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(Revision of ANSI/AWWA A100-15)

AWWA Standard

Water Wells

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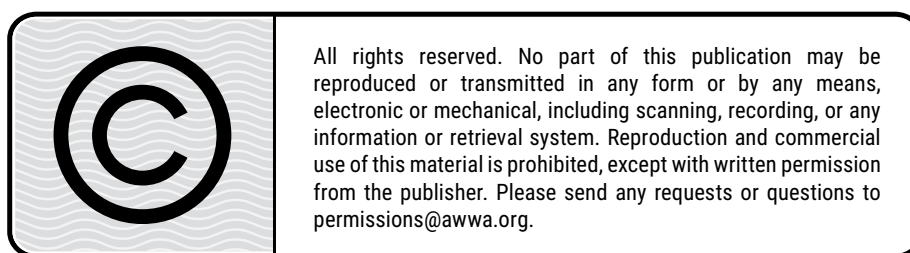
AWWA Standard

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Foreword

This foreword is for information only and is not a part of ANSI/AWWA A100.*

I. Introduction.

I.A. *Background.* This standard was originally used more as a specification than as a standard. Subsequent changes have been directed at developing a true standard as opposed to a specification. This standard is designed primarily for vertical wells for municipal and industrial water supply.

I.B. *History.* The first edition of this standard was approved by the AWWA Board of Directors on May 10, 1946, and was titled “Standard Specifications for Deep Wells,” with the designation 4A1-1946. Amendments to Sec. 1-1.1, Sec. 1-3.2, and Sec. 1-3.3 of that standard were approved by the board on Oct. 1, 1946, and the standard was redesignated AWWA A100-46. Subsequently, a number of minor editorial changes were made; a recommended procedure for sealing abandoned wells was added as appendix Sec. A1-13; and the standard was published on June 18, 1952, titled “Standard for Deep Wells.” The standard was revised on Jan. 26, 1958, and was adopted jointly by AWWA and the National Water Well Association (NWWA). The standard was revised again in 1966. In 1984, the standard was reorganized substantially and revised to be a standard for well construction, rather than a specification, and republished under the title “Standard for Water Wells.” The standard was again revised in 1990 and 1997. Subsequent editions were approved by the AWWA Board of Directors on Feb. 12, 2006, and June 7, 2015. This edition was approved on Jan. 23, 2020.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) 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 (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

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

[†] Persons outside the United States should contact the appropriate authority having jurisdiction.

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/CAN[†] 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI/CAN 61, Drinking Water System Components—Health Effects.

Various certification organizations may be involved in certifying products in accordance with NSF/ANSI/CAN 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.

Annex A, “Toxicology Review and Evaluation Procedures,” to NSF/ANSI/CAN 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of “unregulated contaminants” are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Annex A procedures may not always be identical, depending on the certifier.

ANSI/AWWA A100 does not address additives requirements. Users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.
2. Determine the status of certifications by all parties offering to certify products for contact with, or treatment of, drinking water.
3. Determine current information on product certification.

II. Special Issues.

II.A. *Screen Capacity.* The physical conditions of aquifers, as well as the experience and practice related to their utilization as groundwater resources, vary between well sites and geographic regions. Historically, a common practice for sizing well-screen length and diameter was based on screen open area and inlet velocity (entrance velocity). However, the recommended upper limit for this screen inlet velocity has varied greatly among designers and remains a subject of considerable technical debate. Many designers have, for various technical reasons, limited well-screen entrance velocities to not exceed 0.1 ft/s (0.03 m/s). Others have used and demonstrated successful well designs and installations with velocities substantially exceeding 0.1 ft/s

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

[†] Standards Council of Canada, 55 Metcalfe Street, Suite 600, Ottawa, ON K1P 6L5 Canada.

(0.03 m/s), and prior editions of this standard (through the 1997 edition) proposed an upper limit of entrance velocity of 1.5 ft/s (0.46 m/s).

Based on a significant body of ongoing research within the groundwater industry, the committee recognizes as part of this current standard that there is no singular uniquely defined criterion for permissible velocity through the screen slot openings that is solely suitable for designing a well screen without consideration of the aquifer characteristics and the manner of well construction. In particular, the aspects of flow surrounding the well screen in the filter and at the filter–aquifer interface are known to play a prominent role in the well’s performance and are, in fact, more influential than screen entrance velocity in determining screen dimensions. Similarly, the sizing of screen length and diameter are greatly influenced by the aquifer thickness, stratigraphic layering, and pump size. Accordingly, the applicable design approach must be regarded as a multifaceted and dynamic problem. Within this context, this standard does not recommend screen design solely on the basis of screen entrance velocity criterion (Sec. 4.5.3).

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 information should be provided by the purchaser:

1. Standard used—that is, ANSI/AWWA A100, Water Wells, of latest revision.
2. Whether compliance with NSF/ANSI/CAN 61, Drinking Water System Components—Health Effects, is required, in addition to the requirements of the Safe Drinking Water Act.
3. Scope of the exploratory investigation (Sec. 4.2.1).
4. Whether additional formation samples are needed (Sec. 4.2.2.2).
5. Time, place, and mode of sample delivery (Sec. 4.2.2.5).
6. Type of geophysical log desired, if any (Sec. 4.2.3).
7. Details of federal, state, and local requirements (Sec. 4.3).
8. Options for type of casing material (Sec. 4.3.4).
9. Whether the purchaser wants to specify temporary casings (Sec. 4.4.1).
10. Minimum casing wall thickness (Sec. 4.4.5).
11. Determination of the capacity of the well screen by careful evaluation of the composition of the aquifer. (The well-screen selection should be made by a qualified professional engineer, hydrogeologist, or well-drilling constructor.) (See Sec. 4.5, Appendix L, and Sec. II.A, Screen Capacity, of the foreword.)

12. Maximum rate of flow from well (Sec. 4.5.2 and Sec. 4.5.3).
13. Available options for screen construction (Sec. 4.5.7).
14. Requirements for approval of filter pack sampling (Sec. 4.6.3).
15. Alternate-alignment tolerance (Sec. 4.7.9.4 and Appendix D).
16. The depth of the completed well, which defines the lower limit to which construction tolerances are to be applied (Sec. 4.7.9.5).
17. Height of well casing above ground level (Sec. 4.7.10.3).
18. Flow rate and protocol for performance testing (Sec. 5.1 and Sec. E.4.2 in Appendix E).
19. Accuracy of water-level measurements (Sec. E.2.2 in Appendix E).

