American Water Works Association

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AWWA Standard

Polyacrylamide

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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.

SEC. PAGE

Foreword

I Introduction vii
I.A Background vii
I.B History ix
I.C Acceptance (water supply service applications) ix
I.D Acceptance (wastewater service applications) xi
II Special Issues xi
II.A Safety xi
II.B Spill Control xi
III Use of This Standard xi
III.A Purchaser Options and Alternatives xi
III.B Product Performance xiii
III.C Modification to Standard xiii
IV Major Revisions xiii
V Comments xiv

Standard

1 General
1.1 Scope 1
1.2 Purpose 1
1.3 Application 1

2 References 2

3 Definitions 2

4 Requirements
4.1 Product Certifications/Affidavit of Compliance 4
4.2 Description 4
4.3 Qualifications 5
4.4 Chemical and Physical Requirements 5
4.5 Impurities (Water) 7
4.6 Additives Requirements (Water) 8
4.7 Impurities (Wastewater) 9
4.8 Additives Requirements (Wastewater) 9
4.9 Product Technical Data Sheet 10

5 Verification
5.1 General 13
5.2 Sampling 13
5.3 Visual Inspection 13
5.4 Test Procedures 14
5.5 Solution Preparation 21
5.6 Product Performance 24
5.7 Residual Acrylamide Monomer 26
5.8 Notice of Nonconformance 26
5.9 Manufacturing Location Contact for Quality Control Inquiries 27

6 Delivery
6.1 Marking 27
6.2 Packaging and Shipping 28
6.3 Product Technical Data Sheets 29
6.4 Affidavit of Compliance or Certified Analysis 29

Tables

1 Typical Concentrations and Ranges for determining Brookfield Viscosity 7

Foreword

This foreword is for information only and is not a part of ANSI/AWWA B453.*

I. Introduction.

I.A. *Background.* Chemical clarification methods have been used to improve the quality of drinking water supplies since the late 1880s. In 1967, the first completely synthetic organic polyelectrolyte was accepted by the US Public Health Service for use in treatment of potable water. The responsibility for accepting additives for drinking water treatment was subsequently assumed by the US Environmental Protection Agency (USEPA) and administered by their Office of Drinking Water as an advisory program. USEPA's acceptance was by the specific name of the suppliers' product and not by generic type. Polyacrylamide is one of several types of synthetic organic polyelectrolytes that were accepted for use in potable water treatment under this program, which was discontinued in 1990.

Polyacrylamides (PAMs) belong to a large family of synthetic organic polyelectrolytes (also called polymers or flocculants) used in water and wastewater treatment to improve the performance of some unit operations in the treatment process, most often by increasing the extent or rate of liquid–solids separation. PAMs may have an anionic, nonionic, or cationic charge and always have a high molecular weight relative to most other polymer types. Because their high molecular weight makes relatively dilute solutions of PAMs highly viscous, PAMs cannot be sold as concentrated aqueous solutions. PAMs are manufactured in the following product forms: emulsions, dry, dilute viscous solutions, and aqueous solutions. For potable water supply service, emulsion and dry forms are most frequently used. All product forms are used for wastewater service. A subclass of PAMs, aminomethylated PAM, also known as Mannich polymers, are only used in wastewater service and are manufactured in dilute, highly viscous solutions.

Nonionic PAMs are made by polymerizing acrylamide monomer. Anionic PAMs are made by copolymerizing acrylamide monomer with an anionic monomer or by alkaline hydrolysis of nonionic PAM. The anionic monomers most widely used are acrylic acid and acrylic acid salts. Cationic PAMS, with the exception of Mannich polymers, are made by copolymerizing acrylamide monomer with a cationic monomer. Several different cationic monomers are used. Mannich polymers are made by reacting dimethylamine and formaldehyde with solution PAM.

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Certain properties of the polymer, such as molecular weight, can be varied by controlling the polymerization reaction. The charge density of PAM copolymers is varied by adjusting the relative amount of anionic or cationic monomer added to the polymerization. Acrylamide monomer is made from acrylonitrile.

Dry PAM that is flake, dry powder, or granular is usually manufactured by first polymerizing the monomer(s) in aqueous solution to form a gel and then drying and grinding the gel. Emulsion PAM is usually manufactured by first emulsifying droplets of monomer(s) and water in a hydrocarbon solvent before polymerization is initiated. Emulsion PAMs contain some surfactants to keep the emulsion from separating and to aid in the dissolution of the PAM upon mixture with water at a specified ratio. The liquid polymerized emulsion is sold as manufactured or further modified to remove water or hydrocarbon solvent. Solution PAM can be manufactured by aqueous polymerization of the monomer(s) or by dissolving emulsion-form or dry-form PAM in water. Aqueous dispersions are manufactured by first emulsifying droplets of monomer(s) in water containing inorganic salt(s) before polymerization is initiated.

Important concepts to remember regarding PAMs include the following:

1. PAMs differ from polyDADMAC polymers (ANSI/AWWA B451, Poly [Diallydimethylammonium Chloride]) and epichlorohydrin-DMA polymers (ANSI/AWWA B452, EPI-DMA Polyamines) in their use, handling, storage, and solution preparation.

2. PAMs are not one polymer but instead a large family of polymers that differ in product form, charge type, charge density, molecular weight, and other properties.

3. The nomenclature used to describe the four forms in which PAMs are supplied follows:

   a. Dry (also called flake, powder, granular, or bead).

   b. Emulsions (also called liquids, dispersions, or inverse emulsions).

   c. Solutions (also called liquids, aqueous solutions, or viscous solutions).

   d. Aqueous dispersions (also called oil-free emulsions, water dispersions, brine dispersions).

4. The physical properties of a PAM cannot be used to judge product performance; only laboratory testing, pilot plant studies, or full-scale plant trials can discern product efficacy.

5. PAMs may or may not contain inactive ingredients such as hydrocarbon solvents, surfactants, and salts, depending on the product form, manufacturing method, and formulation. The typical primary components of each form can be described generically as follows:

a. Dry (PAM, moisture [water]; may contain inert inorganic salts or inert organic compounds).

b. Emulsions (PAM, hydrocarbon oil, water, surfactants). The amount of hydrocarbon oil is typically, but not limited to, 20 percent to 50 percent by weight of the emulsion.

c. Solution (usually a dilute, viscous, aqueous solution of dry or emulsion form PAM; refer to the aforementioned primary components).

d. Aqueous dispersions (PAM, water, salts) in which the PAM is suspended in aqueous solution of inorganic salts. Aqueous dispersion PAMs are currently used for wastewater treatment and may be introduced in the future for potable water supply treatment if they meet appropriate approvals. These products contain no hydrocarbon oil or surfactants.

6. The storage, dissolution, and feeding of PAMs may require specific procedures, considerations, and equipment that are unique for each product form. Failure to use the proper storage equipment and conditions, dissolution procedure and equipment, and feeding equipment and design can result in loss of activity, the formation of insoluble gels, loss of feeding, and increased maintenance problems.

7. The user should consult both the product technical data sheet and the safety data sheet (SDS, also known as material safety data sheet [MSDS]) for the specific PAM product being used for information on the product's composition, physical properties, safety procedures, feeding and storage guidelines, and other important information. The supplier must provide to the user copies of the product technical data sheet, along with the MSDS in some circumstances, in accordance with this standard.

I.B. *History.* The AWWA Standards Council authorized the development of this standard in 1979. The standard was developed by the AWWA Standards Committee on Polyelectrolytes and was approved by the AWWA Board of Directors on Feb. 4, 1996. The AWWA Board of Directors approved subsequent editions of this standard on June 17, 2001, and Feb. 12, 2006. This edition of this standard was approved by the AWWA Board of Directors on June 9, 2013.

I.C. *Acceptance (Water Supply Service Applications).* 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 American Water

* NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48113.

Works Association Research Foundation (AwwaRF, now Water Research Foundation) 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 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.

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

Annex A, "Toxicology Review and Evaluation Procedures," to NSF/ANSI 60 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 B453 addresses additives requirements in Sec. 4.6 (Water) and Sec. 4.8 (Wastewater) of the standard. The transfer of contaminants from chemicals to processed water or to residual solids is becoming a problem of great concern. The language in Sec. 4.6.1. is a recommendation only for direct additives used in the treatment of potable water to be certified by an accredited certification organization in accordance with NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects. However, users of the standard may opt to make this certification a requirement for the product. Users of this standard should consult the appropriate state, provincial, or local agency having jurisdiction in order to

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

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

I.D. *Acceptance (Wastewater Service Applications).* In 2008, the AWWA Standards Council directed standards committees to incorporate wastewater applications into its standards. This is the first revision of ANSI/AWWA B453 that addresses wastewater service applications and standards.

