012	-0.00013	-0.00014	-0.00014
680.0	-0.00009	-0.00010	-0.00011	-0.00011	-0.00012	-0.00013	-0.00014	-0.00014	-0.00015	-0.00016	-0.00017
700.0	-0.00011	-0.00011	-0.00012	-0.00013	-0.00014	-0.00015	-0.00016	-0.00016	-0.00017	-0.00018	-0.00019

APPENDIX B. THE INTERPOLATION ROUTINE

The computer routine used to interpolate the original data tables to produce the tables in Appendix A was taken from the published literature, Akima (1972).

It is neither a curve-fitting routine employing an analytical approximation nor a least squares method, but is instead a numerical technique utilizing the local derivatives obtained from the input data and functions only on monotonic data. Its great advantage lies in its ability to pass a curve **through** a given set of data points and interpolate between the points as smoothly as would be possible.

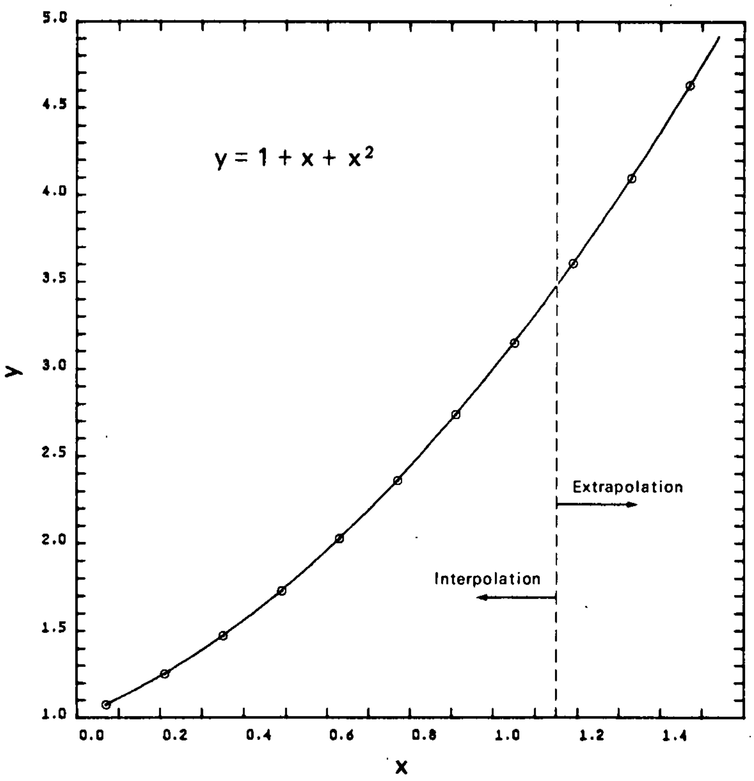
We have tested this routine empirically by numerically computing several points from analytic expressions (polynomials) and asking the routine to interpolate for several values between these points. The estimates were checked against the polynomial and were found to be in excellent agreement. The polynomials used for testing simulated situations actually encountered with our data tables. Thus, we have confidence in using this scheme to provide interpolated values that possess the same accuracy as the original data.

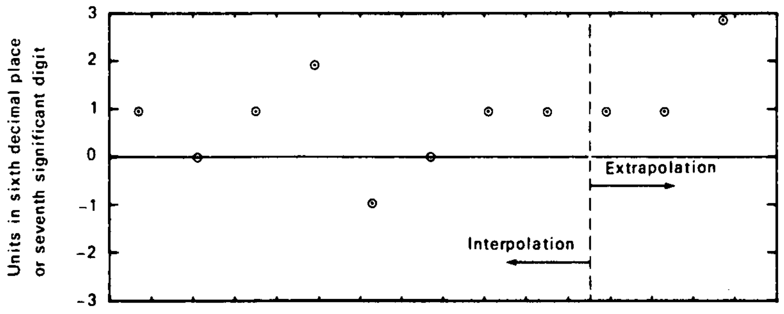
This interpolation routine also greatly assisted us in determining the smoothness of the original data, since it actually passes a curve through the data points, helping to detect inflection points on the plots.

Of course, the fact that our data were mostly well-behaved, being values for a physical parameter measured to a high accuracy, greatly helped in achieving our goals.

When extrapolation was performed, we found that in some instances the estimates deviated somewhat from the corresponding polynomial, depending on the type of curve shape used. However, this routine was not used for extrapolations.

