A recording transparency meter for oceanic plankton estimation

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INTRODUCTION

The transparency meter for *in situ* measurements of the light attenuation of sea water was introduced by Petterson (1936). Improved models were presented by Johnson (1944), Joseph (1955) and Jerlov (1957). Except for a model constructed for fitting to the sounding wells of the German research ships (Joseph loc. sit.) the instruments were intended for submerged measurements at oceanographic stations.

In addition to its value in describing and separating different water masses as to their absorbance and scattering of light, the transparency measurements have shown to give useful indications of particle concentrations in the sea. Operating the instruments within the red range of the light spectrum, variations in light transmission are mainly due to different contents of suspended particles (Joseph 1955), the effect of dissolved organic matter like "yellow substances" being negligible (Jerlov 1957). In the waters of the North Sea, Joseph (loc. sit.) also observed a high correlation between the content of particulate organic matter and the extinction of red light and suggested the use of extinction measurements as a valuable aid in plankton density determinations.

Berge (1961) introduced a stationary, recording transparency meter with continous water feeding. The instrument was specially intended for tracing plankton density in oceanic waters, recording continously the red light transmission of the water at a depth of five meters. In a survey of the Norwegian Sea in 1958, the variations in the recorded transparency also demonstrated a close relation to simultanously observed values of the productivity per unit time and light. The transparency measurements were found satisfactory for superficial surveys of the productivity in highly productive areas like the Norwegian Sea, provided that they were evaluated in conjunction with selected measurements of the productivity.

The recording transparency meter has been used by the Institute of Marine Research for several plankton surveys. Results so far obtained on standing stock or productivity have been used in the studies of fish

distribution and migration and have also been helpful in conjunction with other planktonic observations (Lie, 1961; Berge, 1961). A working description of the transparency meter together with examples of its use in planctology is given below.

DESCRIPTION

The water delivery system, (Fig. 1).

The water intake is a 1 1/4" tube which extends 50 cm below the bottom of the ship and is protected with a streamlined housing made of wood ⓪. This placement of the water intake has proven necessary in order
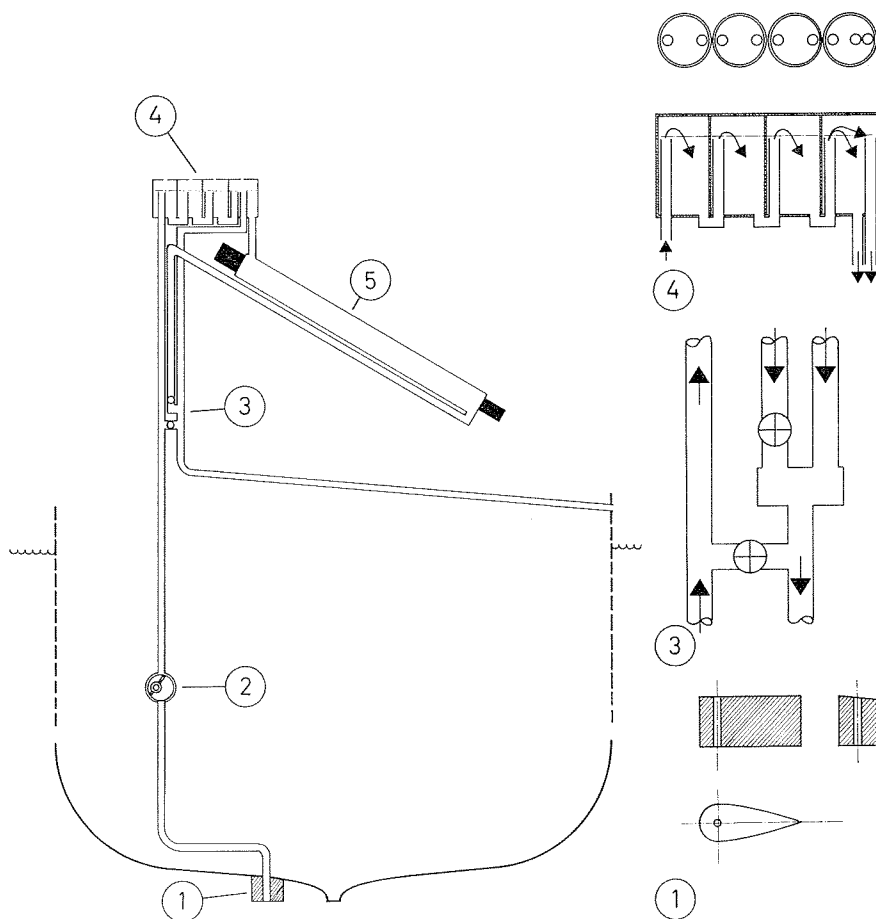
Fig. 1. Schematic illustration of the tranparency meter showing its placing relative to the ship hull and the sea surface. ① water inlet, ② screw pump (Monopump GH30), ③ by-pass and throttle valves, ④ bubble trap and overflow, ⑤ the cylinder with light source and detector at opposite ends.