II. Special Issues.

II.A. *Safety.* PAMs are not considered to be as toxic as some household products nor are they considered to be primary skin or eye irritants as defined by the Consumer Product Safety Commission (US Federal Hazardous Substances Act). Good housekeeping procedures and personal cleanliness are recommended when handling polyacrylamides. The products may contain trace amounts of acrylamide monomer, which has been shown to be toxic. The MCL for acrylamide of 0.05 percent in polyacrylamide products is lower than that which would require labeling under the Occupational Safety & Health Administration (OSHA) Hazard Communication Standard.

Safety glasses should be worn when handling emulsion or solution forms of PAM and, although not required, when handling the dry form. Appropriate first-aid practices should be followed in all cases of exposure. In case of eye contact, flush with plenty of water for at least 15 min and call a physician. Emulsion-form PAMs contain hydrocarbon solvents whose vapors can cause nausea, headaches, and other symptoms. Consult the MSDS for the specific product for safety information and procedures before handling any PAM product.

II.B. *Spill Control.* Dispose of PAMs according to federal, state or provincial, and local regulations. Solutions of PAMs make floors and other surfaces extremely slippery. A dike should be formed around the spill area to contain as much spilled material as possible and the contained material should be shoveled, scooped, or pumped, as appropriate, into suitable disposal containers. Any remaining material should be adsorbed on vermiculite or other suitable adsorbing material and placed in a sealed metal container for disposal. The spill area should be thoroughly washed with water only after all possible polymer has been scooped up, absorbed, or wiped up. Use of warm water is beneficial.

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.* This AWWA standard can be used to prepare a purchase specification but is not itself a specification because it cannot address requirements unique to the purchaser's specific situation, nor does it establish business relationships or set additive requirements (MCL or maximum-use dosage). In addition, this PAM standard does not establish physical and chemical property specifications for any one PAM product for two reasons: (1) PAMs are a broad family of products differing widely in properties and product form, and (2) physical and chemical properties of PAMs do not always relate to their performance as a flocculant in specific applications.

Below are requirements that the user might consider when developing a PAM polymer purchase specification. This standard requires the supplier to provide a product technical data sheet in addition to an MSDS for each product and also requires specific information to be included in the product technical data sheet. The information in a product technical data sheet may be used to establish or comply with purchase specifications.

1. Standard used—that is, ANSI/AWWA B453, Polyacrylamide, of latest revision.

2. Compliance with the latest revision of ANSI/AWWA B453, Standard for Polyacrylamide for potable water supply service applications (water) or wastewater service applications (wastewater), as applicable.

3. Description of application.

4. Estimation of annual purchase requirements (pounds/kilograms).

5. Typical order quantity (number of containers and pounds/kilograms product).

6. Shipping address (destination).

7. Special delivery requirements (need for a truck with a lift gate; length and coupling sizes of hoses needed for bulk delivery; transfer pump; allowed times of delivery; limitations on truck size or weight; sampling protocol; other). Are there any product physical property limitations such as a maximum viscosity that cannot be handled by the storage or feed equipment?

8. Order lead time (the number of days between order placement and delivery necessary if typical lead times are insufficient).

9. Billing address.

10. Financial terms.

11. Insurance/performance bond requirements.

12. Details of other federal, state or provincial, and local requirements (Section 4).

13. For potable water applications, whether compliance with NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects, is required (Sec. 4.6.4).

14. Active polymer concentration in the product expressed as a weight percent (Sec. 4.9).

15. Specific physical and chemical properties for quality control. Minimum specifications should include visual inspection, total solids, Brookfield viscosity range, and pH of product's solution. Verification of physical and chemical properties should be by the methods specified in Section 5, Verification, or by other methods acceptable to both purchaser and supplier.

16. Sampling requirements (Sec. 5.2).

17. Requirement for supplier to provide manufacturing-location contact information for quality control inquiries (Sec. 5.9).

18. Marking requirements (Sec. 6.1).

19. Packaging and shipping requirements (Sec. 6.2). State any alternative security measures desired that have been adopted to replace or augment the security measures set out in Sec. 6.2.1 and 6.2.2.

20. State whether the purchaser may reject product from tank trucks (bulk), containers, or packaging with missing or damaged seals. State whether the purchaser may reject product if it fails to meet specifications determined by testing from bulk containers or packages with missing or damaged seals unless the purchaser's tests of representative samples, conducted in accordance with Sec. 5.2 through 5.5, demonstrate that the product meets the standard. Failure to meet the standard or the absence of, or irregularities in, seals may be sufficient cause to reject the shipment. State whether a chain of custody is desired (Sec. 6.2.2.2).

21. Whether alternative security measures have been adopted to replace or augment the security measures set out in Sec. 6.2.1 and 6.2.2.

22. Affidavit of compliance or certified analysis, or both, if required (Sec. 6.4).

III.B. *Product Performance.* Performance evaluation via a laboratory test or pilot plant or plant trial or other performance test is essential for confirming PAM activity (Section 5.6).

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

IV. Major Revisions. Major changes made to the standard in this edition include the following:

1. Requirement that suppliers provide product technical data sheets along with MSDSs.

2. Requirement that product technical data sheets contain specific information.

3. Introduction of a limit for ethoxylated nonylphenols in PAMs, which have been used in emulsion-form PAMs.

4. Clarification of aggregating the applied dosages of multiple applications of PAM polymers in a single water treatment plant in order to determine whether the maximum use limit has been exceeded.

5. Improved guidance on establishing purchasing specifications.

6. Inclusion of a requirement for compliance with the Safe Drinking Water Act and other federal regulations.

7. Inclusion of a requirement for tamper-evident packaging (Sec. 6.2.1 and 6.2.2).

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 standards@awwa.org.

ANSI/AWWA B453-13
(Revision of ANSI/AWWA B453-06)

American Water Works Association

AWWA Standard

Polyacrylamide

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard describes polyacrylamide (PAM) for use in the treatment of potable water, wastewater, and reclaimed water.

Sec. 1.2 Purpose

The purpose of this standard is to provide the minimum requirements for PAM products, including physical, chemical, packaging, shipping, and testing requirements and to provide the means of developing requirements for PAM products.

Sec. 1.3 Application

This standard can be referenced in documents for purchasing and receiving PAM products and can be used as a guide for testing the physical and chemical properties of PAM product samples. The stipulations of this standard apply when this document has been referenced and then only to PAM products used in the treatment of potable water, wastewater, and reclaimed water. Each section or subsection of this standard shall apply to both water supply service applications and wastewater service applications, unless the section or subsection states that it applies only to water supply service applications or the word *water* is stated in the title, or the section or subsection states that it applies only to wastewater service applications or the word *wastewater* is stated in the title.

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.

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

40 CFR 141.111, *US Code of Federal Regulations* (CFR). Treatment Techniques for Acrylamide and Epichlorohydrin.

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Day:* A day is defined as a 24-hr period.

2. *Dry:* A polymer product form in which the polymer is a solid particle (also called *flake*, *dry*, *granular*, or *bead*).

3. *Emulsion:* A liquid polymer product form in which the polymer is present as discontinuous particles suspended in a hydrocarbon solvent (also called *liquid*, *dispersion*, or *inverse emulsion*).

4. *Manufacturer:* The party that manufactures, fabricates, or produces PAM products.

5. *Polyacrylamide (PAM):* Nonionic homopolymers of acrylamide; anionic copolymers of acrylamide; and anionic monomers, such as acrylic acid, cationic copolymers of acrylamide, and cationic monomers; and aminomethylated polyacrylamide (Mannich polymers).

6. *Polymer:* The PAM polymer in the product. Also called the *active* polymer.

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

8. *Product:* The commercial substance "as sold" containing polymer. Products may contain substances other than PAM such as water, hydrocarbon solvents, surfactants, and salts, the presence of which may be related to the product

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form. Product form may be a liquid emulsion, dry, viscous solution, or aqueous emulsion.

9. *Product technical data sheet:* A document that provides technical information, including the specific information required in Sec. 4.9, for the specific product in question.

10. *Purchaser:* The person, company, or entity that purchases any materials, products, or services to be performed.

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

12. *Solution:* A polymer product form in which the polymer is an aqueous solution (also called *liquid*, *aqueous solution*, or *viscous solution*).

13. *Supplier:* The party that supplies material, products, or services. A supplier may or may not be the manufacturer.