An illustrative example of the capabilities of this numerical procedure is provided in the figure given below. In the upper graph the continuous curve represents the polynomial $y = 1 + x + x^2$. As input, pairs of x,y values computed from the equation were supplied, whose position on the curve lies halfway between the circled points, on the 'Interpolation' side only. The subroutine then estimated a series of y values corresponding to given x values in both the 'Interpolation' and 'Extrapolation' regions. These estimates are marked by the circled points on the curve in the upper graph. The differences between these estimates and the true values from the polynomial are plotted in the lower graph. These differences were found to be of the order of two units in the seventh significant digit, with no apparent change from the 'Interpolation' to the 'Extrapolation' region. All the numerical work was performed on an IBM 360/44 computer which employs seven significant digits. Thus in the index of refraction tables small discrepancies would arise in the sixth decimal place, but since we have presented the tables to the fifth decimal place only, we believe that no real numerical problems arise in interpolating.





The actual computer code of the interpolation routine is reproduced below in FORTRAN, as adapted to the IBM 360/44 computer, because we believe this routine should receive wider circulation. For more details and description refer to Akima (1972).

```
      SUBROUTINE INTRPL(IU,L,X,Y,N,U,V)
C     INTERPOLATION OF A SINGLE-VALUED FUNCTION
C
C     THIS SUBROUTINE INTERPOLATES, FROM VALUES OF THE FUNCTION GIVEN
C     AS ORDINATES OF INPUT DATA POINTS IN AN X-Y PLANE AND FOR A GIVEN
C     SET OF X VALUES (ABSCISSAS), THE VALUES OF A SINGLE-VALUED
C     FUNCTION Y = Y(X).
C
C     THE INPUT PARAMETERS ARE
C
C        IU = LOGICAL UNIT NUMBER OF STANDARD OUTPUT UNIT
C         L = NUMBER OF INPUT DATA POINTS (MUST BE 2 OR GREATER)
C         X = ARRAY OF DIMENSION L STORING THE X VALUES (ABSCISSAS) OF
C             INPUT DATA POINTS (IN ASCENDING ORDER)
C         Y = ARRAY OF DIMENSION L STORING THE Y VALUES (ORDINATES) OF
C             INPUT DATA POINTS
C         N =  NUMBER OF POINTS AT WHICH INTERPOLATION OF THE Y VALUE
C             (ORDINATE) IS DESIRED (MUST BE 1 OR GREATER)
C         U = ARRAY OF DIMENSION N STORING THE X VALUES (ABSCISSAS) OF
C             DESIRED POINTS
C
C     THE OUTPUT PARAMETER IS
C
C         V = ARRAY OF DIMENSION N WHERE THE INTERPOLATED Y VALUES
C             (ORDINATES) ARE TO BE DISPLAYED
C
C     DECLARATION STATEMENTS
C
      DIMENSION X(L),Y(L),U(N),V(N)
      EQUIVALENCE (P0,X3),(Q0,Y3),(Q1,T3)
      REAL M1,M2,M3,M4,M5
      EQUIVALENCE (UK,DX),(IMN,X2,A1,M1),(IMX,X5,A5,M5),
     1 (J,SW,SA),(Y2,W2,W4,Q2),(Y5,W3,Q3)
C
C     PRELIMINARY PROCESSING
C
   10 LO = L
      LM1 = LO-1
      LM2 = LM1-1
      LP1 = LO+1
      NO = N
      IF(LM2.LT.0) GO TO 90
      IF(NO.LE.0) GO TO 91
