ANSI/AWWA B114-16
(First Edition)

American Water Works Association
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AWWA Standard

Reverse Osmosis and Nanofiltration Systems for Water Treatment

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STANDARD
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AWWA Standard

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Contents

All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

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Foreword

This foreword is for information only and is not a part of ANSI/AWWA B114.*

I. Introduction.

I.A. *Background.* The purpose of ANSI/AWWA B114-16 is to provide purchasers with a standard for the purchase and installation of membrane treatment systems using reverse osmosis (RO) and nanofiltration (NF) membranes.

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

I.B. *History.* RO membranes have been used to purify water since the late 1960s§ and NF since the 1980s. RO and NF technologies have been and continue 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 RO and NF technology is widely accepted and practiced worldwide.

RO/NF membranes are made from a variety of polymeric and inorganic materials, although polymeric varieties currently predominate. Improvements to existing products and development of new types of RO/NF membrane materials, structures, and surface treatments are ongoing topics of research activities. For comparisons of performance between different membranes to be meaningful, test conditions should be carefully considered, since they can have a marked effect on results. RO/NF membrane separation performance can be described by a variety of measures, including salt rejection or passage, specific solute rejection or passage, and molecular weight cutoff, all within the context of specific test conditions, such as concentration, pH, recovery, pressure, temperature, flux, and flow rate or velocity. Measurement of RO/NF membrane performance including separation and output is 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 USEPA's *Membrane Filtration Guidance Manual* (USEPA 2005) associated with the Long Term 2 Enhanced

* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.
† AWWA and ASCE, *Water Treatment Plant Design*, 5th Ed., McGraw-Hill (2012).
‡ AWWA, *Water Quality and Treatment*, 5th Ed., McGraw-Hill (2011).
§ *Water Desalting Planning Guide for Water Utilities*, John Wiley & Sons Inc. (2004).

Surface Water Treatment Rule (USEPA 2006) and various ASTM standards, including D4194-03, Standard Test Methods for Operating Characteristics for Reverse Osmosis and Nanofiltration Devices; D4472-08, Standard Guide for Recordkeeping for Reverse Osmosis and Nanofiltration Systems; and D4516-00, Standard Practice for Standardizing Reverse Osmosis Performance Data.

Regulatory concerns may or may not be the primary drivers for the use of RO/NF membranes by a municipality, but in all cases the regulations must be assessed for applicability. At present, US federal drinking water standards covering RO/NF membrane treatment deal mainly with how much removal credit can be received from their use as a microbial barrier. Other regulatory requirements may also apply, such as acceptable water contact materials, meeting the primary and secondary contaminant levels in the finished water, frequency of monitoring certain performance parameters, staffing, and isolation during clean-in-place (CIP) (e.g., possible requirements for isolating block and bleed valves).

This standard is intended to aid in the selection and procurement of RO and NF 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 an RO or NF treatment system. However, its proper application requires it be coupled with a thorough professional review of the specific water treatment case and site-specific conditions.

This first edition of this new standard ANSI/AWWA B114-16—Reverse Osmosis and Nanofiltration Systems for Water Treatment, was approved by the AWWA Board of Directors on Jan. 16, 2016. The standard was approved and promulgated in the course of the activities of the AWWA Standards Committee on Membrane Standards.

In 2010, the decision was made by the AWWA Standards Council to partition ANSI/AWWA B110-09—Membrane Systems (first edition) into three standards that cover specific membrane technologies. The AWWA Standards Council then assigned the task of development of three separate standards to the AWWA Standards Committee on Membrane Standards. This standard, ANSI/AWWA B114-16—Reverse Osmosis and Nanofiltration Systems for Water Treatment, is one of the three standards that were developed.

A guide to the AWWA membrane systems standards is presented in the table on the following page.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF

Guide to AWWA membrane standards and typical membrane characteristics

Membrane Type	Applicable AWWA Standard	Nominal Pore Size (µm)	≥3-µm Particle or Surrogate Organism Removal	Virus (MS2 Phage) Removal	Typical Molecular Weight Cutoff (daltons)	Salt (NaCl) Rejection (%)*
Microfiltration (MF)	B112-15	0.1 to 0.5	≥99.9% (≥3 log)	< 90% (<1 log)	≥200,000	None
Ultrafiltration (UF)	B112-15	0.005 to 0.1	≥99.9% (≥3 log)	≥ 90% (≥1 log)	10,000 to 200,000	None
Nanofiltration (NF)† and	B114-16	0.001 (approximate conceptual value)	Same as UF	Same as UF	200 to 1,000	0% to 95%
Reverse Osmosis(RO)†	B114-16	0.001 (approximate conceptual value)	Same as UF	Same as UF	150 to 300	>95%
Electrodialysis/ Ion-Exchange Membranes (IEM)	B116-15	Not applicable	Not applicable: demineralized product does not pass through a membrane barrier	Not applicable: demineralized product does not pass through a membrane barrier	Not applicable	>45%
Membrane Bioreactors (MBR)	B130-13	‡	‡	‡	‡	‡

Abbreviations: Less than <; Greater than >; Greater than or equal to ≥; Approximately ~; micron µ

* NF is similar to RO with the key difference being that NF has lower sodium chloride rejection than RO and NF exhibits greater selectivity in the types of ions that are removed, such that NF allows a comparatively higher percentage of monovalent ions to pass to the permeate than multivalent ions.

† For NF and RO, rejection is generally based on test conditions for a single element, but there is some variation between membrane manufacturers and membrane models. In general, test conditions tend to vary as follows: (1) feed solutions: 500 to 700 mg/L sodium chloride, magnesium chloride, calcium chloride, or mixed solute solutions for NF; 1,500 to 2,000 mg/L sodium chloride for brackish water RO membranes; 32,000 to 38,000 mg/L sodium chloride for seawater RO membranes; (2) 25°C temperature or corrected to that temperature; (3) 6 to 8 pH; (4) 8 to 20 percent recovery per element.

‡ For a description of typical MBR characteristics, please refer to AWWA Standard B-130-13.

