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2–06

Measurement of Oxygen Transfer in Clean Water

This document uses both the
International System of Units (SI)
and customary units

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American Society of Civil Engineers

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STANDARDS

In 2003, the Board of Direction approved the revision to the ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by the Society. All such standards are developed by a consensus standards process managed by the Society's Codes and Standards Committee (CSC). The consensus process includes balloting by a balanced standards committee made up of Society members and nonmembers, balloting by the membership of the Society as a whole, and balloting by the public. All standards are updated or reaffirmed by the same process at intervals not exceeding five years.

The following standards have been issued:

ANSI/ASCE 1-82 N-725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures
ASCE/EWRI 2-06 Measurement of Oxygen Transfer in Clean Water
ANSI/ASCE 3-91 Standard for the Structural Design of Composite Slabs and ANSI/ASCE 9-91 Standard Practice for the Construction and Inspection of Composite Slabs
ASCE 4-98 Seismic Analysis of Safety-Related Nuclear Structures
Building Code Requirements for Masonry Structures (ACI 530-02/ASCE 5-02/TMS 402-02) and Specifications for Masonry Structures (ACI 530.1-02/ASCE 6-02/TMS 602-02)
ASCE/SEI 7-05 Minimum Design Loads for Buildings and Other Structures
SEI/ASCE 8-02 Standard Specification for the Design of Cold-Formed Stainless Steel Structural Members
ANSI/ASCE 9-91 listed with ASCE 3-91
ASCE 10-97 Design of Latticed Steel Transmission Structures
SEI/ASCE 11-99 Guideline for Structural Condition Assessment of Existing Buildings
ASCE/EWRI 12-05 Guideline for the Design of Urban Subsurface Drainage
ASCE/EWRI 13-05 Standard Guidelines for Installation of Urban Subsurface Drainage
ASCE/EWRI 14-05 Standard Guidelines for Operation and Maintenance of Urban Subsurface Drainage
ASCE 15-98 Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)
ASCE 16-95 Standard for Load Resistance Factor Design (LRFD) of Engineered Wood Construction
ASCE 17-96 Air-Supported Structures
ASCE 18-96 Standard Guidelines for In-Process Oxygen Transfer Testing
ASCE 19-96 Structural Applications of Steel Cables for Buildings
ASCE 20-96 Standard Guidelines for the Design and Installation of Pile Foundations
ANSI/ASCE/T&DI 21-05 Automated People Mover Standards—Part 1
ASCE 21-98 Automated People Mover Standards—Part 2
ASCE 21-00 Automated People Mover Standards—Part 3
SEI/ASCE 23-97 Specification for Structural Steel Beams with Web Openings
ASCE/SEI 24-05 Flood Resistant Design and Construction
ASCE/SEI 25-06 Earthquake-Actuated Automatic Gas Shutoff Devices
ASCE 26-97 Standard Practice for Design of Buried Precast Concrete Box Sections
ASCE 27-00 Standard Practice for Direct Design of Precast Concrete Pipe for Jacking in Trenchless Construction
ASCE 28-00 Standard Practice for Direct Design of Precast Concrete Box Sections for Jacking in Trenchless Construction
ASCE/SEI/SFPE 29-05 Standard Calculation Methods for Structural Fire Protection
SEI/ASCE 30-00 Guideline for Condition Assessment of the Building Envelope
SEI/ASCE 31-03 Seismic Evaluation of Existing Buildings
SEI/ASCE 32-01 Design and Construction of Frost-Protected Shallow Foundations
EWRI/ASCE 33-01 Comprehensive Transboundary International Water Quality Management Agreement
EWRI/ASCE 34-01 Standard Guidelines for Artificial Recharge of Ground Water
EWRI/ASCE 35-01 Guidelines for Quality Assurance of Installed Fine-Pore Aeration Equipment
CI/ASCE 36-01 Standard Construction Guidelines for Microtunneling
SEI/ASCE 37-02 Design Loads on Structures During Construction
CI/ASCE 38-02 Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data
EWRI/ASCE 39-03 Standard Practice for the Design and Operation of Hail Suppression Projects
ASCE/EWRI 40-03 Regulated Riparian Model Water Code
ASCE/SEI 41-06 Seismic Rehabilitation of Buildings
ASCE/EWRI 42-04 Standard Practice for the Design and Operation of Precipitation Enhancement Projects
ASCE/SEI 43-05 Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities
ASCE/EWRI 44-05 Standard Practice for the Design and Operation of Supercooled Fog Dispersal Projects
ASCE/EWRI 45-05 Standard Guidelines for the Design of Urban Stormwater Systems
ASCE/EWRI 46-05 Standard Guidelines for the Installation of Urban Stormwater Systems
ASCE/EWRI 47-05 Standard Guidelines for the Operation and Maintenance of Urban Stormwater Systems
ASCE/SEI 48-05 Design of Steel Transmission Pole Structures

FOREWORD

This standard is a revision of the June 1992 standard and represents the current consensus of the ASCE Committee on Oxygen Transfer Standards after five years of monitoring the original standard.

