Region 4
U.S. Environmental Protection Agency
Science and Ecosystem Support Division
Athens, Georgia

OPERATING PROCEDURE

Title: **Reaeration Measurement by Diffusion Dome**

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Revision History

The top row of this table shows the most recent changes to this controlled document. For previous revision history information, archived versions of this document are maintained by the SESD Document Control Coordinator on the SESD local area network (LAN).

History	Effective Date
SESDPROC-505-R3, *Reaeration Measurement by Diffusion Dome,* replaces SESDPROC-505-R2. **General:** Corrected any typographical, grammatical, and/or editorial errors. Throughout the document, the term "stream" was omitted. **Title Page:** Changed the EAB Chief from Bill Cosgrove to John Deatrick. Changed the FQM from Laura Ackerman to Bobby Lewis. **Revision History:** Changes were made to reflect the current practice of only including the most recent changes in the revision history **Section 1.2:** Added the following statement to the first paragraph: "Mention of trade names or commercial products in this operating procedure does not constitute endorsement or recommendation for use." In the second paragraph, "stream" was replaced with "water body." **Section 3.2:** In the first paragraph, the second and third sentence was combined. Added EAB acronym in the first sentence of second paragraph. Omitted the second sentence in the second paragraph and replaced it with the following language: "Currently, EAB uses a luminescent (LDO) probe connected to a digital display but other technologies are available and can be utilized." **Section 4.1**: Omitted the last sentence in the first paragraph. Replaced "every 15 – 30 minutes" with "concurrent with monitoring data readings" in the second sentence of the fourth paragraph.	May 30, 2013
SESDPROC-505-R2, *Reaeration Measurement by Diffusion Dome,* replaces SESDPROC-505-R1.	November 6, 2009
SESDPROC-505-R1, *Reaeration Measurement by Diffusion Dome,* replaces SESDPROC-505-R0.	November 1, 2007
SESDPROC-505-R0, *Reaeration Measurement by Diffusion Dome,* Original Issue	February 05, 2007

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1 General Information

1.1 Purpose

The purpose of this operating procedure is to document both general and specific methods and considerations to be used when measuring reaeration using a diffusion dome.

1.2 Scope/Application

This document describes both general and specific methods to be used by field investigators when obtaining data for the purposes of determining reaeration using a diffusion dome. In the event that Science and Ecosystem Support Division (SESD) field investigators determine that any of the procedures described in this section are either inappropriate, inadequate or impractical for a given site or station or that another procedure must be used to obtain a representative measurement, the variant procedure will be documented in the field log book, along with a description of the circumstances requiring its use. Mention of trade names or commercial products in this operating procedure does not constitute endorsement or recommendation for use.

Reaeration is the rate at which atmospheric oxygen diffuses across the air-water interface of the surface of a water body.

1.3 Documentation/Verification

This procedure was prepared by persons deemed technically competent by SESD management, based on their knowledge, skills and abilities and has been tested in practice and reviewed in print by a subject matter expert. The official copy of this procedure resides on the SESD local area network (LAN). The Document Control Coordinator (DCC) is responsible for ensuring the most recent version of the procedure is placed on the LAN and for maintaining records of review conducted prior to its issuance.

1.4 References

American Public Health Association (APHA), American Waterworks Association (AWWA), and the Water Environment Federation (WEF). 1998. Standard Methods for the Examination of Water and Wastewater, 20th Edition. Washington, D.C.

Buck, A. L. 1981. New Equations for Computing Vapor Pressure and Enhancement Factor. National Center for Atmospheric Research. Boulder, Colorado.

Cavinder. 2002. Reaeration Rate Determination with a Diffusion Dome. United States Environmental Protection Agency, Region 4 Science and Ecosystem Division, Ecological Assessment Branch.

Chapra, S.C. and Canale R.P. 1998 Numerical Methods for Engineers With Programming and Scientific Applications. The McGraw-Hill Companies, Inc., New York.

Copeland, B.J. and Duffer, W.R. 1963. Use of a Clear Plastic Dome to Measure Gaseous Diffusion Rates in Natural Waters. Limnol. Oceanogr. 9:494-499.

Juliano, D. W. 1969. Reaeration Measurements in an Estuary. Journal of the Sanitary Engineering Division, ASCE. 95(SA6):1165-1178.

SESD Operating Procedure for Logbooks, SESDPROC-010, Most Recent Version.

SESD Operating Procedures for Measurement of Dissolved Oxygen, SESDPROC-106, Most Recent Version.

SESD Operating Procedure for Global Positioning System, SESDPROC-110, Most Recent Version.

SESD Operating Procedure for *In situ* Water Quality Monitoring, SESDPROC-111, Most Recent Version.