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. Major revisions made to the standard in this edition include the following:

1. The scope was clarified that this standard is primarily for vertical wells for municipal and industrial water supply (Sec. 1.1).
2. “Gravel packed” terminology was updated to “filter packed” material throughout the standard. The definition was updated to recognize that packs can range from sand to coarse gravel depending on the formation.
3. Test duration was added to the list of driller’s log items (Sec. 4.2.5.1).
4. A constructor requirement to remove drilling fluids has been added to Sec. 4.8.2.
5. Disinfection level of available chlorine has been updated to 100 mg/L for the entire water depth of the well (Sec. 4.9.2).
6. An Alternate-Alignment Tolerance Warning was added to the beginning of Appendix D.
7. The equations in Appendix K have been updated to clarify conversions for use with metric units.

V. Comments. If you have any comments or questions about this standard, please call 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.



**American Water Works
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ANSI/AWWA A100-20
(Revision of ANSI/AWWA A100-15)

AWWA Standard

Water Wells

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard describes the minimum requirements for vertical water supply wells and is designed primarily for municipal and industrial applications.

Sec. 1.2 Purpose

The purpose of this standard is to provide the minimum requirements for water wells, including consideration of the influences of geologic and hydrologic conditions and water quality and well construction.

Sec. 1.3 Application

This standard can be referenced in specifications for constructing water wells and can be used as a guide for vertical water supply wells. The stipulations of this standard apply when this document has been referenced and only to water wells used in water supply service applications. Application of this standard is not limited by well depth.

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.

ANSI*/AWWA B100—Granular Filtration Material.

ANSI/AWWA C200—Steel Water Pipe—6 In. (150 mm) and Larger.

ANSI/AWWA C206—Field Welding of Steel Water Pipe.

ANSI/AWWA C654—Disinfection of Wells.

API[†] Spec. 5L—Line Pipe.

API RP 13B-2—Recommended Practice for Field Testing Oil-Based Drilling Fluids.

API Spec. 10A—Specification for Cements and Materials for Well Cementing.

ASTM[‡] A53/A53M—Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.

ASTM A139/A139M—Standard Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over).

ASTM A606/A606M—Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, With Improved Atmospheric Corrosion Resistance.

ASTM A778—Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products.

ASTM C33/C33M—Standard Specification for Concrete Aggregates.

ASTM C136/C136M—Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.

ASTM C150/C150M—Standard Specification for Portland Cement.

ASTM D75/D75M—Standard Practice for Sampling Aggregates.

ASTM F480—Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), SCH 40 and SCH 80.

NSF/ANSI/CAN[§] 60—Drinking Water Treatment Chemicals—Health Effects.

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

* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10035.

† American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005.

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

§ Standards Council of Canada, 55 Metcalfe Street, Suite 600, Ottawa, ON K1P 6L5 Canada.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Abandoned well:* A well the purpose or use of which has been permanently discontinued or a well in such a state of disrepair that its purpose or use cannot be reasonably achieved.
2. *Air line:* A small-diameter pipe or tube installed in the well and charged with air for the purpose of measuring the water level.
3. *Alignment:* The horizontal deviation between the actual well centerline and a straight line representing the desired undeviating centerline.
4. *Annular space:* The space between two generally concentric, cylindrical structures, such as between two casings or between a casing and borehole.
5. *Aquifer:* A geologic formation, group of formations, or part of a formation that contains water in its voids or pores that may be used as a source of water supply.
6. *Artesian well:* A well in an aquifer where the groundwater is confined under pressure, so that the water level in the well will stand above the top of the aquifer.
7. *Bailer:* A driller's tool made from pipe with a flapper or foot valve in the bottom, used to remove cuttings, sediments, or water from the borehole or well.
8. *Casing:* A pipe installed in the well borehole to maintain the well opening.
9. *Consolidated formation:* Hard rock—material strata of sedimentary-, igneous-, or metamorphic-type rock.
10. *Constructor:* The party that furnishes the work and materials for placement or installation.
11. *Drawdown:* The difference in elevation between the static and pumping water levels.
12. *Filter packed well*:* A well in which filter pack material is placed in the annular space of the well adjacent to the screen section.
13. *Groundwater:* Subsurface water occurring below the water table or potentiometric surface.

* Note: In previous editions, such wells were referred to as gravel packed wells. The definition was updated to recognize that packs can range from sand to coarse gravel depending on the formation.

14. *Grout*: A fluid mixture of Portland cement and water of a consistency that can be forced through a pipe and placed as required or a fluid mixture of high-solids bentonite and water mixed in accordance with the manufacturer's instructions (see Sec. 4.3.7).

15. *Laminar flow*: Movement of fluid particles in essentially parallel paths.

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

17. *Naturally developed well*: A well in which screen slot openings or perforations are placed in direct contact with surrounding aquifer materials, without any intervening artificial filter or gravel.

18. *Plumbness*: The horizontal deviation (drift) of the well centerline from the imaginary vertical centerline.

19. *Pumping level*: The water level in the well when pumping is in progress.

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

21. *Specific capacity*: The ratio of the discharge rate to the unit of drawdown it produces, measured inside the well (gallons per minute per foot [liters per minute per meter] of drawdown).

22. *Supplier*: The party that supplies materials or services. A supplier may or may not be the manufacturer.

23. *Test hole*: Drilled hole used to obtain information on geologic and hydrologic conditions.

24. *Tremie pipe*: A tubular device that carries materials to designated depths in the hole (also known as *filter pack feedline* in filter packed wells).

25. *Unconsolidated formation*: Loose soft rock–material strata of sedimentary-, igneous-, or metamorphic-type rock, which includes sand, gravel, and mixtures of sand and gravel.

26. *Uniformity coefficient*: A ratio of the sieve-size opening that will pass just 60 percent of a representative sample of the filter material divided by the sieve-size opening that will pass just 10 percent of the material.

27. *Unit capacity*: For well screens, the discharge rate-per-unit surface area of the screen face through which flow occurs (gallons per minute per square foot [liters per minute per square meter]).