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 (formerly AwwaRF) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works 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 the following:

1. Specific policies of the state or local agency.

2. USEPA's *Membrane Filtration Guidance Manual* (EPA 815-R-06-009, USEPA 2005).

3. 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.

4. 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 jurisdictions. 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 RO and NF. 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.

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

† 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 20001.

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

1. Standard used, that is, ANSI/AWWA B114-16, Reverse Osmosis and Nanofiltration Membrane Systems, latest revision.
2. Details of other federal, state, local, and provincial requirements (Sec. 4.1.1).
3. Required equipment (Sec. 4.2.1).
4. Excluded systems and facilities (Sec. 4.2.2).
5. Required net production rate (Sec. 4.3.1.b).
6. Required documents for permitting (Sec. 4.3.1.u and Sec. 4.3.3.e).
7. Record drawings format (Sec. 4.3.4).
8. Whether compliance with NSF/ANSI 60 or NSF/ANSI 61 or other standards, rules, or regulations in addition to the requirements of the Safe Drinking Water Act are required (Sec. 4.6.4, 4.6.4.1, 4.6.4.2).
9. Element shipment requirements (Sec. 4.6.6.2).
10. Spare part requirements (Sec. 4.6.7.1).
11. Interface coordination requirements on project drawings (Sec. 4.6.8.1).
12. Electrical coordination requirements on project drawings (Sec. 4.6.8.4).
13. Instrumentation and control requirements on project drawings (Sec. 4.6.8.5).
14. Pneumatic requirements on project drawings (Sec. 4.6.8.6).
15. Flushing requirements (Sec. 5.1.2).
16. Installation requirements (Sec. 5.1.2).
17. Requirements for field testing (Sec. 5.4).
18. Demonstration testing requirements (Sec. 5.4.3).
19. Performance testing requirements (Sec. 5.4.4 and Sec. 5.4.5).
20. Basis for rejection (Sec. 5.5).
21. Affidavit of compliance (Sec. 6.3).

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 Engineering and Technical Services at 303.794.7711, FAX at 303.795.7603; write to the department at 6666 West Quincy Avenue, Denver, CO 80235-3098; or email at standards@awwa.org.

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AWWA Standard

Reverse Osmosis and Nanofiltration Systems for Water Treatment

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard sets minimum requirements for reverse osmosis (RO) and nanofiltration (NF) 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 RO and NF membrane systems used for water and reclaimed water treatment systems. This standard is intended to assist with the design, procurement, installation, and commissioning of RO and NF membrane systems.

Sec. 1.3 Application

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

SECTION 2: REFERENCES

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

American Public Health Association (APHA), American Water Works Association (AWWA), and 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 D4194-03—Standard Test Methods for Operating Characteristics for Reverse Osmosis and Nanofiltration Devices.

ASTM D4472-08—Standard Guide for Recordkeeping for Reverse Osmosis and Nanofiltration Systems.

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

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

US Environmental Protection Agency. 2005. *Membrane Filtration Guidance Manual.* Washington, DC: Office of Water, EPA 815-R-06-009.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Applied pressure:* For a membrane train, feed hydraulic pressure minus permeate and/or filtrate hydraulic pressure.

2. *Array:* The overall arrangement of pressure vessels in a membrane system train, including the groupings in parallel and series. For example, a 12:6 array has two stages with 12 vessels in the first stage and 6 in the second stage.

3. *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.

4. *Brackish water:* Water with an approximate concentration of total dissolved solids ranging from 500 to 10,000 mg/L (see also *Highly brackish water, Seawater*).

5. *Brine:* A concentrated salt solution. Although not preferred terminology according to this standard, the terms *retentate*, *reject*, and *brine* are sometimes used as equivalent to *concentrate*.

6. *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.

7. *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 locations.

8. *Concentrate:* The stream exiting a membrane device, which has increased concentration(s) of solute(s) and/or particle(s) compared with the feed stream. For drinking water applications, concentrate is usually a waste stream. Although not preferred terminology according to this standard, the terms *retentate*, *reject*, and *brine* are sometimes used as equivalent to *concentrate*.

9. *Dalton:* A unit of mass equal to 1/12 the mass of a carbon-12 atom or 1 atomic mass unit (amu).

10. *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.

11. *Desalinization:* Although not preferred terminology according to this standard, the term is sometimes used as an equivalent to *desalination*.

12. *Desalting:* The removal of dissolved solids from water.

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

14. *Element:* The smallest removable component of a membrane system, which includes the membrane.

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

16. *Filtrate:* The portion of the feed stream that has passed through MF/UF membrane.

17. *Flux:* Permeate flow rate divided by the active membrane area on the feed side surface. The unit of measurement is gallons per day per square foot, which is abbreviated gpd/ft^2 or gfd (also, liter per hour per square meter, which is abbreviated L/h·m^2 or Lmh).

18. *Highly brackish water:* Water with an approximate concentration of dissolved solids ranging from 10,000 to 30,000 mg/L (see also *Brackish water, Seawater*).

19. *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 center. For RO and NF, the membrane surface is usually on the outside with the bore (lumen) conveying permeate.

20. *Indirect integrity monitoring:* Monitoring some aspect of product/permeate water quality that is indicative of the removal of particulate matter.

21. *Log removal value (LRV):* A measure of the removal effectiveness of a parameter expressed as the log 10 of the concentration in the feed minus the log 10 of the concentration in the filtrate or permeate (sometimes called *product*). For example, given a 10-fold reduction in a concentration, such as from 200 in the feed to 20 in the filtrate, the LRV equals 1.

22. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.

23. *Material safety data sheet (MSDS):* See *Safety data sheet (SDS).*

24. *Membrane:* An engineered material that is designed to remove solids (dissolved or suspended) that are rejected from the system as a concentrate stream, and that produces a stream containing less solute or particles (the product or permeate stream). Membrane types in this standard include nanofiltration (NF) and reverse osmosis (RO).

25. *Membrane cleaning system:* Tanks, filtration devices, pumps, and associated equipment and appurtenances that are periodically used to prepare and feed chemical solutions to the membrane element(s) to recover lost performance.