SESD Operating Procedure for Reaeration Measurement using Krypton Gas, SESDPROC-506, Most Recent Version.

USEPA. Safety, Health and Environmental Management Program Procedures and Policy Manual. Science and Ecosystem Support Division, Region 4, Athens, Georgia. Most Recent Version.

1.5 General Precautions

1.5.1 Safety

Proper safety precautions must be observed when conducting reaeration studies. Refer to the SESD Safety, Health and Environmental Management Program Procedures and Policy Manual and any pertinent site-specific Health and Safety Plans (HASP) for guidelines on safety precautions. These guidelines, however, should only be used to complement the judgment of an experienced professional. For example, these methods may be employed during periods of high stream flow or in conjunction with boating operations.

1.5.2 Procedural Precautions

The following precautions should be considered when conducting reaeration measurements studies:

- All instrumentation should be in good condition and operating within the manufacturer's recommended tolerances.
- All instrumentation should be calibrated and deployed in accordance with the manufacturer's requirements.

2 Special Sampling Considerations

2.1 Quality Control

The reaeration rate coefficient is expressed as a rate in 1/day corrected to 20° Celsius (C). Dissolved oxygen (DO) meters should be calibrated according to SESD Operating Procedure for Field Measurement of Dissolved Oxygen (SESDPROC-106).

2.2 Records

Information generated or obtained by SESD field investigators will be organized and accounted for in accordance with SESD records management procedures. Field notes, recorded in a bound field logbook, in accordance with SESD Operating Procedure for Logbooks (SESDPROC-010), will be generated, as well as chain-of-custody documentation. All measurements shall be thoroughly documented in field records. All measurements shall be traceable to the personnel making the measurements and the equipment utilized.

3 General Considerations

3.1 General

The techniques and equipment described in Section 4 of this procedure document are designed to provide representative measurements of reaeration rates. Care should be applied in the selection of measurement sites and/or reaches to ensure personnel and equipment safety.

Highly productive waters may cause ambient DO to rise significantly during the day. If it is known ahead of time that this may be the case, diffusion dome measurements may be conducted at night or in the late evening/early morning, as safety considerations allow, to minimize ambient DO changes associated with algal production.

3.2 Equipment Selection Considerations

Diffusion domes currently in use are constructed of stainless steel fitted with a ring of foam insulation for floatation. The domes have two inlet/outlet ports for purging of the dome volume and each dome is equipped with a spinning baffle on a post running through the dome to allow external manual operation. In addition, each dome has an internal bracket to hold a DO probe and external brackets for securing cooling water tubing which is supplied by a submersible pump.

Ecological Assessment Branch (EAB) diffusion domes are custom designed to hold a DO probe without a stirrer. Currently, EAB uses a luminescent (LDO) probe connected to a digital display but other technologies are available and can be utilized. A digital display is preferable in low turbulence systems to better define small changes in DO through the measurement period.

The dome number and DO meter serial number or other identifier should be recorded in the field log book. For DO meters, the log book should include a notation indicating which meter was used in the dome and which provided ambient data.

If measurements are made in a saline environment, a salinometer or other instrumentation should be deployed to allow for correction of dissolved oxygen measurements.

4 Diffusion Dome Reaeration Measurement

The determination of the reaeration rate coefficient is a measure of the rate at which atmospheric oxygen can move across the air water interface. This is a measure of the rate of potential oxygen transfer. The actual quantity of oxygen transferred to the water column is a function of the water column dissolved oxygen deficit and the reaeration rate coefficient.

The diffusion dome technique for measuring reaeration is based on the work of Copeland and Duffer (1963) and Juliano (1969). In general, the method involves purging the volume of a floating dome with nitrogen gas and monitoring the recovery of oxygen within the dome. While applicable to most systems, this method is especially useful in areas where the gas tracer method (SESDPROC-506) may not feasible (e.g., very shallow streams or large water bodies) or too resource intensive. Where site conditions allow, the dome should be free-floating in the water body. Usually, the dome is tethered to an unanchored boat to allow the field crew access to the dome for purging and mixing during the float. If necessary, based on the site, a "static" float may be conducted, where the dome is tethered to a stationary object.

4.1 Field Measurement Method

The diffusion dome method requires two DO meters. One meter is installed inside the dome to measure DO and temperature in the dome air space. The second meter is used to measure ambient water column DO and temperature. The ambient DO probe should be located just below the water surface, deep enough to represent the entire water column for a non-stratified system. If DO probes are equipped with attachable stirrers, the stirrer should be installed on the ambient probe, but not on the dome probe. The dome is equipped with a manual baffle for circulating air inside the dome.