28. *Well efficiency (E)*: The ratio of actual to theoretical specific capacity.

29. *Well screen:* A cylindrical filtering device used to stabilize the aquifer or filter pack while allowing the flow of water into the casing and permitting development of the screened formation.

SECTION 4: REQUIREMENTS

Sec. 4.1 General

The requirements that follow for construction, development, and testing for permanent vertical water wells are the minimum requirements for the water supply industry.

4.1.1 *Permits.* Required permits shall be obtained and complied with.

4.1.1.1 *Purchaser.* Unless otherwise specified, the purchaser shall be responsible for providing all government and other permits that are required to be signed by the purchaser.

4.1.1.2 *Constructor.* The constructor or bidder shall be responsible for meeting applicable governmental requirements that are in existence on the date of the bid opening and that are designated as the responsibility of the constructor, unless otherwise provided for by the purchaser.

4.1.2 *Submittals.* Certifications and reports shall be submitted as required in other sections of this standard and as required by the purchaser.

4.1.3 *Protection of groundwater.* All reasonably necessary precautions shall be taken during construction of the well to ensure that contaminants do not reach the subsurface environment.

Sec. 4.2 Investigation of Geologic and Hydrologic Conditions and Groundwater Quality

4.2.1 *General.* The purpose of this section is to present considerations pertaining to the collection, evaluation, and reporting of data that have been developed from the investigations necessary to establish the site-specific geologic and hydrologic conditions and groundwater quality. These considerations apply equally to exploratory programs and to the drilling of production wells. Groundwater investigations sometimes involve drilling one or more test wells before construction of the final production well is begun.

Reliable information regarding specific geologic materials and aquifer conditions at the site is necessary to establish the optimum design for various elements of the final production well. The surest way to characterize the formations

beneath the site is to drill through them, obtaining samples while drilling and recording the data collected.

In addition to the information derived from test-well drilling and test pumping, there are a variety of geophysical logging methods that can provide useful information. The extent and cost of the exploratory and test drilling programs must be balanced against the difficulty in obtaining potable water in a site-specific area, the quantity and quality of the water sought, the use and nature of the well or wells, and the anticipated cost of the permanent well and appurtenances.

The purchaser shall define the scope of the exploratory investigation, including any geophysical logging desired.

4.2.1.1 Purpose of test holes and test wells. Test holes provide hydrogeologic information on aquifers and, if completed with casing and screen, serve as observation wells. Test wells are pumped to provide information on aquifer properties and water quality. Step-drawdown tests conducted in test wells facilitate the design of production wells.

4.2.2 *Formation sampling.*

4.2.2.1 Frequency of sampling. Formation samples shall be obtained at a maximum interval not exceeding 10 ft (3.05 m) and at each change in formation. Particular care shall be taken when collecting samples from expected producing zones.

4.2.2.2 Additional samples. At the direction of the purchaser, additional samples should be obtained at a maximum interval of 5 ft (1.52 m), as required from expected producing zones.

4.2.2.3 Collection and marking. Samples shall be collected, dried, and preserved in separate containers of at least 1.1-lb (500-g) capacity for each interval. Containers shall be plainly marked with well designation, purchaser, location, depth interval, sampling method, sampler type, and the date and time the sample was taken.

4.2.2.4 Storage of samples. The constructor shall be responsible for the safe storage of formation samples until such time as they are accepted by the purchaser.

4.2.2.5 Sample delivery. Time, place, and mode of delivery shall be as directed by the purchaser.

4.2.3 *Geophysical logging.* Various geophysical logs are commercially available and may be required at the discretion of the purchaser (see Appendix I).

The geophysical borehole logs may provide qualitative information on aquifer types and characteristics.

4.2.4 *Water sampling and analyses.*

4.2.4.1 Water sampling. Water samples shall be taken for chemical analyses from each aquifer designated as a possible source for development. The method used to collect samples shall not contaminate the aquifer.

4.2.4.2 Water analyses. When designated, the analyses of the water shall be done according to the requirements of Sec. 5.2. Temperature, pH, specific conductance, and dissolved gases shall be determined by field test and recorded.

4.2.5 *Reports.*

4.2.5.1 Driller's log. During drilling and completion of the well, the constructor shall maintain a complete log, setting forth the following items as they apply:

1. Reference point for all depth measurements.
2. Depth at which each change of formation occurs.
3. Depth at which the first water was encountered, when applicable to the drilling method.
4. Location and thickness of each aquifer.
5. Identification of the stratigraphy and lithology encountered in the borehole.
6. Depth interval from which each water and formation sample was taken.
7. Depth for each borehole diameter.
8. Depth to the static water level (SWL) and observable changes in SWL with well depth.
9. Total depth of completed well.
10. Location limits of lost circulation zones.
11. Depth of the surface or sanitary seal.
12. Nominal hole diameter of the well bore above and below the casing seal.
13. Quantity, type, and mixture of the grout installed for the seal.
14. Depth, length, diameter, wall thickness, material, and type of connection of the well casing.
15. Well-screen type, diameter, wall thickness, material, aperture size and orientation, type of connection, and depth interval in the borehole.

16. For filter packed wells, the interval, height, thickness, and grain size of filter pack material used; the filter pack material to formation grain-size ratio; and the source or supplier and the supplier's product number.

17. Capacity of the well, pump installed, observed drawdown during testing, and test duration.

18. Sealing off of water-bearing strata, if any, and the exact location thereof.

19. Rate of penetration. During the drilling of the hole, a time log shall be maintained showing the rate of penetration, as well as the types of bits used in each portion of the hole.

20. All other pertinent information specified by the purchaser.

4.2.5.2 Stratigraphic log. The stratigraphic log shall be prepared to accompany the set of drilling samples, noting (1) depth; (2) strata thickness; (3) lithology, including size, range, and shape of constituent particles, as well as smoothness, rock type, and rate of penetration; and (4) such special notes as might be helpful. The description shall conform to the US Geological Survey (USGS) standard gradation of grain sizes shown in Table 1.

4.2.6 *Identification of principal aquifers.*

4.2.6.1 Identification of principal aquifers using geophysical borehole logs. Principal aquifers occurring throughout the depth of a well shall be identified using interpretation of results generated by geophysical borehole logging devices.