Preparation of a standard general enough to be applied to all clean water unsteady-state tests and specific enough to incorporate all essential procedures was difficult. Users of this standard must give particular attention to use of the mandatory “shall” and advisory “should” terms. For particular applications of this standard, it may be advantageous for the user to elevate certain advisory steps to the mandatory level. The body of this standard is supplemented with Annexes and a Commentary, which follow the text. The Annexes provide *mandatory* information and include material that is an essential part of the standard but is too lengthy to place in the text. The Commentary that follows the Annexes provides *nonmandatory* information to supplement the standard. The Commentary is not a part of the standard.

It is intended that this standard be used by engineers in the preparation of specifications for compliance testing. When this is the case, the engineer should consider the costs of requiring extensive compliance testing in relation to the initial cost of the oxygen transfer system and present worth of future operating costs.

The substance of this standard is based on recommendations made in the report, “Development of Standard Procedures for Evaluating Oxygen Transfer Devices,” by the ASCE Oxygen Transfer Standards Subcommittee, Michael K. Strenstrom, Chairman. The user is referred to this document, which contains Refs. [1] to [4], Ref. [5] for background information, and Ref. [6] for a report on accuracy and precision of the method.

Formulas given in parentheses throughout the standard are for use with SI units.

ACKNOWLEDGMENTS

The American Society of Civil Engineers acknowledges the devoted efforts of the Committee on Oxygen Transfer Standards of the Special Standards Division. This group comprises individuals from many backgrounds, including consulting engineering, research, education, wastewater equipment manufacturing, government, industry, and private practice.

The contributions of U.S. EPA for workshops and for laboratory and field studies that supported the development and refinement of this standard are gratefully acknowledged.

This standard was formulated through the consensus standards process by balloting in compliance with procedures of ASCE's Codes and Standards Activities Committee. Those individuals who serve on the Standards Committee are:

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Annexes

Commentary

Measurement of Oxygen Transfer in Clean Water

1.0 SCOPE

This method covers the measurement of the oxygen transfer rate (OTR) as a mass of oxygen per unit time dissolved in a volume of water by an oxygen transfer system operating under given gas rate and power conditions. Methods for measurement of gas rate and power are also described in the Annexes A and B, respectively. The method is applicable to laboratory-scale oxygenation devices with small volumes of water as well as the full-scale system with water volumes typical of those found in the activated sludge wastewater treatment process. The procedure is valid for a wide variety of mixing conditions.

The primary result of this test is expressed as the standard oxygen transfer rate (SOTR), a hypothetical mass of oxygen transferred per unit of time at zero dissolved oxygen concentration, water temperature of 20°C, and barometric pressure of 1.00 atm (101.3 kPa) under specified gas rate and power conditions. The method is intended primarily for clean water meeting the requirements of Sections 5.2 and 6.3. The results can be applied to estimate oxygen transfer rate in process water as described in Commentary G.

2.0 SUMMARY OF METHOD

The test method is based upon removal of dissolved oxygen (DO) from the water volume by sodium sulfite followed by reoxygenation to near the saturation level. The DO inventory of the water volume is monitored during the reaeration period by measuring DO concentrations at several determination points selected to best represent tank contents. These DO concentrations may be either sensed in situ using membrane probes or measured by the Winkler or probe method applied to pumped samples. The method specifies a minimum number, distribution, and range of DO measurements at each determination point.

The data obtained at each determination point are then analyzed by a simplified mass transfer model to estimate the apparent volumetric mass transfer coefficient, $K_L a$ and the steady-state DO saturation concentration, C^*_∞. The basic model is described in Ref. [1] and is given by

$$C = C^*_\infty - (C^*_\infty - C_0)\exp(-K_L at) \qquad \text{(Eq. 2-1)}$$

where

C = DO concentration, mL^{-3};
C^*_∞ = determination point value of the steady-state DO saturation concentration as time approaches infinity, mL^{-3};
C_0 = DO concentration at time zero, mL^{-3};
$K_L a$ = determination point value of the apparent volumetric mass transfer coefficient, t^{-1}, defined so that
$K_L a$ = rate of mass transfer per unit volume$/(C^*_\infty - C)$.

Throughout this standard, the terminology for units will be shown as follows: m = mass units, l = length units, f = force units, and t = time units.

Nonlinear regression is employed to fit Eq. (2-1) to the DO profile measured at each determination point during reoxygenation. In this way, estimates of $K_L a$ and C^*_∞ are obtained at each determination point. These estimates are adjusted to standard conditions, and the standard oxygen transfer rate (mass of oxygen dissolved per unit time at a hypothetical concentration of zero DO) is obtained as the average of the products of the adjusted determination point $K_L a$ values, the corresponding adjusted determination point C^*_∞ values, and the tank volume. Recent developments that have the potential to be recognized in a future edition of this standard appear in Commentary A.

3.0 SIGNIFICANCE AND LIMITATIONS

Oxygen transfer rate measurements are useful for comparing the performance and energy efficiency of oxygenation devices operating in clean water. However, performance of these devices in process water may significantly differ from the performance in clean water, and the amount of difference will depend on the device, on how it is applied, and on the nature of the process water.