Once the DO probe is installed in the dome, the dome is placed on the water surface and the nitrogen gas line is connected to an inlet valve on the dome. The circulation pump should then be place in the water and started and DO/temperature monitoring initiated. The ambient probe is deployed in the water column and ambient DO, temperature and salinity (if appropriate) are also monitored. The temperature inside the dome should stabilize relatively close to the ambient temperature before purging is conducted. Based on the ambient data, the DO deficit is calculated and the dome is purged with nitrogen to create a DO deficit between the water column and the dome atmosphere which approximates the water column DO deficit. If a method for calculating the deficit has not been predetermined, the following example method may be used.

Example Deficit Calculation:

Ambient DO - DO Saturation Concentration = Deficit

Where:

DO Saturation Concentration = $0.0035T^2 - 0.3369T + 14.407$

Then:

Ambient DO – Deficit = Dome Purged DO Value

Ambient and dome monitoring data should be recorded at 15 minute or more frequent intervals throughout the measurement period. If possible, monitoring should continue for a period sufficient to recover at least 5% of the initial DO deficit imposed in the dome. Depending on the magnitude of the deficit and environmental conditions affecting the measurement (e.g., debris blocking channel, rapids affecting dome seal), a 5% recovery may not be possible. In such cases, the measurement should continue for a minimum of 30 minutes or until conditions prevent continued monitoring. Locational data (latitude/longitude) and depth should also be recorded concurrent with monitoring data readings, in accordance with SESD Operating Procedure for Global Positioning System (SESDPROC-110).

Wind data should always be collected during diffusion dome measurements on open water bodies (e.g., lakes, estuaries) and may be desirable on river or stream systems. Wind speed from a hand-held wind meter should be recorded, concurrent with monitoring data readings, with an approximation of wind direction. Alternatively, a weather station or stationary logging wind meter deployed in the study area can provide wind data. If the hand held meter or weather station is so equipped, barometric pressure should also be recorded.

The circulation pump helps maintain a constant temperature in the dome and should be checked frequently throughout the diffusion measurement period. If temperatures rise significantly even with proper operation of the circulation pump, the dome should be shaded and/or a small amount of ice placed on top of the dome.

4.2 Reaeration Rate Coefficient Calculation

Following field data collection, a reaeration rate coefficient is calculated for each diffusion measurement period and corrected to a base temperature of 20°C as follows:

The amount of oxygen diffused into the dome, D, during the test is represented by:

$$\textbf{(1) } D\ (g/m^3/hr) = \frac{(V)(32\ g/mole)(0.0446\ moles/liter)}{(CA)(t)(Z)}$$

where V = change in volume of O_2 in chamber (liters),
CA = diffusion Dome area at water-surface interface (meters $[m]^2$)
t = period of measurement (hours)
Z = average depth of unstratified water column (m)

The change in O_2 chamber volume, V, is calculated as follows:

$$\textbf{(2) } V \text{ (liters)} = \{(273.15V_1)/(273.15 + T_1) - (273.15V_0)/(273.15 + T_0)\}(CV)(f)$$

where V_1 = final dome DO as percent saturation (as fraction)
V_0 = initial dome DO as percent saturation (as fraction)
T_1 = final temperature in dome (^oC)
T_0 = initial temperature in dome (^oC)
CV = dome (chamber) volume (liters)
f = % O_2 in ambient atmosphere (atm) (as fraction)

$$f = \frac{0.2095(P - P_{wv})}{P}$$

where P = barometric pressure (atm)
P_{wv} = water vapor partial pressure (atm)

When barometric pressure is not available, local pressure, P, can be estimated from altitude and air temperature as:

$$P = \{(273.15T - 0.0065Z)/(273.15T)\}^{5.2559}$$

where T = ambient temperature (^oC)
Z = local elevation (m)

When water vapor partial pressure is not available, P_{wv}, can be estimated by the Arden Buck Equation:

$$P_{wv} \text{ (hPa)} = 6.1121\exp\{(17.502T)/(240.97+T)\}$$

where T = ambient temperature (^oC)
1 (hPa) = 9.8692 e -4 (atm)

The reaeration rate, K_a (Base e), is then calculated as:

$$\textbf{(3)} \quad K_a \text{ (1/day)} = \frac{(D)(24 \text{ hrs/day})}{(S_{def})(C_s)}$$

where D = oxygen diffusion from equation 1 ($g/m^3/hr$)

S_{def} = average saturation deficit between dome and water column (as fraction)
= {1 – (average dome DO/average water column DO)}
C_s = average water column saturation DO (g/m^3)

The reaeration rate, K_a (Base e, @ 20 ^oC), is then calculated as:

(4) K (1/day) = (1.024)^(20 – T_a)

where T_a = average ambient temperature (^oC)