



**American Water Works
Association**

The Authoritative Resource on Safe Water®

ANSI/AWWA B110-09
(First Edition)

AWWA Standard

Membrane Systems



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Foreword

This foreword is for information only and is not a part of ANSI/AWWA B110-09.

I. Introduction.

I.A. *Background.* The purpose of ANSI/AWWA B110 is to provide purchasers with a standard for the purchase and installation of membrane treatment systems.

A wealth of information about membrane systems and their design is available from various sources, including *Journal AWWA*, *Water Treatment Plant Design*,[†] *Water Quality and Treatment*,[‡] and references listed in appendix A.

I.B. *History.* Membranes have been used to purify water using electrodialysis since the 1950s and reverse osmosis since the late 1960s.[§] Membrane technology has been and continues to be developed, improved, and widely applied in a myriad of water purification applications, including producing potable water from seawater, brackish water, groundwater, and surface water sources. Today, potable water production with membrane technology is widely accepted and practiced worldwide.

The potential for membranes in the production of potable water was already well-proven when the United States Environmental Protection Agency (USEPA) promulgated the Surface Water Treatment Rule (SWTR), which allowed the states to accept and permit alternatives to conventional granular media filtration. Pilot studies conducted during the development of the SWTR led to the acceptance of the first microfiltration (MF) and ultrafiltration (UF) membrane installations for microbial removal credit in the mid 1990s. Today, numerous utilities throughout the United States and globally have installed membrane systems for potable water and reclaimed water applications, and the number is on an upward growth curve. Utilities in the United States and Canada routinely consider membrane systems as treatment methods.

Membranes are made from a variety of polymeric and inorganic materials, although polymeric varieties currently dominate. New membrane materials, structures, and surface treatments are being developed. Comparison between membrane performance parameters must carefully consider the test conditions, because they have a marked effect on results. Membrane separation performance is specified by a variety of measures, including salt and/or specific solute rejection, molecular weight cutoff, nomi-

* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

† *Water Treatment Plant Design*, 4th Ed., AWWA and ASCE, McGraw-Hill (2005).

‡ *Water Quality & Treatment*, 5th Ed., AWWA, McGraw-Hill (1999).

§ *Water Desalting Planning Guide for Water Utilities*. John Wiley & Sons, Inc. (2004).

nal and absolute pore sizes, and bubble point, all within the context of specific test conditions. Measurement of membrane performance including separation and output are not standardized by regulatory agencies. However, some standards groups have published standardized measurement methods, and the industry has developed common and accepted approaches. This is one of the purposes of the testing requirements outlined in the USEPA *Membrane Filtration Guidance Manual* (USEPA 2005) associated with the Long Term 2 Enhanced Surface Water Treatment Rule (USEPA 2006).

Regulatory concerns may or may not be the primary drivers for the use of membranes by a municipality, but in all cases the regulations must be assessed for applicability. At present, US federal drinking water standards covering membrane treatment deal mainly with how much removal credit can be received from its use as a “microbial barrier.” Such other issues as acceptable water contact materials and meeting the primary and secondary contaminant levels in the finished water may also apply. It is likely more regulatory issues will be developed.

This membrane standard is intended to aid utilities in the selection and procurement of membrane filtration systems and in the regulatory permitting process. This standard should be considered as a list of minimum requirements for planning, procurement, selection, construction, and commissioning of a membrane-based treatment system. However, its proper application requires that it be coupled with a thorough professional review of the specific water treatment case and site-specific conditions.

The AWWA Standards Council authorized a new AWWA standard for membrane systems on Sept. 10, 2004, and assigned the task of development to the AWWA Standards Committee on Membrane Standards.

This first edition of the new standard ANSI/AWWA B110-09, Membrane Systems, was approved by the AWWA Board of Directors on June 14, 2009. The standard was approved and promulgated in the course of the activities of the AWWA Standards Committee on Membrane Standards.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency entered into a cooperative agreement with a consortium led by NSF International* (NSF) to develop voluntary third-party consensus standards and a certification program for direct and indirect drinking water additives. Other members of the original consortium included the Water Research Foundation and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works

* NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48105.

Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.* Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

1. Specific policies of the state or local agency.
2. Two standards developed under the direction of NSF: NSF/ANSI[†] 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI 61, Drinking Water System Components—Health Effects.
3. Other references, including AWWA standards, *Food Chemicals Codex*, *Water Chemicals Codex*,[‡] and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with NSF/ANSI 60 and 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

II. Special Issues. There is no consensus of opinion among academic, scientific, applied engineering, and regulatory practitioners for the precise definitions of reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF). The definitions and typical membrane characteristics of the membrane types shown in this standard are considered applicable to this standard and its use.

III. Use of this Standard. It is the responsibility of the user of an AWWA standard to determine that the products described in that standard are suitable for use in the particular application being considered.