14. *Tamper-evident packaging:* Packaging having one or more indicators or barriers to entry which, if breached or missing, can reasonably be expected to provide visible evidence to the purchaser that tampering has occurred. The tamper-evident features of the packaging shall be designed to, and shall, remain intact when handled in a reasonable manner during manufacture, storage, shipment, and delivery to the purchaser. Properly constructed, labeled, and sealed drums, returnable bins, pails, or bulk containers constitute effective forms of tamper-evident packaging.

15. *Wastewater:* A combination of the liquid and water-carried waste from residences, commercial buildings, industrial plants, and institutions, together with any groundwater, surface water, and stormwater that may be present.

16. *Wastewater service applications:* The application of polymer for the treatment of wastewater for any purpose other than for water supply service applications.

17. *Water supply service applications:* The application of polymer for the treatment of water for public consumption (potable water).

SECTION 4: REQUIREMENTS

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

Sec. 4.1 Product Certifications/Affidavit of Compliance

4.1.1 *Water supply service applications.* PAM is a direct additive used in the treatment of potable water. This product should be certified as suitable for contact with or treatment of drinking water by an accredited certification organization in accordance with NSF/ANSI Standard 60. Evaluation shall be accomplished in accordance with requirements that are no less restrictive than those listed in NSF/ANSI 60. Certification shall be accomplished by a certification organization accredited by the American National Standards Institute.

4.1.2 *Wastewater service applications.* PAM is a direct additive used in the treatment of wastewater. PAM in solution or dry form does not need to be certified as having been manufactured in accordance with this standard because there are no specific additive (content) requirements in this standard that apply. However, the user may wish to require the use of this standard's requirements with respect to product marking, packaging and shipping including security requirements, nonconformance, manufacturing location identification, quality control test procedure, and product technical data sheet information requirements. PAM in emulsion form should be certified by its manufacturer or supplier or an accredited certification organization as suitable for use in wastewater service applications in accordance with requirements that are no less restrictive than those of this standard, and reclaimed water systems as applicable.

4.1.3 *Affidavit of compliance.* The purchaser may require an affidavit from the manufacturer or supplier that the PAM product provided complies with all applicable requirements of this standard for either water supply service applications or for wastewater service applications, as applicable. Product technical data sheets are required to state whether the product meets the requirements of this standard for water supply service applications and, for emulsion form PAMs only, wastewater service applications. For products certified for water supply service applications, the product technical data sheet is required to state the certifying organization that approved the use of the product for potable use based on NSF/ANSI 60 and the maximum use level permitted by that certification.

Sec. 4.2 Description

Polyacrylamides (PAMs) belong to a large family of synthetic organic polyelectrolytes (also called *polymers* or *flocculants*) used in water and wastewater treatment to improve the performance of some unit operations in the treatment process, most often by increasing the extent or rate of liquid–solids separation. PAMs may have an anionic or cationic charge or may be nonionic. PAMs are manufactured in the following product forms: emulsions, dry, dilute viscous solutions, and aqueous dispersions. For potable water supply service, emulsion and dry forms are most frequently used. All product forms are used for wastewater service. A subclass of PAMs, aminomethylated PAM, also known as Mannich polymers, are only to be used in wastewater service and are manufactured in dilute, highly viscous solutions.

Nonionic PAMs are made by polymerizing acrylamide monomer. Anionic PAMs are made by copolymerizing acrylamide monomer with an anionic monomer or by alkaline hydrolysis of nonionic PAM. The anionic monomers most widely used are acrylic acid and acrylic acid salts. Cationic PAMS, with the exception of Mannich polymers, are made by copolymerizing acrylamide monomer with a cationic monomer. Several different cationic monomers are used. Mannich polymers are made by reacting dimethylamine and formaldehyde with solution PAM.

Certain properties of the polymer, such as molecular weight, can be varied by controlling the polymerization reaction. The charge density of PAM copolymers is varied by adjusting the relative amount of anionic or cationic monomer added to the polymerization.

Sec. 4.3 Qualifications

Because PAMs are a broad family of polymers, which are manufactured in multiple product forms, qualifications for the physical and chemical requirements described in Sec. 4.5 cannot be generically established. None of the physical or chemical requirements in this standard can be used to identify the PAM product with the best performance in a specific application prior to performance testing. Only actual performance testing can determine which PAM performs best. Therefore, these requirements are best used to ensure product quality and uniformity after a specific PAM product has been chosen for use.

Sec. 4.4 Chemical and Physical Requirements

Chemical and physical requirements shall be determined by the purchaser from the supplier's product technical data sheet in accordance with the information required by this standard to be in the product technical data sheet (Sec. 4.9), using the methods specified in Section 5. Verification, or other methods acceptable to both the purchaser and supplier. Certain parameters in the product technical data sheet, as stated in Sec. 4.9, are not to be used to establish chemical or physical requirements. The purchaser and supplier may mutually agree to other chemical and physical requirements.

4.4.1 *Appearance (visual inspection).*

a. Dry form: White to off-white, free-flowing powder, granular, flake, or bead. May have a slight ammonia odor.

b. Emulsion form: Transparent, translucent, or opaque white, free-flowing, moderately viscous liquid with a hydrocarbon odor. Separation of a clear hydrocarbon layer on top may occur. Gels or insoluble particles should be absent.

c. Solution form: Transparent, translucent, or opaque white viscous liquid. Gels or insoluble materials should be absent.

d. Aqueous dispersion form: Transparent, translucent, or opaque white, free-flowing, moderately viscous liquid. Gels or insoluble particles should be absent.

4.4.2 *Particle size distribution.*

a. Dry form: Varies with particle type; typically 99 percent less than 1.7 mm and 92 percent greater than 0.15 mm for granular powders.

4.4.3 *Moisture content.*

a. Dry form: Varies with product; typically less than 10 percent but may reach 15 percent. Moisture content increases with increasing charge density.

4.4.4 *Total solids.*

a. Dry form: Varies with product; typically ranges from 85 percent to 100 percent by weight.

b. Emulsion form: Varies with product and manufacturing procedure; typically ranges from, but is not limited to, 20 percent to 60 percent by weight.

c. Solution form: Varies with product and manufacturing procedure; typically, but not limited to, less than 10 percent, often less than 5 percent.

d. Aqueous dispersion form: Varies with product.

The total solids of a PAM product may be the same as or greater than the active polymer content. Total solids and active polymer content may be different because of the possible presence of inert or inactive ingredients.

The supplier must provide the polymer content (active polymer concentration) of each specific product, regardless of the product form (See Sec. 4.9). The difference between the measured total solids and the supplier's stated active polymer content is the nonvolatile inert or inactive content of the product. Requirements vary with each product.

4.4.5 *Bulk Brookfield viscosity.* The bulk Brookfield viscosity (viscosity of a liquid form PAM product as sold) of emulsion, solution, or aqueous dispersion form PAM varies with each product. Emulsion-form PAM products are typically, but not limited to (not a specification), a bulk viscosity range of 200 to 4,000 centipoise. The

Table 1 Typical concentrations and ranges for determining Brookfield viscosity

Form	Product Solution (Weight %) Typical	Product Solution (Weight %) Range	Viscosity Requirements
Dry	0.1%	0.1%–1.0%	Varies with product
Emulsion	0.5%	0.2%–1.0%	Varies with product
Solution	5.0%	1.0%–15.0%	Varies with product
Aqueous dispersion	NA	NA	Varies with product

NA—not available

bulk viscosity of solution-form PAM products can range up to tens of thousands of centipoise. The bulk viscosity of aqueous dispersion–form PAM varies with each product.

4.4.6 *Brookfield viscosity of a specific solution concentration.* The range of concentrations and most frequently used concentration (typical) chosen to specify the Brookfield viscosity of a PAM product after it has been dissolved are given in Table 1. Requirements vary with each product.

4.4.7 *Standard viscosity.* Requirements vary with each product.

4.4.8 *pH of a solution.* Requirements vary with each product.

Sec. 4.5 Impurities (Water)*

4.5.1 *Absence of deleterious substances.* PAM supplied according to this standard shall contain no soluble inorganic or organic substances in quantities capable of producing deleterious or injurious effects to the health of those consuming water that has been properly treated with PAM in accordance with the supplier's recommendations and within the maximum allowed dosage.