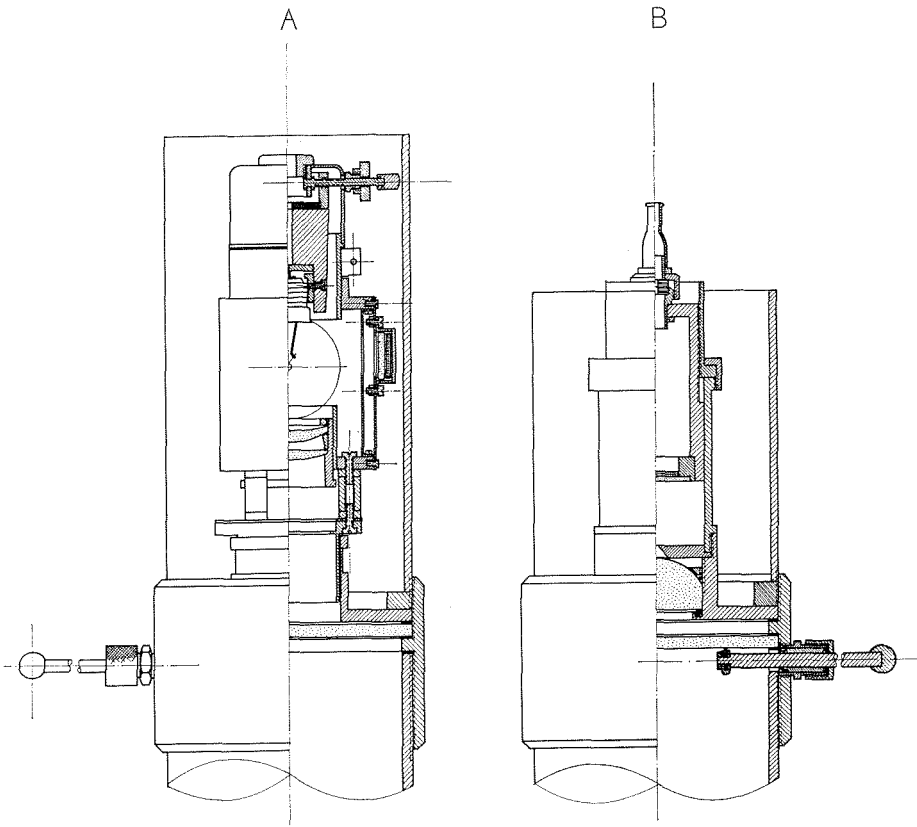A   B

Fig. 2. The construction of the light source (left) and the light detector. A photo resistor for control of light stability is mounted on the side of the lamp housing. The figure also shows the connections of the units to the cylinder, and the window wipers.

to avoid the milky water due to the presence of minute air bubles which occasionally occurs close to the ship hull. Placed in the engine room below the water line, a screw pump with nylon stators (Monopump 1 1/4" type GH30) ⊘ provides the supply of water to the transparency meter in the laboratory on deck. The capacity of the pump is approximately 40 l/min., but by means of a "by pass" ⊘ the water supply to the instrument can be reduced. A "bubble trap" ⊘ is placed before the entrance of water to the cylinder of the instrument to remove any air bubbles in the water. The trap allows the incoming water to come into contact with the atmosphere in a series of four chambers. This system has proven to be satisfactory if weather conditions and the stirring of the sea by waves are causing only moderate milkiness of the water.