Table 1 USGS grain-size classification

	Grain-Size Range	
	<i>in.</i>	<i>(mm)</i>
Boulder	≥10.08	(≥256)
Cobble	2.52–10.08	(64–256)
Very coarse gravel	1.26–2.52	(32–64)
Coarse gravel	0.63–1.26	(16–32)
Medium gravel	0.31–0.63	(8–16)
Fine gravel	0.16–0.31	(4–8)
Granule (very fine gravel)	0.08–0.16	(2–4)
Very coarse sand	0.04–0.08	(1–2)
Coarse sand	0.02–0.04	(0.5–1)
Medium sand	0.01–0.02	(0.25–0.5)
Fine sand	0.005–0.01	(0.125–0.25)
Very fine sand	0.002–0.005	(0.063–0.125)
Silt	0.0002–0.002	(0.004–0.063)
Clay	<0.0002	(<0.004)

Identification shall be made by a qualified engineer, hydrogeologist, or well constructor.

4.2.6.2 Identification of principal aquifers using formation samples. Differentiation of principal aquifers in a well shall be determined on the basis of formation samples obtained.

Sec. 4.3 Material Requirements

Materials shall comply with the requirements of the Safe Drinking Water Act and federal regulations for potable water, wastewater, or reclaimed water systems as applicable.

4.3.1 *NSF/ANSI/CAN 61*. Components used in well systems shall, if specified by the purchaser, be certified as suitable for contact with, or treatment of, drinking water by an accredited certification organization in accordance with NSF/ANSI/CAN 61.

4.3.2 *Toxicity levels*. Products and components must not leach toxic substances into the water that is distributed to the public or the environment in their intended use. 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/CAN 60 or 61, respectively, if specified by the purchaser. Certification shall be accomplished by a certification organization accredited by the American National Standards Institute.

4.3.3 *Drilling-fluid materials*. Drilling fluids are used in the process of drilling to facilitate the removal of formation cuttings and to stabilize the borehole during drilling and completion operations.

4.3.3.1 Types of drilling fluids. The following types of drilling fluids are acceptable for water-well drilling:

1. Freshwater-based drilling fluids.
2. Air-based drilling fluids.

4.3.3.2 Fluid additives. Acceptable additives to drilling fluids are as follows:

1. Dissolved additives.
 - a. Mud-thinning agents.
 - b. Inorganic phosphates.
 - c. Surfactants.
 - d. Drilling detergents.
 - e. Foaming agents.
 - f. Natural and synthetic polymers.

2. Nondissolved additives.
 - a. Native solids (clays and sand).
 - b. Bentonite.
 - c. Density-increasing materials.
 - d. Loss-circulation materials (not to be used in the production zone).

4.3.4 *Casing materials.* All casing materials shall be new and shall conform to one of the manufacturing standards listed in Table 2. It shall be the responsibility of the constructor to ensure that the purchaser is provided with documented mill certifications by the manufacturer for metallic casings.

4.3.4.1 *Two-ply casing.* Two-ply casing shall be fabricated from high-strength corrosion-resistant steel with the minimum material properties set forth in Table 2. Two-ply casing shall be made of inner and outer sections, each 4 ft (1.2 m)

Table 2 Water-well casing materials

A. Manufacturing standards for single-ply carbon-steel well casing:	
ANSI/AWWA C200	
API Spec. 5L	
ASTM A53 Grade B	
ASTM A139 Grade B	
B. Manufacturing standards for alternative single-ply well-casing materials:	
<i>Casing Material</i>	<i>Manufacturing Standard</i>
Carbon steel	ASTM A139 Grade B
Copper-bearing steel	ASTM A139 Grade B with the additional requirement that the steel contains a minimum of 0.20% copper
High-strength low-alloy steel	ASTM A606 Type 4
Stainless steel	ASTM A778
PVC*	ASTM F480
C. Two-ply steel-casing material properties:	
<i>Chemical Composition, Percent:</i>	
Carbon	0.20–0.30
Manganese	0.85–1.30
Phosphorus	0.05 maximum
Sulfur	0.05 maximum
Silicon	0.12 maximum
Copper	0.20 minimum
<i>Physical Properties:</i>	
Yield strength, psi (MPa)	55,000–70,000 (379–483)
Ultimate strength, psi (MPa)	80,000–95,000 (552–655)
Elongation, percent in 8 in. (200 mm)	17–25
Rockwell “B” hardness	80–90
Elastic ratio	69:73

* PVC: polyvinyl chloride.

in length. Longitudinal seams of the sections shall be welded and processed so that the outer casing fits snugly to the inner casing. The ends of the sections shall be lathe-trimmed square to the longitudinal axis so that the fit around the entire circumference will be snug when the ends are placed together. The circumferential joints of the inner sections shall be placed midway between the circumferential joints of the outer sections. After assembly, each outer circumferential joint shall be electrically welded.

4.3.5 *Well-screen material.* To reduce the possibility of corrosion, metallic well screen and its fittings should be fabricated of the same material. This material shall be AISI* Type 304 stainless steel unless otherwise specified. A manufacturer's certification of materials shall be provided to the purchaser by the constructor.

4.3.6 *Filter pack material requirements and impurity limits.*[†]

4.3.6.1 Specific gravity. The filter pack material shall have an average specific gravity of not less than 2.5.

4.3.6.2 Minimum specific gravity. Not more than 1 percent, by weight, of the material shall have a specific gravity of 2.25 or less.

4.3.6.3 Nonround pieces. Thin, flat, or elongated pieces, the maximum dimension of which exceeds three times the minimum, shall not be in excess of 2 percent, by weight.

4.3.6.4 Acid solubles. Not more than 5 percent of the filter pack material shall be soluble in hydrochloric acid.

4.3.6.5 Washed material. The material shall be washed and free of shale, mica, clay, dirt, loam, and organic impurities of any kind.

4.3.6.6 Metals. The material shall contain no iron, manganese, copper, lead, or other heavy metals in a form or quantity that will adversely affect the quality of the well water.

4.3.6.7 Gradation. Tests for gradation of filter pack material shall be performed according to the method of testing specified in ASTM C136.

4.3.6.8 Filter pack material to formation ratio. The ratio of grain size of filter pack material to formation material shall range from 6:1 to 4:1. Usually, the 50th or the 70th percentiles of the grain sizes retained of both materials are compared.