26. *Module:* The smallest component of a membrane unit in which a specific membrane surface area is housed in a device with feedwater, permeate, and concentrate and/or backwash connections.

27. *Molecular weight cutoff (MWCO):* The rating of a membrane based on the size of uncharged solutes it will reject. Also referred to as *nominal molecular weight cutoff* (NMWCO). Typically expressed in daltons.

28. *Nanofiltration (NF):* Membrane filtration process that removes dissolved constituents from water—including dissolved organics, color, disinfection byproduct (DBP) precursors, calcium and magnesium (hardness) ions, and other ions. NF membrane elements typically exhibit an NMWCO in the range of about 200 to 1,000 daltons and sodium chloride rejection of 0 to 95 percent. NF is similar to RO

with the key difference being slightly higher NMWCO ratings and more selectivity for ion rejection based on charge, with NF allowing a higher percentage of monovalent ions to pass to the permeate than divalent or multivalent ions.

29. *Net driving pressure:* The pressure available to force water through a semipermeable membrane, defined as the average feed side pressure (i.e., the average of the feed and concentrate hydraulic pressures) minus the permeate side hydraulic pressure and minus the average differential osmotic pressure across the membrane. The unit of measurement is psi (bar).

30. *Pass:* A treatment step in which the product, filtrate, or permeate passes through a membrane. For example, in a two-pass system the product from the first pass becomes feed to the second pass and at least a portion of that feed flows through the second-pass membrane.

31. *Permeability:* Temperature-corrected flux divided by net driving pressure. The unit of measurement is the same as flux units divided by pressure units; therefore, gfd/psi (Lmh/bar). Also called *specific flux*.

32. *Permeate:* The water that passes through RO or NF membrane.

33. *Plate and frame:* A configuration containing flat sheets of membranes separated by alternating product or permeate spacers and feed/concentrate spacers, held in place by a structure.

34. *Posttreatment:* Any treatment applied to the filtrate, permeate, or product of a membrane process generally applied to achieve finished water quality objectives.

35. *Potable water:* Water that is safe and satisfactory for drinking and cooking.

36. *Pressure-driven system:* Type of system applying force obtained from a pump or other source (such as taking advantage of available pressure or hydraulic elevation differentials across the system) that provides positive hydraulic pressure to a feed stream that permits a type of membrane system to operate.

37. *Pretreatment:* Any treatment applied to the feedwater ahead of a membrane process, generally to achieve desired water quality objectives and/or protect the membrane from damage or fouling.

38. *Product:* For RO and NF, the portion of the separated feed stream that has reduced constituent concentrations. In accordance with this standard, the preferred term is *permeate*.

39. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.

40. *Reclaimed water:* Wastewater that becomes suitable for beneficial use as a result of treatment.

41. *Recovery:* For RO/NF, the ratio of product flow to feed flow. Recovery is expressed as a percent.

42. *Resolution:* The size of the smallest integrity breach that contributes to a response from a direct integrity test; also applicable to some indirect integrity monitoring methods. The unit of measurement is micron (μm).

43. *Reverse osmosis (RO):* Membrane filtration and desalination process that removes dissolved constituents from water, including dissolved organics, color, DBP precursors, calcium and magnesium (hardness) ions, and other ions. RO membrane elements have an NMWCO in the range of 150 to 300 daltons and sodium chloride rejection greater than 95 percent.

44. *Safety data sheet (SDS):* Document obtained or developed by chemical manufacturers and importers concerning each hazardous chemical they produce or import describing information for safe transport, handling, and use. Employers are required to have an MSDS in the workplace for each hazardous chemical used there.

45. *Salt (or solute) passage:* For RO/NF, the concentration of salts or specific solute(s) in the permeate stream divided by the concentration(s) in the feed stream, expressed as a percentage.

46. *Salt (or solute) rejection:* For RO/NF, 100 percent minus the salt or solute passage, expressed as a percent.

47. *Seawater:* Ocean water with an approximate concentration of total dissolved solids ranging from 30,000 to 60,000 mg/L (see also *Brackish water, Highly brackish water*).

48. *Sensitivity:* The maximum log removal value that can be reliably verified by a direct integrity test; applicable to some continuous indirect integrity monitoring methods.

49. *Silt density index (SDI):* Silt density index is an indication of the amount of particulate matter in water; it is a type of fouling index. SDI indicates the rate of plugging of 0.45-μm membrane filter as a dimensionless index value as described in ASTM D4189. SDI_{15} is the most commonly used value, which is determined by using a 15-minute filtration duration.

50. *Solute:* A substance dissolved in a solution.

51. *Specific flux:* Flux divided by transmembrane pressure. The unit of measurement is the same as flux units divided by pressure units; therefore, gfd/psi (Lmh/bar). Related term, *permeability*, is temperature-corrected specific flux.

52. *Spiral wound:* A configuration in which flat sheets of a semipermeable membrane, a porous support matrix, and a spacer are wrapped around a central filtrate/permeate collector tube; typically associated with NF and RO but can be applied to other types.

53. *Stage:* A group of membrane units operating in parallel. *Staging* is the process in which the concentrate from one stage is used as the feed to another stage (see also *Array*).

54. *Supplier:* The party who supplies material or services. A supplier may or may not be the manufacturer.

55. *Temperature-corrected:* Value, such as flux or driving pressure, corrected from ambient temperature to a reference temperature—for RO/NF the reference temperature is commonly 25°C.

56. *Total dissolved solids (TDS):* Residual material remaining after filtering suspended material from a solution through a standard glass fiber filter and evaporating the filtrate to a dry state at 180°C. Specific methods for determination given in appropriate section of *Standard Methods for the Examination of Water and Wastewater*, Method 2540 C (APHA, AWWA, and WEF). Usually expressed as mg/L.

57. *Train:* A group of membrane vessels with common inlet and outlet connections, complete with common monitoring and control equipment. Often a membrane treatment facility has multiple parallel trains. A train can be operated independently from other trains and can be isolated from the rest of the system.