From the "bubble trap" the water is siphoned through the transparency meter ⊘. The siphoning is regulated by a throttle ⊘ in such a way
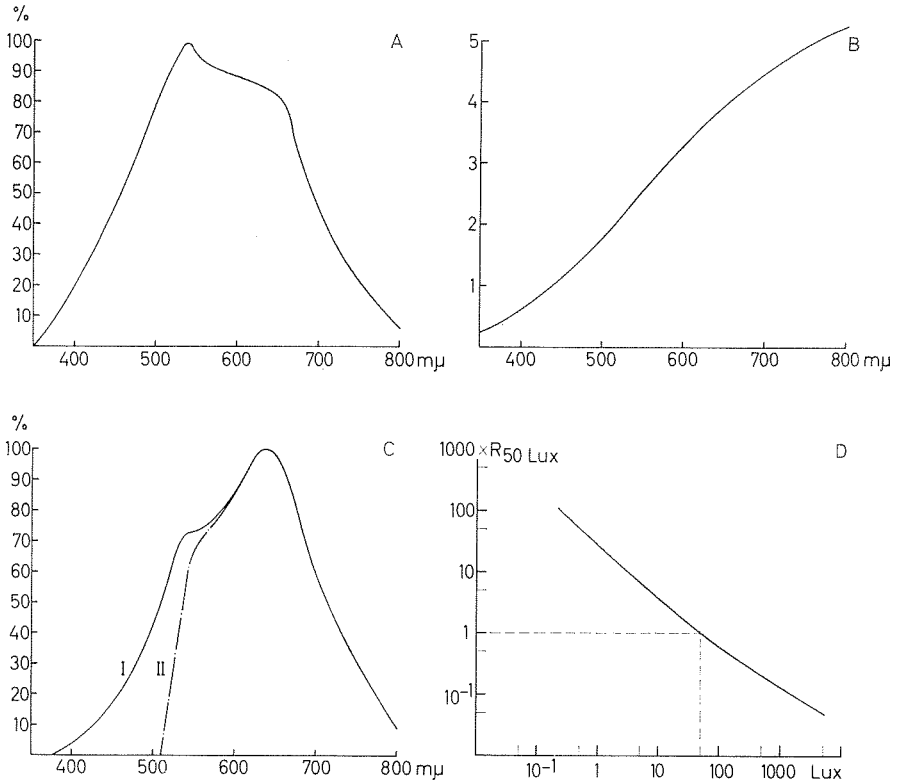
Fig. 3. Optical characteristics of the transparency meter. A) Spectral response of the PTW R III photo resistor. B) Spectral composition of the light source at 3100 K° C) Reaction spectrum of the transparency meter with the above photo detector and light source: I — without light filter, II — with Jena RGI filter. D) Response of the photo resistor to varying light intensities (I). The curve can closely be expressed by the equation: $\dfrac{R}{R_0} \approx I^{-f}$ where R_0 is the dark resistance and f a constant.

that the water transport through the instrument is less than the supply to the "bubble trap", the surplus water passing out through a second by-pass situated in the trap. Ordinarily the instrument is operated with a water supply of approximately 20 l/min.

A tap system on the "bubble trap" makes parallel sampling for other analyses possible, and the by-pass stream might also be used e.g. for net sampling of plankton. Except for the inlet walve, all tubes are made of alcathene plastic.

The transparency meter, (Fig. 1 and 2).