* American Iron and Steel Institute, 1140 Connecticut Avenue, Suite 705, Washington, DC 20036.

[†] Filter pack material testing procedures for specific gravity, acid solubility, and shape can be found in ANSI/AWWA B100.

4.3.6.9 Uniformity coefficient. The uniformity coefficient of the filter pack shall not exceed 2.5.

4.3.6.10 Distribution curve. The size-distribution curve of the filter pack shall parallel the central part of the formation-sand distribution curve for formation sands having a uniformity coefficient of less than 2.5.

4.3.6.11 Site-specific selection. No two vertical water supply wells are exactly the same. Therefore, filter pack materials and methods of placement must be selected on a site-specific basis. The filter pack materials and the thickness of the filter pack should be based on all of the information available, including production formation data, well screen, and filter pack materials that are practically and economically available. Purchasers, constructors, engineers, and others involved in vertical production water well design are urged to consult the various appendixes of this standard. They are also urged to consult reference books, such as the US Environmental Protection Agency's (USEPA's) *Manual of Water Well Construction Practices* (EPA-570/9-75-001), Johnson Screens's* *Ground Water and Wells*, and Roscoe Moss Company's† *Handbook of Ground Water Development*.

4.3.7 Grouting and sealing materials. The listed materials are commonly used for sealing wells. The purchaser must select sealing material on a site-specific basis.

4.3.7.1 Neat cement. Neat cement shall consist of a mixture of ASTM C150, Type I (similar to API Spec. 10, Class A) or ASTM C150, Type II (similar to API Spec. 10, Class B) Portland cement and water in the ratio of not more than 6.0 gal (22.8 L) of water per 94-lb (42.6-kg) sack of cement weighing approximately 118 lb/ft³ (1,880 kg/m³).

4.3.7.1.1 A maximum of 6 percent, by dry weight, unbeneficiated (not enhanced or "high yield") bentonite may be added to the neat cement grout. With bentonite additive, the mixture of cement and water should begin at the base ratio of 5.2 gal (19.7 L) of water per 94-lb (42.6-kg) sack of cement plus an additional 0.65 gal (2.5 L) of water per sack of cement for each 1 percent bentonite additive. Note also that the bentonite contribution to the mixture is affected by the mixing protocol, that is, whether the bentonite is mixed dry with the dry cement prior to adding mixing water or instead is added first to the mixing water (prehydrated) prior to the addition of cement. Prehydrated bentonite generates more effect, such that 1 percent of bentonite added first to the mixing water (prehydrated) has the same effect as 3.6 percent of bentonite by dry weight mixed first with the dry

* Johnson Screens, 1950 Old Hwy 8 NW, New Brighton, MN 55112.

† Roscoe Moss Company, 4360 Worth Street, Los Angeles, CA 90063.

cement. The additional gallons of mixing water required (0.65 gal of water for each 1 percent bentonite dry mixed) must be selected with consideration to the different mixing protocols and the relative effect of the bentonite in each protocol.

4.3.7.1.2 Type II (Class B) cement is resistant to moderate sulfate aggression (sulfate concentrations of 150–1,500 mg/L in groundwater). Hydrogeologic conditions in which ASTM C150 Type V cement (for sulfate concentrations exceeding 1,500 mg/L) might be considered would be encountered only infrequently for water supply wells.

4.3.7.2 Concrete. Concrete shall contain 5.3 sacks of ASTM C150, Type I or Type II Portland cement per cubic yard (0.76 m³) of concrete and a maximum of 7 gal (26.5 L) of water per 94-lb (42.6-kg) sack of cement. The maximum slump shall be 4 in. (102 mm). The aggregate shall consist of 47 percent sand and 53 percent coarse aggregate, conforming to ASTM C33.

4.3.7.2.1 The maximum size aggregate should be 0.75 in. (19 mm).

4.3.7.2.2 Concrete seal shall not be placed in an annular space having a radial thickness of less than 3 in. (76 mm).

4.3.7.3 Bentonite grout. Bentonite grout shall consist of a high-solids bentonite grout and water mixture with a minimum of 20 percent solids, mixed and placed in accordance with the manufacturer's written instructions. Conventional bentonite drilling clay and water mixtures are not allowed. Such products shall not impart harmful characteristics to the well and shall be mixed and placed according to the manufacturer's instructions.

4.3.7.4 Sand–cement grout. Sand–cement grout shall consist of a mixture of ASTM C150, Type 2 cement, sand, and water in the proportion of not more than 2 parts, by weight, of sand to 1 part of cement with not more than 6 gal (22.7 L) of water per 94-lb (42.6-kg) sack of cement.

Sec. 4.4 Well Casing

4.4.1 *General.* This section sets forth standards applicable to permanent casings for water wells. Selection of temporary casings used only for construction is left to the constructor unless otherwise specified by the purchaser.

4.4.2 *Permeation.* The selection of materials is critical for well casing in locations where there is a likelihood that the well casing will be exposed to significant concentrations of pollutants composed of low-molecular-weight petroleum products or organic solvents or their vapors. Documented research has shown that casing materials, such as polyethylene, polybutylene, polyvinyl chloride (PVC), and asbestos cement and elastomers used in gaskets and packing glands, are subject to

permeation by lower-molecular-weight organic solvents or petroleum products. If well casing must pass through such a contaminated area or an area subject to contamination, consult the manufacturer regarding permeation of casing materials and associated factors *before* selecting materials for use in that area.

4.4.3 *Permanent casings.* Permanent well casings shall be continuous and watertight from top to bottom of the installed casing, except for well screens.

4.4.4 *Casing diameter.* Casings shall meet the minimum diameter requirements given in Table 3.

4.4.5 *Casing wall thickness.* Well-casing wall thickness specified by the purchaser shall be sufficient to withstand anticipated formation and hydrostatic pressures and mechanical forces imposed on the casing during its installation, well development, and use. The minimum wall thickness tables (Tables 4 and 5) represent a committee judgment with respect to the minimum wall thickness normally necessary in the absence of unusual stresses to be placed on the casing in the course of installation and well development, corrosion, or use. Depths of well casing deeper than those listed in Tables 4 and 5 are not precluded but require a careful study of casing collapse strength. Selection of casing wall thickness merits analysis and judgment by experienced, qualified engineers and drilling experts. Actual wall thickness should, in each instance, be based on an analysis of the anticipated stresses to which the casing will be subjected during each phase of construction and any pertinent state or local requirements. An appropriate corrosion allowance shall be included.