58. *Transmembrane pressure (TMP):* The difference in hydraulic pressure from the feed or feed-concentrate average to the filtrate, permeate, or product across a membrane barrier (see also *Applied pressure*).

59. *Unit:* A group of membrane modules that share common control and valving and that can be isolated as a group for testing or cleaning.

60. *Waste neutralization system:* Tanks, devices, pumps, associated equipment, and appurtenances that are periodically used to prepare and feed chemical solutions to the waste streams from membrane cleaning, or other operations systems before the waste is discharged.

SECTION 4: REQUIREMENTS

Sec. 4.1 Materials

4.1.1 *Materials.* If required by applicable regulatory agency and/or required in the purchase documents, materials shall comply with the requirements of the Safe Drinking Water Act and other federal regulations for potable and reclaimed water systems as applicable.

Sec. 4.2 Scope of Supply

4.2.1 *Required equipment.* RO/NF membrane systems according to this standard include the following systems and facilities unless otherwise required in the purchase documents:

a. Membrane elements/modules.

b. Support devices such as a frame welding for membranes, piping, and panels.

c. Piping, tubing, valves, and fittings on the membrane unit, including isolating block and bleed valves if required by regulatory agency and/or purchase documents.

d. Membrane feed pumps, drivers, and energy recovery devices (if any).

e. Membrane unit flow, pressure, and water quality monitoring instrumentation as required in the purchase documents or recommended by supplier.

f. Liquid and/or air backwash pumps and air blowers (if applicable).

g. Membrane integrity system air supply and conditioning equipment (if applicable).

h. Programmable logic controller (PLC) or computer, software, programming, and instrumentation.

i. A PLC/human–machine interface control system.

j. Special tools or equipment required for locating and repairing RO/NF membrane modules having integrity defects and for the disassembly and reassembly or analysis of membrane modules.

k. Spare parts as required in the purchase documents.

4.2.2 *Excluded systems and facilities.* RO/NF membrane systems per this standard do not include the following systems and facilities unless required in the purchase documents:

a. Source water supply.

b. Membrane pretreatment.

c. Concentrate, spent backwash, spent membrane cleaning, and waste neutralization handling and disposal facilities.

d. Chemical storage and transfer piping systems for membrane cleaning systems.

e. Chemical feed pumps, valves, and appurtenances for membrane cleaning systems (CIP, chemically enhanced backwash, and chemical wash).

f. Interconnecting piping, valves, and appurtenances.

g. Electrical and control wiring and conduits external to membrane units.

h. Process air supply.

i. Facility where membrane system is housed.

j. Regulatory agency permits.

Sec. 4.3 Data to Be Provided by System Supplier

4.3.1 *Data provided by the supplier.* The supplier of the RO/NF membrane system shall supply the following information:

a. Complete system description table (see appendix B).

b. Net production rate on a daily (24-hour) basis from duty trains, as required in the purchase documents.

c. Flux as a function of water temperature and net flux with duty trains in service and standby trains out of service at production capacity.

d. Preliminary process flow diagram and flow balance.

e. Preliminary process and instrumentation diagrams (P&IDs).

f. Preliminary layout drawing, including information about elevation change between unit inlet and permeate (or product) and concentrate discharge points.

g. Floor loads of all equipment as shipped and during operation.

h. Preliminary electrical one-line diagram.

i. List of major materials of construction.

j. List of cleaning procedures.

k. List of pretreated feedwater quality requirements.

l. Statements indicating membrane system materials are compatible with other systems to be used in the process, including pretreatment or other process chemicals.

m. Time required for (1) fabrication of the system and (2) delivery of major equipment after approval by purchaser.

n. List of proposed chemicals for use as membrane preservative and method of disposal.

o. List of proposed chemicals and quantities for startup, operations, and maintenance activities.

p. Safety data sheets of any proprietary cleaning chemicals shall be included.

q. Services and equipment to be provided by others, including if applicable, services such as on-site erection and installation of membrane equipment and element/module loading.

r. Predicted filtrate, permeate, or product quality based on supplied source water quality and key operating parameters.

s. Predicted transmembrane pressure for RO/NF at startup and after the guaranteed period of operation.

t. Written description of the automatic membrane integrity test procedure, means to locate specific modules requiring repair, and repair methods and materials (if applicable).

u. Plans, procedures, and required testing for permitting RO/NF membrane system shall be provided as required in the purchase documents.

4.3.2 *Data required prior to manufacturing.* The supplier of the membrane system shall provide the following information prior to manufacturing the system:

a. Revised versions of the above documents and drawings, including all piping with sizes, pressure ratings, and materials of construction identified.

b. Revised process flow diagram and flow balance table for major streams.

c. Completed process and instrumentation diagrams (P&IDs) including information concerning all equipment, instrumentation and control (I&C) components, and various types of valves as well as indicating all chemical injection points.

d. Description of the control system and PLCs' software, and how the membrane system will be integrated into overall water plant control system.

e. Revised layout drawing showing how the equipment footprint will fit into the building or other structure(s) that will house the system.

f. Location of anchor bolts and equipment supports for preceding (e.).

g. Electrical termination drawings, indicating all internal and external electrical connections.

h. Product data sheets and tables describing major equipment items. These shall be clearly marked and annotated to show the applicable model numbers, ratings, and features.

1. Major equipment shall include pumps and drives, pressure vessels, membrane elements/modules, tanks, heaters, control valves, and instruments, as applicable.

2. Details on pumps and drives shall include manufacturer, model number, impeller size, pump curves, efficiency, materials of construction, seal type and manufacturer, and motor data that include manufacturer, model, type, rated size in horsepower or kilowatts, and service factor.