      DO 11 I=2,LO
        IF(X(I-1)-X(I)) 11,95,96
   11 CONTINUE
      IPV = 0
C
C     MAIN DO-LOOP
C
      DO 80 K=1,NO
        UK = U(K)
C
C     ROUTINE TO LOCATE THE DESIRED POINT
C
   20 IF(LM2.EQ.0) GO TO 27
      IF(UK.GE.X(LO))GO TO 26
      IF(UK.LT.X(1)) GO TO 25
      IMN = 2
      IMX = LO
   21 I = (IMN+IMX)/2
      IF(UK.GE.X(I))GO TO 23
   22 IMX = I
      GO TO 24
   23 IMN = I+1
   24 IF(IMX.GT.IMN) GO TO 21
      I = IMX
      GO TO 30
   25 I = 1
      GO TO 30
   26 I = LP1
```

```
      GO TO 30
   27 I = 2
C
C     CHECK IF I = IPV
C
   30 IF(I.EQ.IPV) GO TO 70
      IPV = I
C
C     ROUTINES TO PICK UP NECESSARY X AND Y VALUES AND TO ESTIMATE THEM
C     IF NECESSARY
C
   40 J = I
      IF(J.EQ.1) J=2
      IF(J.EQ.LP1) J=LO
      X3 = X(J-1)
      Y3 = Y(J-1)
      X4 = X(J)
      Y4 = Y(J)
      A3 = X4-X3
      M3 = (Y4-Y3)/A3
      IF(LM2.EQ.0) GO TO 43
      IF(J.EQ.2) GO TO 41
      X2 = X(J-2)
      Y2 = Y(J-2)
      A2 = X3-X2
      M2 = (Y3-Y2)/A2
      IF(J.EQ.LO) GO TO 42

   41 X5 = X(J+1)
      Y5 = Y(J+1)
      A4 = X5-X4
      M4 = (Y5-Y4)/A4
      IF(J.FQ.2) M2=M3+M3-M4
      GO TO 45
   42 M4 = M3+M3-M2
      GO TO 45
   43 M2 = M3
      M4 = M3
   45 IF(J.LE.3) GO TO 46
      A1 = X2-X(J-3)
      M1 = (Y2-Y(J-3))/A1
      GO TO 47
   46 M1 = M2+M2-M3
   47 IF(J.GE.LM1) GO TO 48
      A5 = X(J+2)-X5
      M5 = (Y(J+2)-Y5)/A5
      GO TO 50
   48 M5 = M4+M4-M3
C
C     NUMERICAL DIFFERENTIATION
C
   50 IF(I.EQ.LP1) GO TO 52
      W2 = ABS(M4-M3)
      W3 = ABS(M2-M1)
      SW = W2+W3
      IF(SW.NE.0.0) GO TO 51
      W2 = 0.5
      W3 = 0.5
      SW = 1.0
   51 T3 = (W2*M2+W3*M3)/SW
      IF(I.EQ.1) GO TO 54
   52 W3 = ABS(M5-M4)
      W4 = ABS(M3-M2)
      SW = W3+W4
      IF(SW.NE.0.0) GO TO 53
      W3 = 0.5
      W4 = 0.5
      SW = 1.0
   53 T4 = (W3*M3+W4*M4)/SW
      IF(I.NE.LP1) GO TO 60
      T3 = T4
```

```
      SA = A2+A3
      T4 = 0.5*(M4+M5-A2*(A2-A3)*(M2-M3)/(SA*SA))
      X3 = X4
      Y3 = Y4
      A3 = A2
      M3 = M4

      GO TO 60
   54 T4 = T3
      SA = A3+A4
      T3 = 0.5*(M1+M2-A4*(A3-A4)*(M3-M4)/(SA*SA))
      X3 = X3-A4
      Y3 = Y3-M2*A4
      A3 = A4
      M3 = M2
C
C     DETERMINATION OF THE COEFFICIENTS
C
   60 Q2 = (2.0*(M3-T3)+M3-T4)/A3
      Q3 = (-M3-M3+T3+T4)/(A3*A3)
C
C     COMPUTATION OF THE POLYNOMIAL
C
   70 DX = UK-P0
   80 V(K) = Q0+DX*(Q1+DX*(Q2+DX*Q3))
      RETURN
C
C     ERROR EXIT
C
   90 WRITE(IU,2090)
      GO TO 99
   91 WRITE(IU,2091)
      GO TO 99
   95 WRITE(IU,2095)
      GO TO 97
   96 WRITE(IU,2096)
   97 WRITE(IU,2097) I,X(I)
   99 WRITE(IU,2099) L0,N0
      RETURN
C
C     FORMAT STATEMENTS
C
 2090 FORMAT (1X/22H  ***    L = 1 OR LESS./)
 2091 FORMAT (1X/22H  ***    N = 0 OR LESS./)
 2095 FORMAT (1X/27H  ***    IDENTICAL X VALUES./)
 2096 FORMAT (1X/33H  ***    X VALUES OUT OF SEQUENCE./)
 2097 FORMAT (6H   I =,I7,10X,6HX(I) =,E12.6)
 2099 FORMAT (6H   L =,I7,10X,3HN =,I7/36H ERROR DETECTED IN ROUTINE
     1INTRPL)
      END
```