Table 3 Standard well-casing sizes for wells

Maximum Diameter of Pump Assembly*		Minimum (Actual) Inside Diameter (ID) of Well Casing	
<i>in.</i>	<i>(mm)</i>	<i>in.</i>	<i>(mm)</i>
4	(101.6)	6	(152.4)
5	(127.0)	8	(203.2)
6	(152.4)	10	(254.0)
8	(203.2)	12	(304.8)
10	(254.0)	13	(330.2)
12	(304.8)	14	(355.6)
14	(355.6)	16	(406.4)
16	(406.4)	20	(508.0)
18	(457.2)	22	(558.8)
20	(508.0)	24	(609.6)
22	(558.8)	26	(652.6)

* For pumps larger than 22 in. (558.8 mm) in diameter, casing diameter shall be at least two nominal sizes larger than the diameter of the pump being installed.

Table 4 Minimum thickness for steel well casing—single casing

Depth of Casing <i>ft (m)</i>	Nominal Casing Diameter— <i>in. (mm)</i>									
	8 (203)	10 (254)	12 (305)	14 (356)	16 (406)	18 (457)	20 (508)	22 (559)	24 (610)	30 (762)
0–100 (0–30)	¼ (6.35)	¼ (6.35)	¼ (6.35)	¼ (6.35)	¼ (6.35)	¼ (6.35)	¼ (6.35)	⅝ (7.94)	⅝ (7.94)	⅝ (7.94)
100–200 (30–60)	¼ (6.35)	¼ (6.35)	¼ (6.35)	¼ (6.35)	¼ (6.35)	¼ (6.35)	¼ (6.35)	⅝ (7.94)	⅝ (7.94)	⅝ (7.94)
200–300 (60–90)	¼ (6.35)	¼ (6.35)	¼ (6.35)	¼ (6.35)	¼ (6.35)	⅝ (7.94)	⅝ (7.94)	⅝ (7.94)	⅝ (7.94)	⅜ (9.52)
300–400 (90–120)	¼ (6.35)	¼ (6.35)	¼ (6.35)	¼ (6.35)	⅝ (7.94)	⅝ (7.94)	⅝ (7.94)	⅝ (7.94)	⅜ (9.52)	⅜ (9.52)
400–600 (120–180)	¼ (6.35)	¼ (6.35)	¼ (6.35)	¼ (6.35)	⅝ (7.94)	⅝ (7.94)	⅝ (7.94)	⅜ (9.52)	⅜ (9.52)	⅞ (11.11)
600–800 (180–240)	¼ (6.35)	¼ (6.35)	¼ (6.35)	⅝ (7.94)	⅝ (7.94)	⅝ (7.94)	⅜ (9.52)	⅜ (9.52)	⅜ (9.52)	⅞ (11.11)
800–1,000 (240–300)	¼ (6.35)	¼ (6.35)	¼ (6.35)	⅝ (7.94)	⅝ (7.94)	⅝ (7.94)	⅜ (9.52)	⅞ (11.11)	⅞ (11.11)	½ (12.70)
1,000–1,500 (300–450)	¼ (6.35)	⅝ (7.94)	⅝ (7.94)	⅝ (7.94)	⅜ (9.52)	⅜ (9.52)	⅜ (9.52)	⅞ (11.11)	—	—
1,500–2,000 (450–600)	¼ (6.35)	⅝ (7.94)	⅝ (7.94)	⅝ (7.94)	⅜ (9.52)	⅜ (9.52)	⅞ (11.11)	⅞ (11.11)	—	—

* Reference Sec. 4.4.5 of A100-15 regarding thickness of well casings.

Table 5 Minimum thickness for two-ply steel well casing*

Depth of Casing <i>ft (m)</i>	Diameter— <i>in. (mm)</i>								
	10 (254)	12 (305)	14 (356)	16 (406)	18 (457)	20 (508)	22 (559)	24 (610)	30 (762)
0–100 (0–30)	12 (2.66)	12 (2.66)	12 (2.66)	12 (2.66)	10 (3.42)	10 (3.42)	10 (3.42)	10 (3.42)	8 (4.18)
100–200 (30–60)	12 (2.66)	12 (2.66)	12 (2.66)	10 (3.42)	10 (3.42)	10 (3.42)	10 (3.42)	8 (4.18)	8 (4.18)
200–300 (60–90)	12 (2.66)	12 (2.66)	10 (3.42)	10 (3.42)	10 (3.42)	10 (3.42)	8 (4.18)	8 (4.18)	8 (4.18)
300–400 (90–120)	12 (2.66)	12 (2.66)	10 (3.42)	10 (3.42)	10 (3.42)	8 (4.18)	8 (4.18)	8 (4.18)	8 (4.18)
400–600 (120–180)	10 (3.42)	10 (3.42)	10 (3.42)	10 (3.42)	8 (4.18)	8 (4.18)	8 (4.18)	8 (4.18)	8 (4.18)
600–800 (180–240)	10 (3.42)	10 (3.42)	10 (3.42)	8 (4.18)	8 (4.18)	8 (4.18)	6 (4.94)	6 (4.94)	6 (4.94)
800–1,000 (240–300)	10 (3.42)	8 (4.18)	8 (4.18)	8 (4.18)	8 (4.18)	6 (4.94)	6 (4.94)	6 (4.94)	6 (4.94)

* Values are US standard steel thickness gauge (mm).

4.4.5.1 Minimum thickness for carbon-steel casing. The purchaser shall specify the minimum wall thickness for carbon-steel casing.

4.4.5.2 Minimum thickness for plastic casing. The purchaser shall specify the minimum wall thickness for plastic casing.

Sec. 4.5 Well Screens

4.5.1 *General.* This section sets forth standards for screens to be used for water wells. All available information on the character of the water-bearing formation must be evaluated for proper well design. The screen length required to ensure a highly efficient well is determined by the thickness and hydrologic character of the aquifer.