The cylinder, 1.5 m long and 10 cm in diameter, is made of clear perspex, closed at both ends by glass windows with waterproof gaskets.
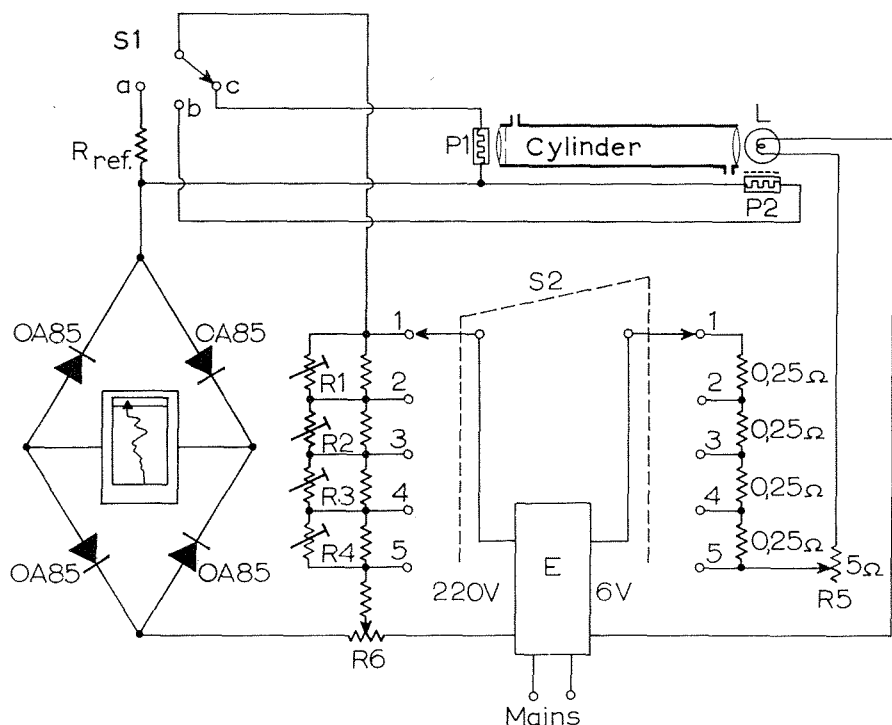
Fig. 4. The electronic circuit of the transparency meter. E stabilized a.c. power supply. L light source. P 1 photo detector. P 2 photo detector for control of light stability (adjustment at rheostat R5). R ref. reference resistor checking stability of the measuring circuit (adjustment at potentiometer R6). S 1 switch for selecting checkpoints (a and b) and automatic recording (c).

Its sloping position and the downward direction of the water current has been found suitable for reducing turbulent mixing and minimizing sedimentation of particles on the end window. Window wipers with waterproof fittings are mounted at both ends of the tube.

The light source (Fig. 2a) is an Osram 6 V, 5 A bulb in a Leitz Ortholux EUMZE housing. The spectral composition of its radiation at 3100° K (sensitivity range 5 on the instrument, Fig. 4) is given in Fig. 3b. A convex lens provides parallel light which can be accurately focused on the light detector by adjusting the movable lamp socket. A photo resistor for control of light stability is mounted on the lamp housing (Fig. 2a).

The light detector (Fig. 2b) consists of a convex lens, a pin hole diaphragma to remove non-parallel incident light and a PTW R III photo resistor. The spectral response of the photo resistor is shown in Fig. 3a. The sensitivity of the instrument with the above described light source will be in the red region of the spectrum (Fig. 3c I).
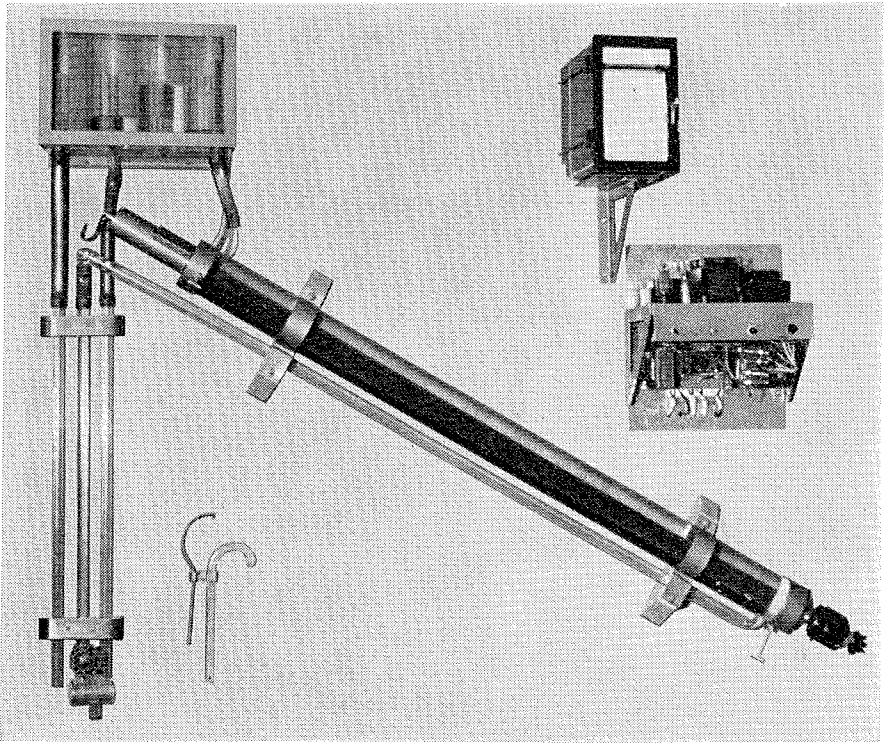
Fig. 5. A photograph showing the laboratory unit of a transparency meter made for FAO by Bergen Nautic.