3. Details on the membranes shall include data sheets.

4. Details on control valves shall include manufacturer, model number, pressure class, materials of construction, and table or figure to show flow coefficient (C_v) as a function of percent open.

i. Piping schedule listing service, pipe code, diameter, pressure class, and materials of construction.

j. Valve schedule listing tag number, manufacturer, model number, size, type, pressure class, and materials of construction for all valves, including vacuum breakers and check valves.

k. Instrumentation/device schedule listing tag number, manufacturer, model number, measured parameter, and ranges for instruments and devices.

l. Control philosophy (process control narratives).

m. Automatic integrity test description (if applicable).

n. Chemical dosing system and purpose.

o. Functional test plans.

p. Startup and commissioning plans with operational and maintenance forms, instructions and/or checklists, including plan for flushing and disposal of membrane module preservative.

q. Updated plans, procedures, and required testing for permitting RO/NF membrane system shall be provided as required in the purchase documents.

r. List of manufacturer-recommended spare parts, special tools, and special services including startup and installation that will be provided with the system.

4.3.3 *Data provided prior to startup.* The supplier of the RO/NF membrane system shall provide the following information prior to startup of the system:

a. Revised versions of the documents and drawings listed in the previous subsection.

b. Operation and maintenance (O&M) manuals for the membrane system and appurtenances (see Sec. 4.6.7.4).

c. Factory test and membrane unit manufacturer's quality control reports for all equipment provided.

d. Functional performance test report for PLC/human–machine interface system.

e. Documentation required for permitting the membrane system as required in the purchase documents.

4.3.4 *Record drawings.* After startup of the system, the supplier of the RO/NF membrane system shall provide a complete set of the documents (including drawings) listed in the previous subsections, revised to describe the system "as installed" and in a format required in the purchase documents.

Sec. 4.4 Water Flow and Water Quality Data Requirements

The RO/NF membrane system shall meet the performance criteria based on the project's water quantity requirements. The following data shall be provided by the purchaser:

4.4.1 *Flow rates.* Flow rates (feed and permeate), in gpm, gpd, or acre-foot/year (m^3/d, m^3/h, or m^3/year), or an alternative approach whereby permeate flow rate and minimum recovery are provided.

4.4.2 *Recovery.* Minimum, maximum, and design target recovery (percent).

4.4.3 *Design water temperature.* The design temperature and temperature range, in °F (°C), and permeate flow rate as a function of temperature and/or applied pressure as a function of temperature.

4.4.4 *Source.* The source(s) of feedwater shall be documented.

4.4.5 *Pretreatment.* Description of treatment processes upstream from the membrane process, including recirculation of streams to points upstream from the membrane process.

4.4.6 *Water quality.* The raw or feedwater quality data provided for design shall be as shown in Table 1. The table identifies required items with "R" and optional items "O." It is recommended that feedwater quality variation and temperature be documented and used in the system design. For each item, it is recommended that values be presented for minimum, maximum, and average or typical, if available. Alternatively, values may be presented for 10 percent, 95 percent, and 50 percentiles (or mean or median).

Sec. 4.5 Performance Criteria

4.5.1 *Performance criteria.* RO/NF membrane systems shall be designed to meet the following performance criteria that are summarized below:

4.5.1.1 Production rate. Net production rate per day at a required design temperature or range of temperatures as well as including all waste flows from the system.

Table 1 Raw and/or feedwater quality data to be provided

Parameter (mg/L unless noted otherwise)	Required or Optional
Temperature (°F or °C)	R
Turbidity (ntu)	R
SDI_{15} (dimensionless)	O
pH (standard pH units)	R
Total Organic Carbon (TOC)	O
Dissolved Organic Carbon (DOC)	O
Ultraviolet Light UV-254 (m^{-1})	O
Color, True and Apparent (color units)	O
Iron, Total	R
Iron, Dissolved	O
Manganese, Total	R
Manganese, Dissolved	O
Alkalinity (mg/L as $CaCO_3$) or Carbonate and Bicarbonate	R
Total Hardness (mg/L as $CaCO_3$)	R
Oil and Grease	O
Biochemical Oxygen Demand (BOD)	O
Chemical Oxygen Demand (COD)	O
Total Suspended Solids (TSS)	O
Total Dissolved Solids (TDS) or Conductivity (µS/cm)	R
Microbiological Parameters, Such as Algae, Total Coliform, Fecal Coliform, and Heterotrophic Plate Count (in standard units)	O
Calcium	R
Magnesium	R
Sodium	R
Potassium	O
Barium	R
Strontium	R
Aluminum	O
Ammonia	O
Sulfate	R
Chloride	R
Fluoride	R
Silica (SiO_2)	R
H_2S (if present)	R
Arsenic	O
Boron	O
Bromide	O
Conductivity (µS/cm)	O
Nitrate and Nitrite	O
Oxygen, Dissolved	O
Phosphate	O

4.5.1.2 Water quality. Product, filtrate, or permeate water quality shall meet the following requirements:

a. Turbidity in accordance with USEPA's *Membrane Filtration Guidance Manual*, or state, provincial or local requirements, and as required.

b. Required water quality parameters. Each of the measurement values, measurement techniques, frequency, and test conditions shall be defined.

4.5.1.3 Recovery. Minimum, maximum, and design target recovery.

4.5.1.4 pH. Minimum, maximum, and design target feed pH.

4.5.1.5 Feedwater seasonal temperature. Minimum, maximum, and average water temperatures.

4.5.1.6 Membrane flux. Maximum membrane flux at a required temperature or over a temperature range for the overall system.

4.5.1.7 Pressure. Pressure criteria requirements including the following:

a. Maximum allowable transmembrane pressure (TMP) at required design temperature and range of temperatures.

b. Maximum allowable feed, concentrate, and permeate hydraulic operating pressures at design conditions.

c. Maximum allowable backwash inlet pressure at unit (if applicable).

d. Maximum allowable hydraulic pressure drop, across the entire system and/or individual stages on the feed–concentrate side of the membrane.

e. Maximum allowable pressure in the permeate stream plumbing.

f. Maximum allowable inlet pressure at unit and at vessel, module, or stack.

g. Maximum allowable backpressure on the concentrate side at unit and/or at vessel, module, or stack.

4.5.1.8 Integrity testing (if applicable). Membrane integrity test frequency and operating conditions shall be performed as required by regulation. The appropriate local, state or provincial, and USEPA requirements shall be followed as defined by the agency of authority for the site. For reference on testing, see USEPA's *Membrane Filtration Guidance Manual*.