4.5.2 *Screen diameter.* The diameter of the selected well screen shall not be less than the minimum size needed to maintain a vertical velocity within the screen barrel of not greater than 4 ft/s (1.22 m/s), based on the maximum well flow in gallons per minute specified by the purchaser. If it is anticipated that the pump setting will be into or below the screen, the minimum inside diameter of the screen shall conform to Table 3.

4.5.3 *Screen length.* The length of screen most appropriate for the well's construction must be selected with regard to the aquifer's thickness and stratigraphic layering, in addition to the various hydraulic factors affecting a well's performance and water quality. Where possible, the portion of the aquifer exposed to the screen should be sufficient to minimize the effects of partial penetration. In unconfined aquifers, the length and position of the screen required to negate partial penetration must be balanced against limiting the available drawdown. Stratigraphic layers varying in coarseness and permeability may also influence the length and position of screen selected.

The use of screen entrance velocity as one hydraulic consideration is discussed in Appendix L. Although screen entrance velocity has been used for many years as the primary hydraulic factor for selection of screen length, the lack of consensus regarding the most appropriate entrance velocity for design, and the fact that actual velocities cannot be known, discourage its use as the sole criterion. Other aspects affecting the well screen's hydraulic performance are discussed in Sec. 4.5.4.

4.5.4 *Other considerations.* As discussed in the foreword of this standard (Sec. II.A), hydraulic factors other than screen entrance velocity, such as approach velocities, turbulent versus laminar flow, and velocity distribution along the screen, are regarded as being of equal or greater influence on the performance of a well screen. In general, these factors vary with the specific discharge (flow per unit area)

at the screen face and at the filter–aquifer interface, regardless of the well screen’s open area. The user of this standard is encouraged to incorporate these additional design considerations during selection of screen length, as well as for establishing the diameters of the screen and borehole. By using these various additional considerations during design, the range of design options and performance can be better defined, from which the most appropriate well construction can be selected.

4.5.5 *Screen-aperture size.*

4.5.5.1 Naturally developed wells. In naturally developed wells, screen apertures shall be sized according to the following criteria:

1. Where the uniformity coefficient of the formation is greater than 6, the screen aperture shall be sized to retain 30–40 percent of the aquifer sample.
2. Where the uniformity coefficient of the formation is less than 6, the screen aperture shall be sized to retain 40–50 percent of the aquifer sample.
3. If the water in the formation is corrosive or the accuracy of the aquifer sample is in doubt, a size shall be selected that will retain 10 percent more than is indicated in items 1 and 2 in Sec. 4.5.5.1.
4. Where fine sand overlies coarse sand, use the fine-sand aperture size for the top 2 ft (0.61 m) of the underlying coarse sand. The coarse-sand aperture size shall not be larger than twice the fine-sand aperture size.

4.5.5.2 Filter packed wells. For filter packed wells, the screen-aperture openings shall be sized to retain between 80 and 95 percent of filter pack material.

4.5.5.3 Total aperture area. The total aperture area of most commercial well screens is normally sufficient to achieve satisfactory well performance and efficiency. In general, well capacity does not directly correspond to variations in aperture area among manufacturers and methods of screen construction. This concept is discussed further in Appendix L.

4.5.6 *Screen strength.* Screens shall be designed to minimize the possibility of damage during installation, development, and use.

4.5.7 *Screen construction.* The purchaser’s specifications shall dictate the type of well-screen construction using one of the following methods.

4.5.7.1 Punched- or louvered-pipe screens. Openings shall be punched in the casing screens in such a way that no material is removed from the casing wall. The spacing and size of openings shall be uniform.

4.5.7.2 Wire-wound continuous-slot screens. Continuous-slot wire-wound well screens shall be fabricated by circumferentially wrapping a triangular-shaped wire around an array of equally spaced rods. Each juncture between the

horizontal wire and the vertical rods shall be fusion welded underwater for maximum strength. The wire shape must produce inlet slots with sharp outer edges, widening inwardly to minimize clogging. Screen-end fittings shall be fabricated of the same material as the screen body and shall be securely welded to each section.

4.5.7.3 *Perforated-pipe base screens.* Pipe conforming to the well-casing standards specified in Sec. 4.4 shall be perforated with uniformly spaced and sized openings. Telescoped over this shall be a continuous-slot screen of AISI Type 304 stainless steel identical in construction to the requirements of Sec. 4.5.7.2.

4.5.8 *Screen joints.* Joints between screen sections and blank casing shall be welded or threaded and coupled. If welded, the welding rod shall be of equal quality to the most noble metal. The joint shall be watertight, straight, and as strong as the screen.

4.5.9 *Screen-to-casing seals.* The screen or screen casing shall be sealed to the well casing by one of the following methods.

4.5.9.1 *Elastomeric seals.* For naturally developed wells, a nonmetallic seal of neoprene or rubber made to fit the casing surrounding the screen shall be attached to the screen or screen casing to affect the seal. The screen or screen casing shall extend at least 5 ft (1.52 m) into the exterior casing.

4.5.9.2 *Grout seal.* If an elastomeric seal is not used on naturally developed wells, the space between the screen casing and casing surrounding the screen shall be filled with grout to form a seal at least 3 in. (76 mm) thick and 3 ft (0.91 m) long. The screen casing shall extend at least 5 ft (1.52 m) into the casing surrounding the screen.

4.5.9.3 *Filter pack screen casing seal.* Where the construction of the well is the filter packed type, and the screen casing extends at least 50 ft (15.2 m) into the casing above, and the space between the two is filled with filter pack material, no other seal will be required unless special local conditions warrant it or if it is required by local, state, or federal regulations. When the screen casing does not extend at least 50 ft (15.2 m) into the casing, a grout seal of at least 3 ft (0.91 m) in length shall be placed to fill the space between the two casings.

4.5.10 *Continuous casing and screen.* When the screen and casing are one continuous unit, joints may be of any of the types approved for casing in Sec. 4.7.4.1 and Sec. 4.5.8.

4.5.10.1 *Bottom of screen seals.* The bottom of the deepest screen or screen sump shall be sealed by any one of the following methods.

4.5.10.1.1 Threaded or welded plate. A threaded or welded plate shall be installed at the bottom of the screen or screen sump. The plate shall be made of the same material as that used for the screen or the screen sump to which the plate is attached.