Variations in the conductivity of the photo resistor, when the instrument is operated with a stabilized light source, are due to different transparency properties of the water. These variations are suitably recorded either by means of a millivolt potentiometric recorder or a bolomatic current recorder, connected to a full wave rectifying bridge, (D.C. currents tend to polarize the PTW R III photo resistors. Improved types of resistors without such tendencies are now available, however).

The response of the photo resistor to varying light intensities (Fig. 3d) demonstrates that the sensitivity of the instrument will be increased by a decrease in light. Different ranges of sensitivity can thus be obtained by an appropriate choice of the initial light intensity. In the present instrument five ranges have been obtained through four calibrated resistors which in turn can be switched in series with the light bulb. The electronics of the instrument is shown in Fig. 4.
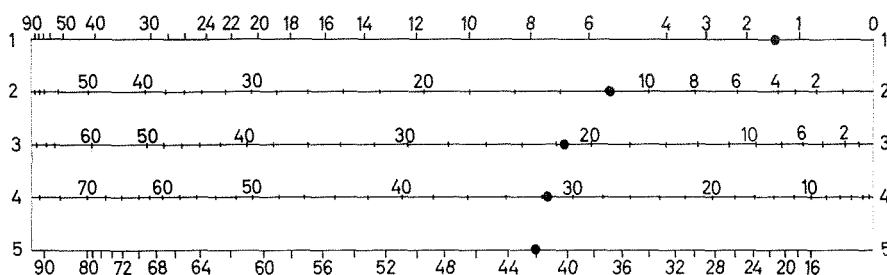
Fig. 6. Examples of the relative scales of partial extinction. Scale 1—5 corresponds to the 5 ranges of sensitivity in Fig. 4.

CALIBRATION

The primary aim with the present instrument is to record the effect (Δ a) on the extinction coefficient (a) by the suspended matter:

$$(1)\ \Delta a = a - a_o;$$

where a_o refers to the extinction coefficient of the medium when free of particles. Accordingly, the response of the transparency meter to varying consentrations of hydrosols was determined emperically. Hydrosols were prepared from distilled water with varying additions from a freshly made stock suspension of black china ink in water ($E_{4mm} = 1.0$ at $\lambda = 575$ mμ). One ml of this suspension in 10 l of distilled water was given the value of one. Examples of the relative scales thus obtained for the 5 ranges of sensitivity on the instrument are shown in Fig. 6.

When using the transparency meter for the relative evaluation of plankton concentrations or productivity, the above standardisation should be satisfactory. From Beer's law, however, it follows that the relative units (n) of the recorder are related to the light transmission of the suspensoids (ΔT) the following way:

$$(1)\ \Delta T = \frac{I_n}{I_o} = e^{-a.n.l}$$

where a is the extinction coefficient of the unit and l the length of cylinder. I_n and I_o are the light intensities transmitted by the suspension and the distilled water, respectively. By measuring the I_n of a suspension with the concentration n, and the I_o, ΔT as well as a can be determined. Such measurements have been made by replacing the photodetector with a selenium cell combined with a galvanometer. The responses on this instrument A_n and A_o are proportional to the light intensities:

$$(2)\ \frac{A_n}{A_o} = \frac{I_n}{I_o} = \Delta T$$

Since (3) $\Delta T = e^{-\Delta a.1}$ it follows that $\Delta a = a.n$. The relative units on the scales can thus be converted to the difference in extinction coefficient between the sample and distilled water.