4.5.2 *Residual acrylamide.* The Phase II Rule National Primary Drinking Water Regulations issued by the US Environmental Protection Agency regulates acrylamide monomer sourced from PAMs (flocculant) as follows: maximum contaminant level (MCL)—0.05 percent dosed at 1 mg/L (or equivalent); maximum contaminant level goal (MCLG)—0. These treatment technique requirements (per 40 CFR 141.111) became effective July 1992. Residual acrylamide monomer levels shall be no greater than 0.05 percent by weight of the active polymer content at a dose of 1 mg/L active PAM polymer or equivalent based on the combination (or product) of active polymer dose and monomer level.

* See Sec. I.C of the foreword.

4.5.3 *Other impurities.* Dry-form PAM products may contain sodium chloride or other inert substances. Emulsion-form PAM products contain hydrocarbon solvent and surfactants and may contain other inert substances. Solution-form PAM products' inert ingredients may include those that are present in the emulsion-form or powder-form PAM from which they are usually prepared.

Sec. 4.6 Additives Requirements (Water)

The user of PAMs shall comply with the following additive requirements:

4.6.1 *Product certifications.* The PAM product should be certified as suitable for contact with, or treatment of, drinking water by an accredited certification organization in accordance with NSF/ANSI Standard 60. Certification shall be performed by a certification organization accredited by the American National Standards Institute. The certification protocol shall require annual random retesting of the product.

4.6.2 *Maximum use level.* The maximum use level shall be specified for each specific PAM product by the agency certifying the product under NSF/ANSI Standard 60.

4.6.3 *Multiple uses of PAM products.* The user of PAM should be aware of the possibility that there may be more than one application of PAM products in their water supply system and that the maximum use level and any other additive requirements apply to the aggregate of the maximum effective use levels of applications of PAM to the water, including applications within the water treatment plant. The following method may be used to estimate the aggregate effective dosage of multiple applications of PAM over an entire year:

a. Determine PAM polymer applications that have been used in your water system over the past year.

b. Exclude from further calculations the usage of any PAM product where both the water and solids it contacts do not subsequently come in contact with water that will become potable water. For example, if sludge dewatering is done by a belt press and the sludge it produces is not recycled in the plant and the filtrate is discharged to a sewer and not recycled within the plant, the PAM used to treat the belt press sludge feed can be excluded from the calculation.

c. Determine the quantity of each PAM polymer used over the year.

d. Multiply the amount of each PAM product used by its active polymer content (percent).

e. Add the active polymer amounts of each PAM product used from d, above.

f. Divide the sum from e, above, by the total amount (weight) of water treated by the water system over the same period of time.

g. If the resulting aggregate active PAM dosage exceeds 1 mg/L, reduce the usage of PAM products so that the aggregate dosage calculated in f, above, does not exceed 1 mg/L. The current US Environmental Protection Agency Acrylamide Treatment Technique dosage limit of 1 mg/L applies at all times.

4.6.4 *Any federal, state or provincial, and local requirements, including approval, certification, and additive requirements.* The 1 mg/L limit stated above may change if NSF Standard 60 certifying agencies start to establish maximum use levels for dry PAM products above 1 mg/L.

Sec. 4.7 Impurities (Wastewater)

4.7.1 *Absence of deleterious substances.* PAM supplied according to this standard shall contain no substances in quantities capable of producing deleterious ecotoxicological effects to the receiving water into which wastewater treated with PAM in accordance with the supplier's recommendations and this standard is discharged.

4.7.2 *Mannich polymers.* Mannich polymers may contain acrylamide monomer, dimethylamine, dimethylaminomethanol, dimethylformamide, tetramethylenediamine, and formaldehyde. The user of Mannich polymers should be aware that dimethylamine may react with disinfectants and other compounds to form N-nitrosodimethylamine (NDMA).

4.7.3 *Other impurities.* Dry-form PAM products may contain sodium chloride or other inert substances. All emulsion-form PAM products contain hydrocarbon solvent and surfactants and may contain other inert substances. Solution-form PAM products' inert ingredients may include those that are present in the emulsion- or powder-form PAM from which they are usually prepared.

Sec. 4.8 Additives Requirements (Wastewater)

The user of PAM shall comply with the following additive requirements:

1. Any federal, state or provincial, and local requirements, including approval, certification, and additive requirements.

2. For PAM manufactured in the emulsion form that contains nonylphenol, ethoxylates, or ethoxycarboxylates of nonylphenol, the maximum use level shall be limited so as not to exceed the Freshwater or Saltwater Chronic Criterion for nonylphenol, as applicable, calculated as the concentration of nonylphenol exclusive of any ethoxylate or ethoxycarboxylate groups. In the United States, use

the Final Aquatic Life Ambient Water Quality Criteria for Nonylphenol (USEPA). In Canada, use the Canadian Water Quality Guidelines for the Protection of Aquatic Life: Nonylphenol and its Ethoxylates (Canadian Council of Ministers of the Environment).

Sec. 4.9 Product Technical Data Sheet

The following specific information shall be provided for each product on a product technical data sheet, which shall be provided by the supplier as specified in Sec. 6.3:

4.9.1 *Polymer type.* State polyacrylamide.

4.9.2 *Active polymer concentration.* The weight percent active PAM polymer in the product as manufactured. For nonionic PAM products, this shall be expressed as the weight percent polyacrylamide in the product. For anionic PAM products, this shall be expressed as the weight percent acrylamide and anionic monomers in the product after the anionic monomer's weight is, if necessary, adjusted to having single hydrogen atom counterion for each acid group. For cationic PAM products formed by copolymerization, this shall be expressed as the weight percent acrylamide and cationic monomers in the product after the cationic monomer's weight is, if necessary, adjusted to having a single chloride atom counterion for each quaternary nitrogen group. The weight percent active PAM polymer in Mannich polymers and other amine-group-containing PAMs shall be expressed as the weight percent of the polymer reactants added. The weight percent active polymer concentration or range thereof shall be expressed to the nearest one tenth of a percent.

4.9.3 *Relative molecular weight among PAMs.* Report the relative viscosity average or weight average molecular weight in millions of grams/mole and state the specific test method used to estimate the molecular weight (i.e., capillary flow viscosity, Brookfield UL rotational viscosity, other). The user is cautioned against comparing PAM molecular weights determined by different test methods as each test method can produce a significantly different (100% or more) molecular weight. Relative molecular weight information should be used to relate products within a single supplier's product line whose molecular weights were determined by the same method and cannot be used as a purchase specification or for quality control purposes.

4.9.4 *Charge type.* Report PAM as nonionic, anionic, cationic, or amphoteric.

4.9.5 *Relative charge density.* For cationic copolymers, state as the mole percent cationic monomer. For anionic PAM, state as the mole percent anionic monomer or hydrolyzed acrylamide groups. For Mannich polymers, state based on the mole percent of formaldehyde or dimethylamine added, whichever is less.

4.9.6 *Product form.* State as one of the following: aqueous solution, emulsion (or dispersion), dry (or granular, flake or bead), or aqueous dispersion.

4.9.7 *Appearance.* State the appearance.

4.9.8 *Odor.* State the odor, if any.

4.9.9 *Specific gravity or bulk density.* State specific gravity of liquids (g/mL) or bulk density of solids (kg/m^3) expressed to the nearest 0.01 unit.

4.9.10 *Moisture content (dry form only).* State the weight percent moisture (solids) in the product to the nearest percent.

4.9.11 *Product viscosity.* State the Brookfield viscosity of the product at room temperature (state temperature in both Fahrenheit and Celsius degrees, typically 71.6°F (22°C). Provide a graph or table of the product's viscosity as a function of temperature from 32° to 100°F (0° to 37.7°C) and state Brookfield viscometer model, spindle, and speed used to develop the graph. Use of 12 rpm and the procedure specified in this standard is recommended.

4.9.12 *Solution viscosity.* Provide a graph or table of the product's viscosity as a function of dilution at room temperature or at several temperatures. State the temperatures in both Fahrenheit and Celsius, the type of water used, and the Brookfield viscometer model, spindle, and speed used to develop the graph. Use of 12 rpm and the procedure specified in this standard is recommended. Use of tap water to prepare the product solution is recommended. Use of distilled or deionized water is not recommended.

4.9.13 *Shelf life.* Report the length of time the product can reasonably be expected to retain 100 percent of its effectiveness.

4.9.14 *Freezing point.* State in both Fahrenheit and Celsius degrees.

4.9.15 *Freeze-thaw stability.* State the number of freeze-thaw cycles after which degradation of the product's effectiveness can reasonably be expected.

4.9.16 *pH of a solution.* State the pH of a specific concentration of the product. State the weight percent concentration of the product and the temperature at which this measurement was made.