4.5.1.9 Key operating parameters. Key operation and maintenance schedules and parameters shall be measured and documented as part of system performance testing.

4.5.1.10 Clean-in-place (CIP). Including frequency of CIP operations (and any applicable performance triggers); instructions on cleaning methods; duration; chemical concentrations; temperature; chemical exposure limits, including

for temperature, pH, or other limitations; and any other important conditions for CIP or similar activities.

4.5.1.11 Other conditions. Any other conditions for CIP, such as chemical used, concentration, and limits to protect the membrane.

4.5.1.12 Shutdown flush. Flush procedures and flush water source used if needed to protect the membrane system upon shutdown.

4.5.1.13 Membrane storage solutions. Short-term and long-term membrane preservative/storage solutions and protocols.

Sec. 4.6 Products/Components

4.6.1 *Materials of construction.* The products and components of an RO/NF membrane system shall be constructed of materials that are resistant to corrosion in the environment in which they are placed. Metals, fiberglass, and plastics are acceptable materials of construction provided they can withstand the rigors of their internal and external environments.

4.6.2 *Pressure ratings.* The materials of construction shall be suitable for pressures in excess of the greatest possible pressure each component may be exposed to after installation.

4.6.3 *Temperature variations.* RO/NF membrane systems may operate under temperature conditions other than ambient. Materials in such use must be structurally unaffected by these temperature variations at maximum operating pressures.

4.6.4 *Toxicity levels.* Products and components in their intended use must not leach toxic substances into the water that is distributed to the public or the environment. Disposal methods for residuals and used components that meet applicable regulatory requirements shall be available. Evaluation shall be accomplished in accordance with requirements that are no less restrictive than those listed in NSF/ANSI 60 or NSF/ANSI 61. Certification shall be accomplished by a certification organization accredited by the American National Standards Institute.

4.6.4.1 NSF/ANSI 60. Chemicals used in membrane systems shall, if required by applicable regulatory agency or as required in the purchase documents, whichever is more stringent, be certified as suitable for contact with or treatment of drinking water by an accredited certification organization in accordance with NSF/ANSI 60.

4.6.4.2 NSF/ANSI 61. Components used in membrane systems shall, if required by applicable regulatory agency or as required in the purchase documents, whichever is more stringent, be certified as suitable for contact with or treatment

of drinking water by an accredited certification organization in accordance with NSF/ANSI 61.

4.6.5 *Safety considerations.* Products and components shall be safe to use. Protection to personnel, equipment, and the environment must be ensured through the proper installation and use of safety devices, such as pressure relief valves and/or rupture disks.

4.6.6 *Components.* Products/components are composed of the following items:

4.6.6.1 Membranes. Polymeric, metallic, or ceramic. Configuration can be spiral, hollow fiber, tubular, flat sheet, or plate and frame.

4.6.6.2 Pressure vessels. RO/NF pressure vessels are generally plastic or glass reinforced fiberglass but can be metallic materials if appropriate for the level of corrosion. They house one or more membrane assemblies or bundles and are permanently potted or have end plates at each end, usually plastic but can be metallic if appropriate. If there is more than one element per vessel, interconnectors join elements with end plates that are usually plastic. When required in the purchase documents, vessels shall be delivered from their manufacturers with elements already potted or installed in the vessels or shipped separately for field installation.

4.6.6.3 Pumps. Materials of construction shall be suitable for service environment. All types of pump configurations are employed. Both pressure and vacuum pumps are used, as applicable. Interstage booster pressure pumps are used, as applicable. Pressure dampeners and/or discharge control valves are provided if necessary.

4.6.6.4 Energy recovery system, as applicable. Types of systems include direct-coupled energy recovery unit to pump system (e.g., impulse turbine), turbocharger, and isobaric energy recovery unit. Materials of construction shall be suitable for service environment.

4.6.6.5 Cleaning systems. Cleaning-in-place systems are applied to clean one block or unit at a time with the element(s) left in their normal operating locations at almost all full-scale water plants. For some small facilities, elements may be cleaned-in-place or moved to another location for cleaning.

4.6.6.6 Chemicals. Routine and/or continuous additions may be required for acid, base, biocide, or antiscalant chemicals. Cleaning agents may include acids, bases, detergents, disinfectants, biocides, and/or proprietary formulations as appropriate for the specific membrane and system.

4.6.6.7 Piping. Materials of construction are generally plastics or metals suitable for service environment. Manifolds are provided to uniformly split the feedwater.

4.6.6.8 Valves. Materials of construction shall be suitable for the service environment. All types of configurations are possible—isolation, control, regulators, flow check, relief, and other types.

4.6.6.9 Supports. Racks are usually metallic or fiber-reinforced plastic and shall be designed for loads assuming pressure vessels and piping contain water. Supports shall be painted for corrosion protection or made of stainless steel.

4.6.6.10 Instrumentation and control. Recorders and controllers shall be provided with feedback or feed-forward loops. Data shall be sent to a PLC where data are received and analyzed. A computer-monitored alarm, response, control, and data acquistion system or supervisory control and data acquisition system shall be provided and integrated into the purchaser's system. Key variables shall be monitored, including flows, pressures and pressure changes, temperatures, and relevant water quality parameters. Alarms and shutdown switches shall be provided on key variables, including safety measures and quality control.

4.6.6.11 Air compressors and/or blowers (if applicable). Sufficient capacity, redundancy, pressure relief, hydraulic design, and level of air quality (considering level of particle filtering, dryness, and acceptable oil concentration, if any) to protect membrane from damage shall be provided.

4.6.6.12 Sample taps shall be provided to evaluate water quality of the major process streams, such as feed, product, concentrate, recycle, and waste streams.

4.6.6.13 Manual and automatic systems shall be provided that send data to control room or local panel board.

4.6.6.14 General components, as applicable. Provide lifting lugs, anchor bolts, support structure pressure vessel straps for restricting movement, identification labels and numbering on equipment, color and tagging identification of electrical wiring and piping with directional markings (if needed), instrumentation test or calibration equipment, flexible hoses, and restraints.