4.5.10.1.2 Self-closing valve. A self-closing valve shall be installed at the bottom of the screen or screen sump and shall then be covered by a cement plug of at least 1 ft (0.30 m) in depth.

Sec. 4.6 Filter Pack

4.6.1 *General.* This section covers water-well construction where the filter pack material is installed in the annular space between the screen (and casing) and borehole for the purpose of stabilizing the formation.

4.6.2 *Filter pack thickness and location.* Selection of the filter pack thickness surrounding the screen is dependent on individual aquifer characteristics and should be based on individual site-specific aquifer information and construction criteria. The minimum thickness to allow for proper placement of filter pack material shall be 3 in. (77 mm), and the filter pack thickness usually does not exceed 12 in. (305 mm).

Filter pack material shall be placed in the annular space adjacent to the well screens and shall extend above the screen for at least 20 ft (6.10 m), subject to local regulatory requirements.

4.6.3 *Filter pack samples.* Samples of filter pack, including sieve analysis, shall be approved by the purchaser in advance of delivery and placement.

4.6.3.1 Grain-size distribution. Grain-size distribution information provided by the supplier shall be based on sampling and sieve analysis completed within 90 days of submittal of this information to purchaser. If supplier does not have available sieve analyses from within this period, then supplier shall provide purchaser a representative sample for analysis by an independent laboratory.

4.6.3.1.1 All samples shall be plainly labeled to indicate the source of the material, the date, and the name of the supplier.

4.6.3.2 Filter pack materials should be delivered to the jobsite sufficiently in advance of their scheduled emplacement in the well to allow for inspection and confirmation that the supplied grain-size distribution complies with that required for construction of the well. Prior to emplacement, representative composite samples equivalent to at least one sample for each 3 yd³ (2.3 m³) of filter material delivered, but no less than two samples regardless of volume, should be collected and submitted to an independent laboratory for sieve analyses.

4.6.3.3 *Method of sampling.* Method of sampling shall be according to ASTM D75 and ANSI/AWWA B100. Particular care is required to obtain representative composite samples from bulk shipments and semibulk containers (e.g., bags of 1 yd³ or 1 m³ in size). ANSI/AWWA B100 suggests several protocols for representative sampling, by collecting samples from the center of the semibulk container using a thief sampler or by dumping portions of the filter materials in an open-top box and compositing.

4.6.4 *Delivery and storage.* The filter pack material shall be delivered to the well site on approval by the purchaser.

4.6.4.1 *Bag or bulk delivery.* The material may be delivered in bags or in bulk.

4.6.4.2 *Contaminated material.* Filter pack material that comes in contact with the ground surface shall not be used, and all materials shall be protected from contamination until installed.

Sec. 4.7 Well Construction

4.7.1 *General.* Methods of construction and well configuration shall be selected based on aquifer configuration, intended well use, and local experience and regulations. (Typical types of well construction are covered in Appendix J.)

4.7.2 *Drilling methods.* Wells used for water supply are normally constructed by drilling. Drilling may consist of the cable-tool method or the direct or reverse rotary method.

4.7.2.1 *Cable-tool method.* With the cable-tool (percussion) method, drilling is accomplished by the breaking or crushing action of reciprocating drill tools suspended from the drilling machine on a wire line.

4.7.2.1.1 Depending on formation stability, an open hole can be drilled before installation of the casing and screen, or the casing can be installed coincident with drilling.

4.7.2.1.2 Seals and methods of sealing are discussed in Sec. 4.5.9 and Sec. 4.7.8.

4.7.2.1.3 Drive shoes are discussed in Sec. 4.7.4.2.

4.7.2.2 *Rotary method.* Rotary drilling is accomplished by the cutting, grinding, and rotary action of a rotating drill bit forced against the bottom of the hole. The material displaced by the bit is removed by the circulating drilling fluid.

4.7.3 *Drilling-fluid properties and tests.* During the drilling operation, when additives to freshwater are used, drilling-fluid properties shall be maintained within limits that will allow their complete removal from the water produced from the well, if necessary, and shall not damage the potential capacity, efficiency, or

quality of the well. Drilling-fluid properties shall be maintained during normal drilling operations within the following limits using test procedures conforming to API RP 13B-2:

1. Weight (fluid density)—limits: 9.4–11.4 lb/gal (1,126–1,366 kg/m³); test equipment: mud balance.
2. Viscosity—limits: 32–40 s/qt (30–38 s/L) [clear water 26 s/qt (25 s/L)]; test equipment: 1-qt mud cup, Marsh funnel, and stopwatch.
3. Filtration (wall cake and filtration loss)—limits: $\frac{3}{32}$ in. (2.38 mm) with maximum 20-cc water loss in 30 mins; test equipment: filter press, graduated cylinder, and stopwatch.
4. Sand content (solids larger than 200 mesh)—limits: 2–4 percent, by volume; test equipment: sand-content set.

4.7.3.1 Frequency of drilling-fluid property tests. Drilling-fluid properties shall be tested once for every 50 ft (15.2 m) of hole drilled or 4 h of circulating time, whichever is more frequent.

4.7.3.2 Recording. The drilling-fluid properties set forth in this standard shall be measured and recorded.

4.7.4 *Well-casing installation.* The method of well-casing installation shall be at the option of the drilling constructor, provided that the installation meets the requirements of Sec. 4.7.9 and the installation process does not alter the shape, size, configuration, or strength of the casing.

4.7.4.1 Casing joints. Casing joints shall be of the types listed in Table 6.

4.7.4.2 Drive shoes. Special steel drive shoes used when the casing is pushed or driven shall be heat-treated (Rockwell C Hardness 30–32) SAE 1040 steel ring or equivalent.

4.7.4.3 Sealing of well casing. Well casing shall be sealed in accordance with Sec. 4.7.8.

4.7.5 *Well-screen installation.* Well screens installed in filter pack wells shall be centered in the hole. A sufficient number of centralizing devices shall be used to ensure concentricity.

Table 6 Casing joints

Casing Material	Type of Joint	Standard
Steel	Welded or threaded and coupled	ANSI/AWWA C206*
Plastic	Threaded and coupled, solvent-welded, or spline locked	ASTM F480
Two-ply	Welded	ANSI/AWWA C206

* C206 covers field welding only.