4.9.17 *Volatile organic content.* State the weight percent volatile organic compounds (VOC) in the product. Volatile organic content should be used for general information purposes and shall not be used as a purchase specification or for quality control purposes.

4.9.18 *Certification of meeting AWWA standard (water).* State whether the product meets all requirements of ANSI/AWWA B453, Polyacrylamide, for water supply service applications.

4.9.19 *Certification of meeting AWWA standard (wastewater).* If the PAM is in emulsion form, state whether the product meets all requirements of ANSI/AWWA B453, Polyacrylamide, for wastewater service applications.

4.9.20 *Certification of potable approval and maximum use level (water).* State the certifying organization that certified the use of the product for potable use based on NSF/ANSI 60 and the maximum use level permitted by that certification for water supply service applications.

4.9.21 *Laboratory solution preparation procedure.* State the product dilution concentration recommended to be used for laboratory jar tests of the product's efficacy on 1-L samples for water and/or for wastewater clarification applications. State the laboratory solution preparation procedure that may be used to obtain effective dilution (no loss of effectiveness) of the product. State the range of concentrations this procedure applies to if there is an optimum range. State what quality water must be used for the dilution. State the approximate shelf life of diluted concentration solutions and the storage conditions to which the shelf life applies. State concentrations on a volume/volume percentage for liquids and a weight/volume percentage for solids.

4.9.22 *Product storage.* State the recommended storage conditions for liquid products stored in drums, liquid products stored in bulk, and dry products stored in bags or drums.

4.9.23 *Product feeding (general guidelines).* State the general guidelines for effectively preparing dilutions of the product and pumping it into an application. State what quality dilution water should be used or avoided. State the generic types of pumps and mixers that can be used and which type, if any, that is preferred. State the storage and feeding system materials of construction that are most compatible with the product, including pipes, tanks, and rubber parts. State any temperature requirements with respect to storing and feeding.

4.9.24 *Product samples.* State a phone number, email address, fax number, address, and contact name or title that can be contacted to obtain small samples of the product to use in laboratory testing.

4.9.25 *Total solids (optional, liquid forms only).* State the total solids of the product as determined by the procedure in Sec. 5.4.1 or state the procedure, if materially different from Sec. 5.4.1.

SECTION 5: VERIFICATION

Sec. 5.1 General

The methods provided in this standard are acceptable for determining variations in PAM products' physical and chemical properties but may not provide exactly the same quantitative result as another equally valid method.

Sec. 5.2 Sampling

Sampling should be done at the point of destination. Samples shall be taken from each tank car; tank truck; returnable or nonreturnable intermediate bulk container (IBC); or a representative bag, drum, or pail. Each drum and each container, if possible, of emulsion-form PAM should be mixed with a drum mixer for several hours before sampling. PAM in dry form will settle with time, causing segregation by particle size. If mixing the dry-form PAM is not possible, combine samples taken from several depths.

Each sample shall be sealed in a dry, airtight glass container (do not use plastic containers) and carefully identified with a label to include the following information: date and place of sampling, product name/number, lot number, name of supplier, name of sampler, and date of delivery. Sample size should be at least 8 oz (200 mL). Three samples of each lot or shipment should be taken for compliance with the nonconformance procedure (Sec. 5.8). Samples should be thoroughly shaken before each test portion is analyzed. Laboratory examination of the sample should be completed as soon as possible. Samples should be properly disposed of as soon as possible after they reach their shelf life.

Sec. 5.3 Visual Inspection

5.3.1 *General.* Visual inspection is perhaps the easiest qualitative test that can be used for quality assurance of PAM products. It is essential that the sample being inspected is taken properly, stored properly, and inspected as soon as possible during or after the shipment of product is received. The sample shall be observed individually and may also be compared with a previously acceptable sample that has been stored properly and is within its shelf life.

5.3.2 *Emulsion-form PAM.* The samples' appearance shall be similar to previous shipments of the same product. The samples shall not be compared with other emulsion-form PAM products, as some are clear, some are white, and some are translucent, which does not relate to product performance or quality. The samples shall be examined for heterogeneity, lumps, coagulum, or other agglomerates. Each drop of water or condensation that penetrates an emulsion-form PAM product will cause a coagulum to form. Odor may reflect the presence of hydrocarbon solvent. Separation of a top clear hydrocarbon solvent layer over the lower "white" polymer layer is not necessarily an indication of a bad product, but it does indicate that the product needs to be mixed. To inspect for coagulum, the glass sample container shall be rotated in front of a light source and the thin layer of emulsion that adheres to the glass wall observed. The coagulum will appear as heterogeneous particles in the film of emulsion that adheres to the glass.

5.3.3 *Dry-form PAM.* The samples shall be examined for discolored particles or solid contaminants, especially for large particles that may indicate difficulty in solution preparation. An ammonia smell may be present when the sample bottle is initially opened. Microscopic examination may reveal changes in individual particle shape or appearance.

5.3.4 *Solution-form PAM.* Most commercial anionic and nonionic solution-form PAM products are quite viscous and are usually prepared by dissolving either emulsion- or dry-form PAM in water. The appearance may vary from clear to translucent to milky white. The samples shall be examined for coagulum, agglomerates, and contamination by rotating the glass container in front of a light source to inspect for coagulum in the layer of polymer that adheres to the glass wall. Solution-form PAM products may be subject to degradation over time, which may be accompanied by a significant loss of viscosity and performance.

Sec. 5.4 Test Procedures

5.4.1 *Total solids/percent moisture.* This procedure is one of several that are applicable to determining the total solids content of solution-, emulsion-, and dry-form PAM products. The procedure is not corrected for inert ingredients. Therefore, it may not give the polymer content of the sample. Total solids may be determined based on an oven-drying of a sample that leaves a residue of 0.45 g ±0.05 g, or by the procedure that follows.

5.4.1.1 Apparatus.

1. Analytical balance.
2. Aluminum weighing dish.

3. Dropper pipettes or syringes, glass or plastic, 1 mL to 10 mL.

4. Forced draft oven, capable of maintaining temperature at ±2°C of set point.

5. Desiccator and desiccant.

5.4.1.2 Procedure.

1. Heat aluminum pans in oven at 105°C for a minimum of 1 hr; remove and cool in a desiccator.

2. Record tare weight of dried aluminum weighing dish to the nearest 0.0001 g.

3. Using a syringe or dropper pipette, dispense sufficient PAM product into the aluminum weighing dish to yield a dried residue of 0.45 g ±0.05 g. Record the total weight of the sample plus the weighing dish to the nearest 0.0001 g. For dry-form PAM products, add 0.5 g. For emulsion-form PAM products, add approximately 2 g. For solution-form PAM products, add approximately 10 g. Spread the sample over the surface of the aluminum weighing dish to avoid formation of a crust during drying. It may be necessary to add 3–5 mL of deionized water to assist spreading.

4. Place the aluminum weighing dish containing the weighed sample in a 105°C–110°C forced-draft oven for 3 hr. For emulsion-form PAM, samples drying at 105°C–110°C overnight (24 hr) may yield a lower number because of slow evaporation of the higher boiling point portion of the hydrocarbon oil. In this case, use the 24-hr number.

5. Remove the aluminum dish from the oven and cool in a desiccator. Weigh the cooled dish to the nearest 0.0001 g.

5.4.1.3 Calculation.

% Total Solids =

$$\frac{\text{(weight of dish + dried sample)} - \text{(weight of empty dish)}}{\text{(weight of dish + initial sample)} - \text{(weight of empty dish)}} \times 100\% \qquad \text{(Eq 1)}$$

5.4.1.4 Notes.

1. Samples should be run in duplicate.

2. Difference between duplicate samples should be less than ±0.5 percent. If greater than ±0.5 percent, the test should be rerun.

5.4.2 *Particle size distribution.* A weighed amount of dry-form PAM product is placed onto an appropriate series of sieves and mechanically shaken for a specified length of time. The particle size distribution is determined by the weight of the sample retained on each size sieve. Sieve size should be certified or calibrated by an approved procedure.

5.4.2.1 Apparatus.

1. Commercial sieves such as 8-in. B.S. 410 Test Sieves (Endecotts Ltd.) with apertures of 1.7 mm (#12), 1.0 mm (#16), 0.71 mm (#25), 0.212 mm (#70), and 0.15 mm (#100). Larger and smaller sieves may be needed, depending on the type of particle (granular, flake, bead).