III.A. Purchaser Options and Alternatives. The following items should be covered by the purchaser:

1. Standard used, that is, ANSI/AWWA B110, Membrane Systems, of latest revision.
2. Details of other federal, state or provincial, and local requirements (Sec. 4.1.1).

* Persons outside the United States should contact the appropriate authority having jurisdiction.

† American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

‡ Both publications available from National Academy of Sciences, 500 Fifth Street, NW, Washington, DC 2001.

3. Whether compliance with other standards, rules, or regulations in addition to the requirements of the Safe Drinking Water Act are required (Sec. 4.6.4).

4. Whether compliance with NSF/ANSI 60/61, Drinking Water Treatment Chemicals/System Components—Health Effects, is required (Sec. 4.6.4.1 and 4.6.4.2).

5. Affidavit of compliance, if required (Sec. 6.4).

III.B. *Modification to Standard.* Any modification to the provisions, definitions, or terminology in this standard must be provided by the purchaser.

IV. Major Revisions. This is the first edition of this standard.

V. Comments. If you have any comments or questions about this standard, please call the AWWA Volunteer and Technical Support Group at 303.794.7711, FAX at 303.795.7603, write to the group at 6666 West Quincy Avenue, Denver, CO 80235-3098, or e-mail the group at standards@awwa.org.



**American Water Works
Association**

AWWA Standard

Membrane Systems

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard sets minimum requirements for microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), reverse osmosis (RO), electrodialysis (ED), and electrodialysis reversal (EDR) membrane systems for water and reclaimed water treatment systems.

Sec. 1.2 Purpose

The purpose of this standard is to provide a minimum set of requirements for membrane systems used for water and reclaimed water treatment systems. This standard is intended to assist with the design, procurement, installation, and commissioning of membrane systems.

Sec. 1.3 Application

This standard can be referenced for design, procurement, installation, and commissioning of membrane systems used for water and reclaimed water treatment systems.

SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, they form a part of this standard to the extent specified within the standard. In any case of conflict, the requirements of this standard shall prevail.

American Public Health Association (APHA), American Water Works Association (AWWA), Water Environment Federation (WEF). *Standard Methods for the Examination of Water and Wastewater*.

ASTM* D4189-07, Standard Test Method for Silt Density Index (SDI) of Water.

ASTM D6908, Standard Practice for Integrity Testing of Water Filtration Membrane Systems.

NSF†/ANSI‡ 60—Drinking Water Treatment Chemicals—Health Effects.

NSF/ANSI 61—Drinking Water System Components—Health Effects.

US Environmental Protection Agency,§ November 2005. *Membrane Filtration Guidance Manual*. Office of Water, EPA 815-R-06-009, Washington, D.C.

US Environmental Protection Agency, January 2006. Long Term 2 Enhanced Surface Water Treatment Rule. 71 FR 653–702. Washington, D.C.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Air scour*: Distributing air to a membrane surface to improve the effectiveness of filtration or backwashing.
2. *Air scrub*: Air scour during backwash. *See* air scour.
3. *Anion membrane (anion transfer or selective membrane)*: A membrane through which only anions (negatively charged ions) will transfer, generally related to ED/EDR.
4. *Anode (positive electrode)*: The electrode that attracts anions (negatively charged ions), generally related to ED/EDR.

* ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

† NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48105.

‡ American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

§ US Environmental Protection Agency, Office of Water (4101M), 1200 Pennsylvania Avenue, NW, Washington, DC 20460.

5. *Applied pressure*: For a membrane train, feed hydraulic pressure minus permeate and/or filtrate hydraulic pressure. *See also* transmembrane pressure (TMP).

6. *Array*: An arrangement of devices, such as pressure vessels containing spiral-wound elements, connected to common feed, permeate, and concentrate headers. Typically expressed as the ratio of the number of devices that operate in parallel. For example, the feed flow in a 20:10 RO membrane array initially flows to 20 parallel vessels in the first stage and the concentrate from the first stage, flows as feed to the 10 parallel vessels in the second stage.

7. *Backwash (BW)*: An operation in which a water stream of relatively high quality (generally filtrate) is directed through a membrane in a flow direction opposite to normal filtration service flow to remove collected solids from the membrane surface, generally MF/UF. Air is used in some cases to aid in the backwash process (i.e., air scour) or for backflow through the membrane in lieu of water.

8. *Beta value*: For spiral-wound RO/NF, a design parameter indicating the ratio of total dissolved solids concentration at the membrane surface to its concentration in the bulk feed stream.

9. *Block*: *See* unit.

10. *Brackish water*: Water with an approximate concentration of total dissolved solids ranging from 500 to 10,000 mg/L. Related terms: highly brackish water, seawater.

11. *Brine*: A concentrated salt solution; a term sometimes used in this standard interchangeably with *concentrate* for membranes that remove dissolved ions. *See* concentrate.

12. *Bubble point*: Pressure differential at which bubbles first appear on the surface of a membrane in a fluid as gas pressure is applied to the other side.