EXAMPLES OF RECORDINGS

In Fig. 7 selected examples of recordings obtained by the transparency meter in a survey of the Icelandic Sea with R/V "Johan Hjort" are presented. The recordings are given in relative units of particle concentration (n). Large variations are revealed in some areas (Fig. 7c), whereas other areas demonstrate a rather even particle distribution (Fig. 7b). Based on recordings from a network of sections (Fig. 7a) a survey map of the Icelandic Sea was made. 45 chlorophyll measurements spread over the whole area and sampled from the transparency meter, were compared with the recordings. A high correlation factor of 0.81 was demonstrated (Berge—Rossi, unpublished).

DISCUSSION

The transparency meter has worked well in continous operation on cruises of up to four weeks duration. Regular use of the window wipers and inspection of the electronic and light stability using the control switches is the only attention required. In bad weather a reduction in the water flow might be necessary to secure a full clearing of the water entering the cylinder. With this precaution observations have been obtained in weather conditions where outdoor instrumentation would have failed.

The system of pumping water into the transparency meter causes a delay between intake and recording as the ship proceeds. By placing a by-pass system close to the transparency meter and using the full capacity of the pump, the delay has been minimized to correspond to a displacement of approximately 150 m. Also, due to mixing in the system, a smoothing of minor variations in the transmission properties of the water will occur. The details thus lost are assumed to be of minor interest for general oceanic surveys.

The nearly inverse relationship between the response to the light intensities (Fig. 3d), makes the photo resistor specially suited for transparency measurements, resulting in nearly equal responses to differences in the transmission in turbid as well as clear water. By selecting the appropriate initial light, any suited range of sensitivity can be very simply obtained. Interchangeable ranges can be introduced stepwise using neutral filters of various densities. However, a more convenient operation has been obtained by the electrical reduction of the lamp
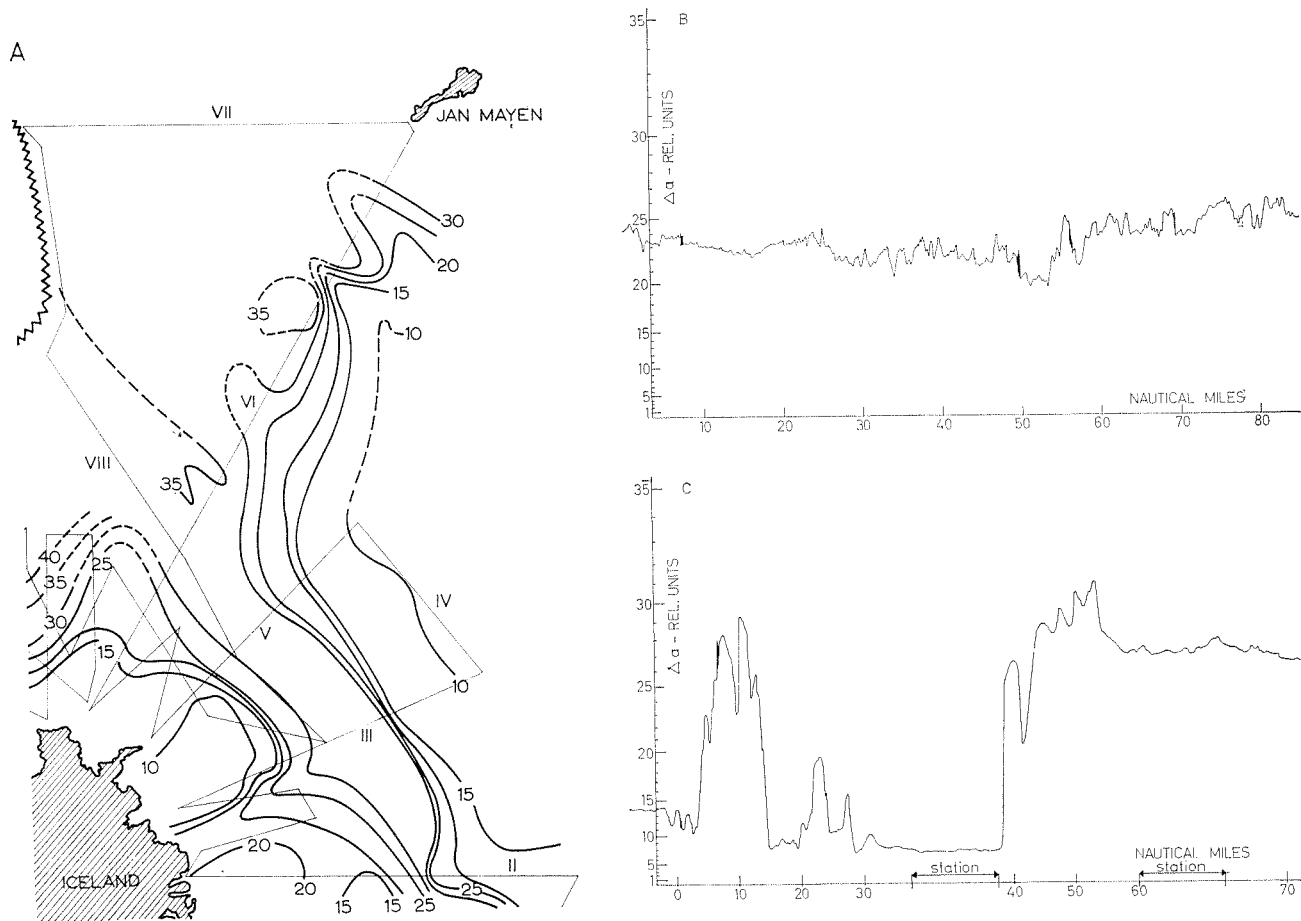
Fig. 7. Examples of a transparency meter survey of the Icelandic Sea. The map (A) was constructed from the sections (thin streight lines). In b and c selected examples of recordings are given to illustrate rather even (B) and uneven (C) distributio of particles.