2. Receiver pan, cover, and bottom pan for the above sieves.

3. Analytical balance.

4. Aluminum weighing dishes.

5. Brass brush for cleaning sieves.

5.4.2.2 Procedure. The procedure to determine the particle size distribution is as follows.

1. Set shaker to constant shake with an amplitude of 40. Add approximately 100 g of dry dry-form PAM sample weighed to the nearest 0.1 g (initial sample) to the top sieve of the required nest of sieves. To keep a dry-form sample dry, take the sample from a newly opened container and store it in a location that does not have high humidity.

NOTE: Dry-form PAM products usually contain particles of differing sizes that tend to settle during storage or transportation. Obtaining a representative sample from a container of dry PAM, whether the container is a 50-lb or 55-lb bag or a sample container itself, can be very difficult without mixing the entire sample prior to and during sampling. If mixing is not possible, samples should be taken from several depths and combined.

2. Cover and shake for 15 min.

3. Transfer the contents of each sieve, one sieve at a time, to the receiver pan, using a brush, if needed, to aid removal from the sieve. Transfer the contents of the receiver pan to a preweighed aluminum weighing dish and weigh to the nearest 0.1 g. Subtract the weight of the weighing dish to determine the weight of dry PAM retained on the sieve. Repeat for each sieve. An alternative procedure is to weigh each sieve to within 0.1 g before and after sieving and then to subtract the former weight from the latter one.

5.4.2.3 Simplified procedure. Repeat steps 1, 2, and 3 of Sec. 5.4.2.2 using only two sieve sizes. This will produce three fractions instead of six. The larger sieve should be sized to retain particles that are difficult to dissolve in the application feed equipment. The smaller sieve should be sized to pass fines, which may cause dusting.

5.4.2.4 Calculations.

1. For the percent of the PAM sample retained on a given sieve (size):

$$\% \text{ weight on a sieve} = \frac{\text{weight of sample on sieve}}{\text{initial sample weight}} \times 100\% \qquad \text{(Eq 2)}$$

2. For a cumulative percent by weight: Cumulative percent larger than a given sieve size = (weight of fraction on given sieve + weight of fractions of all preceding, larger sieves) × 100% ÷ initial sample weight.

5.4.3 *Bulk Brookfield viscosity.* A Brookfield Synchro-Lectric LVT viscometer* or equivalent is used. The readings are taken with an appropriate spindle number, at an appropriate spindle speed, at a constant temperature. The spindle number needed depends on the viscosity range of the specific product being analyzed. The viscosity of PAM solutions increases with polymer solids and molecular weight. PAM solutions are thixotropic such that their viscosity will decrease with increasing spindle speed. It is best to use the spindle and speed used by the manufacturer of the product for quality control purposes. However, in the absence of such information, a speed of 12 rpm may be used and the spindle varied to give a reading in the center of the viscometer's range.

5.4.3.1 Apparatus.

1. Viscometer: Brookfield Model LVT, or equivalent.

2. Beaker: for solution-form PAM, use 180-mL tall-form Griffin beaker or other container of equal diameter and depth; for emulsion form PAM, use 600 mL, or other container of equal diameter and depth.

5.4.3.2 Procedure.

1. Set up the viscometer without the guard attached. Level the instrument.

2. Attach the spindle specified by the polymer supplier. (NOTE: Left-handed threads.) If the manufacturer does not specify a specific spindle, start with spindle number 1 and proceed through step 9; repeat steps 2 through 9, if necessary, with increasing spindle numbers, until a spindle is found that gives a reading in step 9 that is in the middle of the viscometer's scale range.

3. Pour enough sample into the container to cover the spindle up to the groove.

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* Brookfield Engineering Laboratories Inc., 11 Commerce Blvd., Middleboro, MA 02346. www.brookfieldengineering.com.

4. Adjust the temperature of the sample to 25.0°C ±1.0°C.

5. Lower the viscometer with the spindle attached into the sample until the surface of the sample meets the groove on the spindle shaft. The spindle should not contact the bottom or sides of the container.

6. Set the viscometer to the chosen revolutions per minute.

7. Turn on the viscometer motor.

8. After the needle reaches a steady reading and after at least 10 revolutions, depress the clutch lever on the back of the viscometer to "freeze" the needle on the scale. With the clutch depressed, stop the viscometer motor when the needle is visible in the viscometer window.

9. Read and record the position of the needle on the scale.

10. Repeat steps 7 through 9 to obtain three readings.

5.4.3.3 Calculations.

1. Average the three readings.

2. Obtain the Brookfield viscosity by multiplying the average reading calculated in step 1 by the factor for that spindle and speed supplied by the viscometer manufacturer.

5.4.4 *Brookfield viscosity of a PAM solution.* Choose a concentration and the basis of the concentration (weight or volume) to be prepared. Prepare the solution. If possible, the concentration and basis of concentration should be chosen from the supplier's product technical data sheet specifications. For solution-form PAM, the polymer is simply diluted with water and stirred until homogeneous to prepare a less concentrated solution. For emulsion- or dry-form PAMs, use the supplier's recommended procedure or that specified in Sec. 5.5. Measure the Brookfield viscosity by the method described in Sec. 5.4.3.

5.4.5 *Standard viscosity.* One procedure used to determine standard viscosity is as follows.

5.4.5.1 Apparatus.

1. Beaker, 1,000 mL.
2. Beaker, 150 mL.
3. Class "A" 25-mL graduated cylinder.
4. Syringe, 5 cc disposable.
5. Magnetic stirrer and polytetrafluoroethylene (PTFE)*-coated stirrer bars.

* PTFE is the acronym for polytetrafluoroethylene used for nonstick coatings.

6. Electric motor mixer (adjustable speed) and stainless-steel propeller stirring blade.

7. pH meter, reference buffer solutions, fiber junction, and reference electrode.

8. Viscometer, Brookfield Model LVT with UL adapter, spindle, and UL cup.

9. Analytical balance.

10. Aluminum weighing dishes.

5.4.5.2 Reagents. Those reagents needed to perform the standard viscosity test include the following:

1. 10.83 percent NaCl solution made from reagent-grade NaCl.
2. 0.1*N* NaOH solution.
3. 0.1*N* sulfuric acid solution.

5.4.5.3 Procedure.

1. Add 715 g of deionized (DI) water to a 1,000-mL beaker.

2. Stir with electric motor mixer to create a vortex of about two-thirds the height of the water.

3. Calculate the product sample weight needed to form a 1.44-g active polymer. To do this, use the active polymer content stated in the product's technical data sheet or request the information from the supplier. In the absence of this information, proceed with the realization that an exact 1.44-g sample may not be obtained and, therefore, the standard viscosity determined can only be compared with measurements on the identical PAM product determined in the same manner. Do a total solids determination and assume the total solids is the active polymer content.

4. Fill a 5-cc syringe with the appropriate amount of emulsion-form or solution-form PAM product sample and weigh; or weigh the appropriate amount of dry-form PAM product sample into an aluminum weighing dish.

5. Add a small excess of the calculated amount of sample and record this amount (actual sample weight). Calculate the total weight of water required as follows:

g H_2O add =

$$\frac{(715 + \text{actual sample weight})(\text{actual sample weight})}{\text{calculated sample weight}} - (715 + \text{actual sample weight}) \qquad \text{(Eq 3)}$$

Add the g of water to the 715 g of water.

Record total water = (715 g + g of water added).

6. Continue to stir for 2 hr. Adjust the stirring speed to maintain visual surface movement.

7. Weigh 50 g of solution into a tared 150-mL beaker.

8. Add 54 g of 10.83 percent NaCl solution into the beaker.

9. Stir an additional 5 min on a magnetic mixer.

10. Adjust pH of solution with 0.1*N* NaOH solution or 0.1*N* sulfuric acid solution, added as drops, as follows:

Anionic and nonionic PAM	⟶	adjust pH to 8.0
Cationic PAM	⟶	adjust pH to 5.5

11. Quickly pipette 17 mL of the solution into a Brookfield UL cup.

12. Level the viscometer and measure the viscosity at 60 rpm at 25°C ±0.5°C.

13. Take four readings over no more than a 5-min period.

5.4.5.4 Calculation. Calculate the average reading from step 13 in Sec. 5.4.5.3 and multiply the average reading by the UL-cup-correction factor. The correction factor for the UL cup should be verified weekly according to the viscometer manufacturer's procedure.

NOTE: The remaining stock solution from step 6 can be used for other tests as required.