4.6.7 *Miscellanous items.*

4.6.7.1 Spare parts. Spare parts for units, pumps, valves, and piping shall be provided as required in the purchase documents. Provisions for replacement or spare membrane modules shall be as required in the purchase documents.

4.6.7.2 Special tools and equipment provided for disassembly, reassembly, and repair of modules shall enable required activities to be completed in compliance with Occupational Safety and Health Administration standards.

4.6.7.3 Installation instructions. Detailed installation instructions for all equipment shall be provided before equipment installation.

4.6.7.4 Operation and Maintenance (O&M) manuals. O&M Manuals shall be provided before startup and an as-built version shall also be provided after startup. The manuals shall describe the system components, membrane feedwater characteristics including ranges thereof (including seasonal ranges, if any), system and component details, standard operating procedures, limitations including conditions to be avoided or that could damage the equipment or be dangerous, and operation and maintenance procedures. Regulation and control descriptions and operating instructions shall be included for startup and shutdown for routine, normal, and emergency operations. Maintenance instructions and recommended frequencies of maintenance activities shall be included.

Data tables shall be included to show typical operating set points and conditions. O&M manuals shall also include printouts of the programming logic, printouts of the control and data screens, an electronic copy of the control logic in case of emergency, and a list of all information exchanged with the plant control system, including data table addresses. Drawings shall be included showing process flow diagram(s) and flow balance, P&IDs, layout and arrangement drawings, panel and termination point drawings; material details; records for control; appropriate shift log books and/or control data sheets/spreadsheets with instructions for all tests, forms, and checklists; and safety manual(s) and emergency procedures.

4.6.8 *Interface coordination with components supplied by others.*

4.6.8.1 Interface coordination. Interface points shall be coordinated with the other equipment/operating systems on-site.

4.6.8.2 Piping. Interfaces for connecting piping shall be shown on the submittal drawings.

4.6.8.3 Mounting. Support structure, anchors, and mounting and leveling devices shall be provided. Coordinate with the contractor and subcontractors.

4.6.8.4 Electrical conduits, wiring, and termination points. Conduits and wiring integral to the membrane system shall be terminated in a local panel provided by the membrane system supplier. This shall be shown on the project drawings when required in the purchase documents.

4.6.8.5 Instrumentation and control (I&C) conduits and wiring and termination points. An input/output (I/O) control panel shall be provided by the membrane system supplier. Conduits, cables, and wiring from instruments, valves, and other control devices on the membrane system shall be terminated in the panel by the membrane system supplier.

4.6.8.6 Pneumatic termination point. Pneumatic piping to valves and other devices on the membrane unit shall be provided by the membrane system supplier, shall terminate to a single point for each type of air supply, and shall be shown on the submittal drawings.

SECTION 5: VERIFICATION

Sec. 5.1 Installation

5.1.1 *Membrane system supplier representative.* The membrane system supplier shall have a representative on-site during the following activities:

a. Beginning of the installation of the membrane equipment.

b. Final connections, system flushing, and preservative flushing and disposal.

c. Installation of any special coatings or linings.

d. Training.

e. Initial operations.

5.1.2 *Membranes.* The installation of the RO/NF membrane elements shall be the responsibility of the RO/NF membrane system supplier unless otherwise directed in the purchase documents. The RO/NF membrane elements shall only be installed after a thorough flushing of piping to remove construction debris and other debris. Flushing water shall be clean water and not allowed to be in piping for extended periods beyond membrane supplier's guidelines. If readily available, potable water shall be used for flushing or another type of water if acceptable to purchaser and supplier. Solutions with chlorine and other strong oxidants shall not be exposed to membranes in excess of the allowable limits in accordance with the membrane manufacturer's instructions.

Sec. 5.2 Startup and Commissioning

5.2.1 *Startup and commissioning.* Startup and commissioning shall be the responsibility of the RO/NF membrane system supplier. Purchaser and system supplier shall determine, in advance, which party will be responsible for operation

of the system during the various steps necessary to commission and test the equipment before acceptance.

5.2.2 *Electrical and mechanical checks.* Startup shall include electrical and mechanical checks of equipment, leak checking, flushing, membrane installation, placing units in service, reconfirming the function aspects of the system, and flow and performance verification. Initial water flow through membranes shall only occur after the required quality of the feedwater has been met.

Sec. 5.3 Training

5.3.1 *Training.* The system supplier shall provide training to purchaser's maintenance and operating staff. This shall consist of both classroom and hands-on training. Supplier shall provide the number of training material packages as required in the purchase documents, which may include manuals, compact discs (CDs) or digital video discs (DVDs), and programs.

Sec. 5.4 Field Testing

5.4.1 *Field testing.* Field testing shall include mechanical and electrical testing, demonstration testing, and performance testing. A test plan shall be provided by the system supplier.

5.4.2 *Equipment testing.* Equipment mechanical and electrical testing shall include equipment and instrument verification, leak testing, power and signal connection verification, and PLC/PC program verification.

5.4.3 *Demonstration testing.* Demonstration testing shall be conducted for a period as defined in the purchase documents. This testing shall be designed to show that the system can operate through its various operating cycles. The testing shall demonstrate operation of single and multiple trains, planned starts and stops, alarm functions, emergency stops, and flow rate changes. During the testing, the equipment shall be operated by the party or entity assigned that responsibility in the purchase documents. If a failure occurs, the system supplier shall have no more than the period defined in the purchase documents to make adjustments.

5.4.4 *Performance testing.* Performance testing shall commence at the end of the demonstration testing. The system shall meet the performance test requirements for a continuous period or a portion of a period as required in the purchase documents. Scheduling of the performance test is at the purchaser's discretion but shall occur after the completion of the demonstration test. The performance test shall verify that the performance of the system can be met over an extended period of time.

5.4.5 *Performance test report.* Upon completion of the test, a report shall be prepared in accordance with the purchase documents. Purchaser shall determine whether the system performance meets the requirements of the purchase documents. Should the system fail to meet the requirements, the system supplier shall make necessary corrections to the system and the test shall be repeated.