13. *Cation membrane or cation transfer selective membrane*: A membrane through which only cations (positively charged ions) will transfer, generally related to ED/EDR.

14. *Cell pair*: Repetitive section of a membrane stack consisting of a cation membrane, a demineralized water flow spacer, an anion membrane, and a concentrate water flow spacer, generally related to ED/EDR.

15. *Challenge test*: A study conducted to determine the removal efficiency or log removal value of a membrane material for a particular organism, particulate, or surrogate.

16. *Chemical cleaning*: An operation to clean the membrane material using chemical solution(s) and typically having a duration longer than 60 min and less than 12 hr.

17. *Chemical wash (CW)*: A short-duration operation to clean the membrane material in place, using chemical solution(s), that has a total off-line duration of less than 60 min.

18. *Chemically enhanced backwash (CEB)*: Backwash with chemical addition.

19. *Clean-in-place (CIP)*: A common type of membrane cleaning process using a chemical cleaning system in which membrane elements are cleaned without moving them from their normal service location.

20. *Cleaning*: An operation during which a membrane is cleaned using a membrane cleaning system.

21. *Concentrate*: The stream exiting a membrane device, which has increased concentrations of solutes and/or particles compared with the feed stream. For a pressure-driven crossflow device, the portion of the feed stream that does not pass through the membrane. For drinking water applications, concentrate is usually a waste stream. Although not preferred terminology per this standard, the terms *retentate*, *reject*, and *brine* are sometimes used as equivalent to *concentrate*.

22. *Conductivity*: Measure of a substance's ability to conduct an electrical current as measured by a conductivity meter. The inverse of resistivity. Reported in Siemens per meter (S/m) or, commonly, reported in micromhos or microSiemens per centimeter ($\mu\text{mhos/cm}$ or $\mu\text{S/cm}$), temperature corrected to 25°C.

23. *Crossflow*: Flow through a membrane module in which the fluid on the upstream side of the membrane moves parallel to the membrane surface. Fluid on the downstream side of the membrane moves away from the membrane in the direction normal to the membrane surface. This hydraulic configuration is typical of spiral-wound systems and some inside-out hollow-fiber systems.

24. *Dalton*: A unit of mass equal to $\frac{1}{12}$ the mass of a carbon-12 atom or one atomic mass unit (amu).

25. *Dead end*: Flow configuration of a membrane module in which the only outlet for the upstream fluid during service is through the membrane. The upstream fluid is forced through the membrane, which captures the retained particles on and within it.

26. *Desalination*: A process for the removal of significant amounts of dissolved solids from a feedwater stream. Thermal distillation and some membrane processes (e.g., reverse osmosis) are commonly used for seawater desalination.

27. *Desalinization*: Although not preferred terminology per this standard, sometimes used as an equivalent to *desalination*.

28. *Desalting*: The reduction of dissolved solids from water.

29. *Direct integrity test (DIT)*: A physical test applied to a membrane unit in order to identify and/or isolate integrity breaches.

30. *Electrodialysis (ED)*: A demineralization process in which ions are transferred through ion-selective membranes by means of an electromotive force, voltage-driven direct electric current, from a less concentrated solution to a more concentrated solution. NOTE: ED is not a membrane filtration process, because the demineralized (product) water does not pass through the membrane barrier. *See also* electrodialysis reversal (EDR).

31. *Electrodialysis reversal (EDR)*: A type of ED process in which the polarities of the electrodes are periodically reversed to change the direction of ion movement for membrane scaling and fouling control. *See* electrodialysis (ED).

32. *Electrode compartment*: Water flow compartment containing the metal electrode where oxidation or reduction occurs, generally related to ED and EDR.

33. *Element*: The smallest removable component of a membrane system that includes the membrane.

34. *Encased*: For a membrane system, the type in which membrane is contained in a pressure vessel (or housing) and for which positive hydraulic pressure is applied on the membrane feed side to transport water through the membrane.

35. *Feed channel spacer*: A plastic material, often netting, between membrane leaves that provides the flow channel for the fluid passing over the surface of the membrane, which can increase the turbulence of the feed-concentrate stream.

36. *Filtrate*: For MF/UF, the portion of the feed stream that has passed through the membrane.

37. *Flux*: Filtrate (for MF/UF) or permeate (for RO/NF) flow rate divided by available membrane area on the feed side surface. The unit of measurement is gallons per day per square foot, which is abbreviated gpd/ft² or gfd (also, liter per hour per square meter, which is abbreviated L/h·m² or Lmh).

38. *Fouling index*: Related term: SDI.

39. *Highly brackish water*: Water with an approximate concentration of dissolved solids ranging from 10,000 to 30,000 mg/L. Related terms: brackish water, seawater.

40. *Hollow fiber*: Self-supporting cylinder containing membrane material that has an outside diameter of less than 5 mm and a hollow bore (lumen) in the