5.4.6 *pH of a solution.*

5.4.6.1 Apparatus.

1. pH meter.
2. Fiber junction and reference electrode.
3. pH reference buffer solutions above and below the pH range to be tested.
4. 180-mL tall-form Griffin beaker or equivalent.
5. Thermometer.
6. PAM product solution. The specific concentration of the solution should be chosen from the supplier's product literature. Alternatively, the solution prepared for either the Brookfield viscosity of a PAM solution test or standard viscosity test (prior to NaCl addition) can be used.

5.4.6.2 Procedure.

1. Standardize the pH meter with buffer solutions above and below the pH range to be tested.
2. Add polymer solution to a 180-mL beaker.
3. Adjust the temperature setting of the pH meter to that of the polymer solution, which should be at room temperature, 25°C ±2°C.

4. Measure the pH of the polymer solution.
5. Thoroughly rinse the electrodes after each test.

Sec. 5.5 Solution Preparation

5.5.1 *Introduction.* With solution-form PAM products, the polymer is simply diluted with water and stirred until homogeneous to prepare a less concentrated solution.

Dry-form PAM products must be added to water in a manner that avoids the formation of agglomerates of particles that do not fully hydrate or go into solution.

To prepare solutions from emulsion-form PAM products, sufficient mixing must be used to avoid the formation of coagulum, but the shear must not be great enough to result in degradation of polymer molecular weight. Also, the amount of emulsion added must be great enough to result in an aqueous solution with sufficient breaker surfactant present to break (invert) the emulsion, but the polymer concentration cannot be so high that the solution viscosity prevents stirring or handling. The breaker surfactant is present in the emulsion polymer. Thus, an initial emulsion-form PAM product solution must be first prepared above a specific concentration. Finally, the pH may have to be optimized for breaking and product stability.

At the end of this subsection, procedures are given for preparing polymer solutions from dry-form and emulsion-form PAM products. However, because different product formulations may require specific procedures for preparing solutions with optimum characteristics, it is advisable to follow the supplier's recommended procedure for solution preparation.

Several additional factors are important:

1. After the preparation of a polymer solution, the solution may need to be aged for 1 hr or more before testing to allow the polymer chains to uncoil. Although high shear is initially required to either disperse a dry-form polymer or to break an emulsion polymer, during the aging period stirring should be slowed so that the surface of the solution is barely moving to reduce the potential for shear degradation of the polymer.

2. Polymer solution concentrations can be determined on any of three different bases: as-sold, total solids, or active polymer. The basis used is determined by how the polymer solution will be used.

As-sold basis means the product as it comes out of the container. Example: 1 weight percent as-sold solution is 1 g of product (dry, emulsion, or solution) as it comes out of the container in 99 g of water.

Total solids basis means that the weight of the product used to prepare the solution is adjusted to account for the total solids content of the product so that the desired amount of solids is added to the water. Example: To make a 1 percent total solids solution of a product that is 50 percent total solids, add 2 g of product to 98 g of water.

Active polymer basis means that the weight of the product used to prepare the solution is adjusted to account for the active polymer content of the product so that the desired amount of polymer is added to the water. Example: To make a 1 percent active polymer solution of a product that is 30 percent active polymer, add 3.33 g polymer product to 96.67 g of water.

3. The water used to prepare the solution must take into consideration the final use of the polymer solution. If the solution is being prepared for testing in an application, the makeup water being used in that application should be used. If the solution is being prepared for evaluation by an analytical procedure, such as those in Section 5, the solution should be prepared with DI or equivalent quality water unless the sample is an emulsion-form PAM, in which case, clean tap water should be used.

5.5.2 *Example of preparation of a dry-form polymer solution.*

5.5.2.1 Apparatus.

1. Magnetic stirrer and magnetic-stirrer bars coated with PTFE, nonstick coating, or a variable-speed electric motor mixer with stainless-steel shaft and propeller blade.
2. 600-mL beaker.
3. Aluminum weighing dish.
4. Analytical balance.

5.5.2.2 Concentration. The concentration used in this example is 0.2 wt percent, as sold.

5.5.2.3 Procedure.

1. Weigh 299.4 g of water (DI unless otherwise specified) into a 600-mL beaker.
2. Determine the weight of the aluminum weighing dish empty.
3. Weigh 0.60 g of the dry-form PAM product into the aluminum weighing dish.
4. Place the beaker containing the water and a PTFE-coated stirring bar on the magnetic stirrer.

5. Turn on the stirrer so that a strong vortex of approximately two-thirds the height of the water is produced.

6. Carefully pour the dry polymer into the side of the vortex. Do not pour the sample too quickly (do not dump all at once) or too slowly. Typically, the pouring should require no more than 5 to 15 sec. If any polymer remains in the aluminum weighing dish, weigh it to determine the exact quantity of polymer transferred.

7. Continue stirring the solution at high speed for 10 min.

8. Slow the stirrer so that the surface of the solution is barely moving and continue stirring for at least 1 hr.

NOTE: Nonionic PAM, especially in cold or low-conductivity water, can require two or more hours of stirring for complete dissolution.

9. Inspect the solution to determine that it is homogeneous and contains no coagulum or undissolved agglomerates. If it does, continue to mix at high speed for 1 hr, then reinspect.

NOTE 1: If an electric motor mixer is used with a propeller blade, the initial fast mix period can be shortened to 5 min or less. The speed (rpm) of the motor mixer should be adjusted to give a deep vortex as described previously. If this cannot be determined, use 500 rpm.

NOTE 2: Some polymers may require more intense mixing than a magnetic mixer can provide, as evidenced by the presence of coagulum or undissolved agglomerates after 2 hr. In that case, an electric motor mixer is preferred.

5.5.3 *Example of preparation of an emulsion polymer solution (inversion).*

5.5.3.1 Apparatus.

1. Magnetic stirrer and PTFE-coated magnetic stirrer bars or variable-speed electric motor mixer and stainless-steel shaft and propeller blade.
2. 600-mL beaker.
3. Analytical balance.
4. Plastic syringes, 5 mL.

5.5.3.2 Concentration. The concentration for this example is 0.5 wt percent, as sold.

5.5.3.3 Procedure.

1. Weigh 298.50 g of water (DI unless otherwise specified) into a 600-mL beaker containing a magnetic stirrer bar. Record the exact weight of water added to the nearest 0.01 g.

2. Mix the emulsion-form PAM product in its container thoroughly by vigorously shaking the sample bottle for 15 to 30 sec or by stirring. Withdraw approximately 1.5 mL of polymer emulsion into a disposable syringe. It is better to withdraw too much sample than too little. A pipette can be used in place of a syringe, but it may be less accurate because the viscous polymer sticks to the walls of the pipette.

3. Weigh the syringe containing the emulsion on an analytical balance to 0.0001 g (0.1 mg) and record the weight.

4. Stir the water with the magnetic stirrer on a high speed to produce a vortex in the water, which is about two-thirds the height of the water.

5. Rapidly add 1.5 g of the emulsion-form PAM product to the vortex of the mixing water. To calculate the volume of 1.5 g of the emulsion polymer, multiply 1.5 by the ratio of the density of water (8.34 lb/gal) divided by the density of the PAM product as reported in the product's literature. If the literature reports only the product's specific gravity, divide 1.5 by the specific gravity. Weigh the syringe after addition to determine the exact amount of emulsion polymer added (subtract from weight in step 3).

6. Continue to mix with the magnetic stirrer on the same high speed for 10 min.

7. Slow the stirrer so that the surface of the solution is barely moving and continue stirring for 1 hr.

8. Inspect the solution to determine that it is homogeneous and contains no coagulum or undissolved agglomerates. If it does, continue to mix at high speed for another hour, then reinspect.

Note 1: If an electric motor mixer is used with a propeller blade, the initial fast mix period can be shortened to 5 min or less. The speed (rpm) of the motor mixer should be adjusted to give a deep vortex as described previously. If this cannot be determined, use 500 rpm.

Note 2: Some polymers may require more intense mixing than a magnetic mixer can provide, as evidenced by the presence of coagulum or undissolved agglomerates after 2 hr. In that case, an electric motor mixer is preferred.

Sec. 5.6 Product Performance

The tests and requirements set forth in this standard can help determine if one sample of a specific product is similar to another sample of that same product, an important part of quality control.

The performance of a polymer is the result of a specific interaction between the polymer molecules and the particles that they are helping to remove. This interaction is influenced by the composition and temperature of the water. Performance will change if the polymer, the particle, or the water changes. There are no analytical tests that can reliably determine changes in the particles. Thus, a change in a PAM product's performance in a water treatment plant or even in a laboratory performance test cannot determine with certainty that the product's activity has changed unless the present product sample is compared with a properly stored sample of the same product taken when its performance was observed to be adequate.