current as shown in Fig. 5. The method involves a slight change in the light spectrum according to the temperature of the lamp filament. This change does not, however, seriously affect the spectral sensitivity of the instrument, the maximum peak at 645 mμ (Fig. 3c) being retained.

The calibration of the instrument as shown might easily be made using suitable absorbing solubles in known concentrations (Glover 1956). Since the scattering matrix of the suspended particles in the sea deviates from such solubles, a more valid calibration for particle tracing was assumed to be obtained by using suspensions similar to the actual particles in the sea as obsorbant. Lenoble (1961) used black colored polyvinyl chloride and acetate in water in reproducing the forward scattering of sea water, the hydrosols thus obtained containing even spherical particles varying in sizes between 0.2μ—75μ. China ink in water was assumed to be suitable for the special purposes required here, the ink forming uneven particles varying in sizes between 2μ—170μ, thus reproducing in size the dominating phytoplankton species in the Norwegian Sea (Paasche 1961).

With the spectral response curve obtained using the Osram 8110 bulb and the PTW photo resistor (Fig. 3c), the instrument will be negligably affected by the yellow substances according to the absorbance curve shown by Jerlow (1957). The pronounced sensitivity maximum at $\lambda = 645$ mμ, corresponds closely to the absorbance maximum by chloroplastic pigments present in the euphotic zone of the sea (Yentsch 1962) and thus increases the response of the instrument to autotrophic phytoplankton as compared with the main bulk of other particles present in the sea water.

The high correlations between transparency recordings and plankton concentrations observed in the Norwegian Sea, indicates that variations in Δ a recorded are mainly due to variations in the density of phytoplankton. The validity of the transparency recordings in plankton density indications is further supported by the close correlations with particulate organic matter observed by Joseph (1955). In coastal waters, estuaries with melting ice and areas with upwelling waters etc., the recordings will often probably be dominated by variations in inorganic particles similar to the findings by Wyrtki (1961) in the Coral and Solomon Seas, and as demonstrated by Joseph (loc. sit.) in selected localities of the North Sea.

It is concluded, however, that when properly used in connection with conventional methods of plankton determination, the transparency meter will afford detailed information about the relative density of phytoplankton, as well as primary productivity (Berge 1961). As demonstrated by the recordings in Fig. 6, the continuous information thus obtained reveals

variations and details which would have been lost by conventional point observations.

The convenient handling of the transparency meter and the large volume of data which becomes available make the instrument specially suitable for area surveys in fisheries oceanography.

ACKNOWLEDGEMENT

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