Beam Transmissometers for Oceanographic Measurements

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Abstract

The theoretical basis for the measurement of the beam transmittance of water is reviewed. Existing data for the beam transmittance of clean and distilled water are compared to demonstrate the current state of knowledge regarding the beam transmittance of clean water. Several recent instruments of sophisticated design are briefly described and data are given for surface particle concentration.

Introduction

The importance of optical measurements for studying the properties of particulate matter in the ocean has been demonstrated at both the theoretical and experimental levels. At the present time the theoreticians seem to have progressed further than have the experimentalists. This is due, perhaps, to the fact that the former enjoy certain simplifications not found in the real world; for example, they are able to work with spherical particles which, conveniently, refrain from multiple scattering. Further, the theoreticians never have the problem of an adequate and stable supply of radiant flux; there is never any time variability in the composition of their samples; and the measurement concepts they employ do not engage in mutual interference. The experimentalist, on the other hand, must deal with the real ocean and with the complex optical problems associated with its real burden of particulate matter. His job is to devise the instruments and measure the optical quantities defined by theory.

Each theoretically defined optical quantity confronts the ex-
perientalist with unique requirements for the control of the ra-
diant flux involved. There is almost always a gross mismatch be-
tween the spectral and geometrical emission properties of the avail-
able source of radiant flux and the properties required, by defi-
nition, for the measurement. Radiant flux that does not conform to
a definition from theory becomes spurious and must be eliminated.
Unfortunately, the techniques for eliminating spurious radiant flux
cannot be systematically organized, the procedures being more a
matter of recognizing the problem, locating the source of error,
and providing a solution. Failure to eliminate spurious radiant
flux easily leads to gross errors.

BEAM TRANSMISSOMETERS

The idea of measuring the transmittance of water by means of
a beam of light has been used (and abused) for many years. The
beam transmittance for exceptionally clean water is of special in-
terest since it represents a limiting case. In Figure 1, four of
the most widely referenced determinations of the total attenuation
coefficient for exceptionally clean water are compared. These data
have been computed directly from measurements of the beam transmis-
sion over long paths.

It is interesting that Clarke and James [1939] and James and
Berge [1938] used identical equipment in both studies with only
one modification: Clarke and James lined the sample tube with
ceresin wax, whereas James and Berge used a bright silver lining
in the tube. The implication of the data from the two studies is
consequently obvious. The silver lining acted to reflect much more
of the forward scattered light toward the photodetector resulting
in apparent high values of transmittance which, in turn, yielded
low and incorrect values for the attenuation coefficient in the
blue region of the spectrum where absorption is low. In the red
region of the spectrum the high absorption of water significantly
reduced this effect.

Sullivan [1963] and Hulburt [1945] both used glass tubes with
no internal baffles. In both of these cases there exists the very
real possibility that forward scattered light could have been re-
lected toward the photodetector by total internal reflection from
the walls of the glass tubing and, further, that the reported at-
tenuation coefficients in the blue region of the spectrum are still
too small for clean water.

In the phenomological theory of radiative transfer developed
by Preisendorfer [1960], the equation of transfer is given in the
form,

$$\frac{1}{V} \frac{d[N/n^2]}{dr} = -(a + s) \frac{N}{n^2} . $$

(1)

where

$$a \frac{N}{n^2}$$

is the absorption-loss term