If the old (acceptable) and new product samples perform similarly in a laboratory performance test (jar test, etc.), the product has not changed, even if the observed performance is different from that originally observed. If the performance of both of the samples remains unacceptable, a different polymer (molecular weight, charge type, charge density, etc.) may be needed and a thorough rescreening of all available types of polymers should be undertaken.

If the performance of the old (acceptable) and new product samples differs significantly, their physical and chemical properties should be compared, as described in this standard, both to each other and to the typical physical property values stated on the product's technical data sheet. If their physical and chemical properties are also different, the polymer has changed. If they are similar, a second laboratory performance comparison should be undertaken, because this testing is sometimes subject to error or different interpretation. It is important to consult the supplier in these situations. The supplier can help identify which requirements are most important, suggest other tests specific to that product, and interpret the data.

An important part of verification is to retain, label, and properly store samples of product used to determine acceptable performance. Because PAM products degrade with time, it is also important to take samples periodically, preferably of all shipments and lots. Generally, when stored at room temperature, dry PAMs are stable for at least a year, emulsions are stable for at least six months (or longer if periodically shaken), and solutions are stable for two months. Check the product's technical data sheet for shelf-life information.

Verification is improved if the test procedures outlined in this standard or separately agreed on by the purchaser and supplier are tried in the purchaser's laboratory to confirm knowledge of the test, availability of necessary equipment, and confidence in the procedure at the onset of the PAM product's use.

Sec. 5.7 Residual Acrylamide Monomer

The determination of residual acrylamide monomer in a PAM product is conducted using sophisticated analytical procedures that require experienced analytical personnel and a high-performance liquid chromatograph (HPLC), or a gas chromatograph (GC) and ancillary instrumentation. Proper sample preparation, taking into account the form of the PAM, must be employed in order to isolate the active PAM from the other constituents of the PAM product.

The user may be advised to employ an outside laboratory familiar with the instrumentation and the chosen procedure to perform such an analysis. A reference HPLC procedure for this analysis is provided.* Alternatively, NSF International uses an HPLC method described in NSF/ANSI 60, Annex B, that is applicable to all three forms of PAM products. For dry PAMs, solutions must be prepared for analysis.

The purchaser should be aware that the PAM supplier should be able to provide a simplified version of this test or a suitable substitute procedure that the manufacturer uses for quality control and which has been adapted for use for the specific PAM form or product.

Sec. 5.8 Notice of Nonconformance†

If the PAM polymer delivered to the purchaser does not meet the chemical, physical, safety, or security requirements of this standard, the purchaser shall provide a notice of nonconformance to the supplier within 30 days after receipt of the shipment at the point of destination. The results of the purchaser's test shall prevail unless the supplier notifies the purchaser within five days after receipt of the notice of conformance that a retest is desired. On receipt of the request for a retest, the purchaser shall forward to the supplier one of the sealed samples taken in accordance with Sec. 5.2. In the event the results obtained by the supplier do not agree with the test results obtained by the purchaser, the other sealed sample shall be forwarded, unopened, for analysis to a referee laboratory agreed on by both parties. The results of the referee analysis shall be accepted as final.

* Tseng, A.M. 1990. Determination of residual acrylamide monomer in solution and emulsion polymers by column-switching, high-performance liquid chromatography, *Jour. of Chromatography*, 519:363–368.

† An associated uncertainty or lack of precision is involved with the experimental determination of any value. Therefore, when comparing measured values with those indicated by the manufacturer's or supplier's affidavit of compliance, the value indicated by the affidavit of compliance should fall within the range of the measured value—that is, within the range set by the average and its standard deviation.

Material not complying with the requirements of this standard and the purchaser's documents may be rejected. Replacement and retesting shall be accomplished in accordance with the purchaser's documents.

Because the exact concentration of the active ingredient in specific shipments of some materials can vary within an acceptable range (thereby conforming to the Standard), the purchase documents between purchaser and supplier should address treatment of concentration variation.

Sec. 5.9 Manufacturing Location Contact for Quality Control Inquiries

For the purposes of quality control, the purchaser may request, and the supplier must supply, the location of manufacture of the polymer batch in question along with the phone number and name of a person at the manufacturing location whom the purchaser can directly contact to obtain quality control data on the batch of polymer in question and discuss the quality control data and the analytical tests used. At the time of the request, the purchaser must supply the following information about the polymer product batch whose quality is in question: product supplier (company name and location, contact person, phone number), product name and number, product batch number, date the shipment of polymer containing the batch was received, the quantity (number of drums, number of pounds if dry, number of gallons if bulk) of the shipment in which the product was received, and the amount of the shipment the batch in question represents.

SECTION 6: DELIVERY*

Sec. 6.1 Marking

6.1.1 *Required.* Each shipment of PAM shall be identified as to product, grade, net weight, name and address of the manufacturer or supplier, and the brand name. Packages or containers shall show a lot number and identification of manufacturer, production facility identification number that is traceable through the supplier to the location of production, and the product number. In addition, PAMs that are approved for potable water service under NSF/ANSI Standard 60

* Governmental packaging and marking references reflect US requirements. Users of B453 outside the United States should verify applicable local, provincial, and national regulatory requirements. Because of frequent changes in these regulations, all parties should remain informed of possible revisions. Provisions of the purchaser's documents should not preclude compliance with applicable regulations.

shall be so marked. All markings on packaged, containerized, or bulk shipments shall conform to applicable laws and regulations.

6.1.2 *Optional.* Packages may also bear the statement "Guaranteed by (name of supplier or manufacturer) to meet the requirements of ANSI/AWWA B453, Standard for Polyacrylamide," provided that the requirements of this standard are met.

Sec. 6.2 Packaging and Shipping

Emulsion-form and solution-form PAMs are supplied in drums, returnable bins, pails, or in bulk. According to this standard, if PAM is shipped in bulk by tank car or railcar, the tanks shall be thoroughly cleaned before shipping. Dry PAMs are supplied in bags, fiber drums, or supersacks. All truck shipments shall be accompanied by weight tickets, which are machine printed and dated. The shipper shall follow federal, state or provincial, and local requirements.

The purchaser may require that bulk shipments of PAM (tank trucks, tank cars, etc.) have all openings sealed at the time of loading to detect possible tampering with the product during shipment. The purchaser may also require that bulk shipments be made in trucks dedicated or suitable for food-grade substances with the understanding that these dedicated trucks are less available and entail higher shipping rates. If the PAM is being shipped in tank trucks by a shipping company that does not accept PAM as food, the shipping company will not allow shipment of PAM on food-grade trucks. If the purchaser requires shipment on food-grade trucks, the purchaser, supplier, and shipping company should agree on acceptable clean-out procedures and prior content of the nonfood-grade tank trucks used for shipping.

6.2.1 *Security requirements for nonbulk shipments.* Packaged product shall be stored, shipped, and delivered in tamper-evident packaging as defined in Sec. 3, item 14, or an alternative method or methods may be agreed on by the manufacturer and purchaser that would provide a reasonable assurance of protection against tampering.

6.2.2 *Security requirements for bulk shipments.* Bulk quantities of product shall be secured by employing one of the following security measures or a combination of measures:

6.2.2.1 Seals. Bulk quantities of product may be sealed with a uniquely numbered tamper-evident seal(s). The seal numbers shall be recorded and disclosed on shipping documents such as the Bill of Lading. Seals shall be inspected upon receipt of product by the purchaser, and evidence of tampering or removal should be reported to the carrier and supplier.

6.2.2.2 Chain of custody. A continuous chain of custody may be maintained between the manufacturer and the purchaser during storage and shipment if so specified by the purchaser.

6.2.2.3 Alternative method. An alternative method or methods may be agreed on by the manufacturer and purchaser that provide reasonable assurance of protection against tampering.

Sec. 6.3 Product Technical Data Sheets

Supplier shall provide a copy of the product technical data sheet:

1. Whenever a Material Safety Data Sheet is sent.
2. With its price proposal/public bid response.
3. Upon any significant change to the information in the product technical data sheet.
4. Upon any change in the product's designation (product number, product trade name, supplier's name change).

Supplier need not provide product technical data sheets to users under Sec. 6.3, item 3 and 6.3, item 4, above, who have not ordered the product in the preceding 12 months.

Sec. 6.4 Affidavit of Compliance or Certified Analysis

The purchaser may require either (1) an affidavit from the manufacturer or supplier that the PAM product provided complies with applicable requirements of this standard or (2) a certified analysis of the PAM product at the time of delivery detailing the desired items.

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