Sec. 5.5 Basis for Rejection

Any membrane system not complying with the requirements of this standard and/or the purchase documents may be rejected. Repairs, replacements, and retesting shall be accomplished in accordance with the purchase documents.

SECTION 6: DELIVERY

Sec. 6.1 Packaging

Equipment, spare parts, special tools, and other items provided shall be properly marked and packaged for protection during shipping, handling, and storage.

Sec. 6.2 Shipping, Handling, and Storage

6.2.1 *Deliveries.* Deliveries shall be properly sequenced to have needed items on-site and on time so that construction and installation schedules are not negatively affected. Deliveries shall be coordinated with the contractor, subcontractors, and the purchaser.

6.2.2 *Manufacturer recommendations.* Items shall be handled and stored as recommended by the manufacturer or supplier.

6.2.3 *Storage.* Membranes shall be kept clean, in the recommended storage solution, and at the required environmental temperature range, and shall not be removed from shipping package materials until time of installation.

6.2.4 *SDS.* Supplier shall provide SDS or other form of disclosure regarding the membrane preservative solution, if any, and shall provide quantity of preservative used, method to remove the preservative, and recommended disposal practices.

Sec. 6.3 Affidavit of Compliance

The purchaser may require an affidavit from the supplier that the material provided complies with applicable requirements of this standard and that to the best of supplier's knowledge the equipment provided has been installed and functions as supplier intended.

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APPENDIX A

Bibliography

This appendix is for information only and is not a part of ANSI/AWWA B114.

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APPENDIX B

System Description Table

Table B.1 RO/NF system(s)

Description	Units of Measurement: If US Customary Units	Units of Measurement: If Metric Units	Data
MANUFACTURER	—	—	
MODULE DESCRIPTION	—	—	—
Module model number	—	—	
Type (RO, NF, or other)			
Module dimensions:			
Diameter or width (indicate which)	in.	mm	
Length	in.	mm	
Height, if applicable	in.	mm	
Active membrane area, feed-side surface	ft^2	m^2	
Membrane material (Examples: TFC, CA, CTA, and so on)	—	—	
Second membrane material, if more than 1 type in system	—	—	
If more than 1 membrane type, describe each type (i.e., first is anionic, etc.)	—	—	
Configuration, select one or add description: flat plate, hollow fiber, spiral, tubular, or other (add description)	—	—	
Geometry (horizontal or vertical)	—	—	
Hydrophobic or hydrophilic?	—	—	
Membrane charge (neutral, negative, or positive)	—	—	
Molecular weight cutoff, nominal	dalton	dalton	
Standard test conditions and performance			
Feed concentration and solute	mg/L	mg/L	
Feed pressure	psi	bar	
Feed temperature	°F	°C	
Feed pH	pH units	pH units	
Recovery	percent	percent	
Rejection	percent	percent	
Permeate concentration, maximum	mg/L	mg/L	
Permeate concentration, average	gpd	Lpd	
Permeate flow, range	gpd	Lpd	
Permeate flow, average	gpd	Lpd	

NOTES: TFC = thin film composite
CA = cellulose acetate
CTA = cellulose triacetate

(Table continued next page)

Table B.1 RO/NF system(s) (continued)

Description	Units of Measurement: If US Customary Units	Units of Measurement: If Metric Units	Data
Feed channel space or spacer (if applicable): thickness	mil	mm	
Module operating limitations:			
Pressure range	psi	bar	
Temperature range	°F	°C	
pH range	Standard units	Standard units	
Maximum feed turbidity	ntu	ntu	
Maximum feed SDI_{15}	SDI units	SDI units	
Chlorine tolerance (and related conditions)	mg/L hr	mg/L hr	
Other oxidant tolerance (and related conditions)	Describe	Describe	
Other limitations (and related conditions)	Describe	Describe	
Module cleaning limitations:			
Pressure range	psi	bar	
Temperature range	°F	°C	
pH range	Standard units	Standard units	
Maximum feed turbidity	ntu	ntu	
Chlorine tolerance (and related conditions)	mg/L hr	mg/L hr	
Other oxidant tolerance (and related conditions)	Describe	Describe	
Other limitations (and related conditions)	Describe	Describe	
DESIGN DESCRIPTION	—	—	—
Number of trains:			
Online	—	—	
Standby	—	—	
Daily net production of permeate	Average—gpd	Average—m^3/d	
Permeate water quality:			
TDS	Average—mg/L	Average—mg/L	
Other required parameters	Average—mg/L	Average—mg/L	
Flux at ambient temperature:*			
Maximum membrane element flux	gfd	Lmh	
Average stage flux	gfd	Lmh	
Average overall system flux	gfd	Lmh	
Flux, temperature corrected to 25°C:*			
Maximum instantaneous flux	gfd	Lmh	

*There may be a different set of values, i.e., pressures, for each set of feed conditions, such as temperature or concentration.

(Table continued next page)

Table B.1 RO/NF system(s) (continued)

Description	Units of Measurement		Data
	If US Customary Units	If Metric Units	
Reference temperature used for previous line	°F	°C	
Recovery	%	%	
DESCRIPTION OF EACH TRAIN	—	—	—
Number of modules (i.e., pressure vessels)	Enter value	Enter value	
Number of hydraulic stages	Enter value	Enter value	
Arrangements (i.e., number of vessels or stacks in each stage, such as 20:10:5)	Describe	Describe	
Number of elements per vessel	Enter value	Enter value	
Pressure			
Feed pressure, pump design	psi	bar	
Feed pressure, clean	psi	bar	
Feed pressure, typical (5 years)	psi	bar	
Feed pressure, just before CIP, approximate	psi	bar	
Feed-concentrate pressure drop, design conditions	psi	bar	
Permeate pressure, design basis	psi	bar	
Maximum allowable feed pressure	psi	bar	
Maximum allowable feed-concentrate pressure drop	psi	bar	
Describe control system	Describe	Describe	
Unit dimensions:			
Width	in.	mm	
Length	in.	mm	
Height	in.	mm	
Wet weight	lb	kg	

American Water Works Association

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