

\*\*\*\*\*  
USACE / NAVFAC / AFCEC / NASA UFGS-33 46 16 (April 2008)  
-----  
Preparing Activity: USACE Superseding  
UFGS-33 46 16 (July 2006)

## UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2013

\*\*\*\*\*

### SECTION TABLE OF CONTENTS

#### DIVISION 33 - UTILITIES

#### SECTION 33 46 16

#### SUBDRAINAGE SYSTEM

04/08

#### PART 1 GENERAL

- 1.1 MEASUREMENT AND PAYMENT
  - 1.1.1 Pipe Subdrains
  - 1.1.2 Blind or French Drains
  - 1.1.3 Manholes
  - 1.1.4 Flushing and Observation Risers
  - 1.1.5 Filter Fabric
- 1.2 REFERENCES
- 1.3 SUBMITTALS
- 1.4 DELIVERY, STORAGE, AND HANDLING
  - 1.4.1 Delivery and Storage
  - 1.4.2 Handling

#### PART 2 PRODUCTS

- 2.1 PIPE FOR SUBDRAINS
  - 2.1.1 Concrete
  - 2.1.2 Clay and Perforated Clay
    - 2.1.2.1 Clay
    - 2.1.2.2 Perforated Clay
  - 2.1.3 Perforated Concrete
  - 2.1.4 Perforated Corrugated Steel
  - 2.1.5 Perforated Corrugated Steel, Fully Bitumin. Coated
  - 2.1.6 Drain Tile
  - 2.1.7 Porous Concrete
  - 2.1.8 Perforated Corrugated Aluminum Alloy
  - 2.1.9 Perforated Corrugated Aluminum Alloy, Fully Bitumin. Coated
  - 2.1.10 Precoated Corrugated Steel
  - 2.1.11 Plastic
    - 2.1.11.1 Acrylonitrile-Butadiene-Styrene (ABS)
    - 2.1.11.2 Polyvinyl Chloride (PVC) and Fittings
    - 2.1.11.3 Corrugated Polyethylene (PE) and Fittings
    - 2.1.11.4 Pipe Perforations
- 2.2 FILTER FABRIC
- 2.3 SUBDRAIN FILTER AND BEDDING MATERIAL

## 2.4 DRAINAGE STRUCTURES

- 2.4.1 Concrete
- 2.4.2 Mortar
- 2.4.3 Manholes and Appurtenances
  - 2.4.3.1 Precast Reinforced Concrete Manhole Risers and Tops
  - 2.4.3.2 Precast Concrete Segmental Blocks
  - 2.4.3.3 Precast Concrete Manhole Bases
  - 2.4.3.4 Brick
  - 2.4.3.5 Prefabricated Corrugated Metal
  - 2.4.3.6 Glass Fiber-Reinforced Polyester (FRP)
  - 2.4.3.7 Frames and Covers or Gratings
  - 2.4.3.8 Steel Ladder

## PART 3 EXECUTION

- 3.1 EXCAVATION AND BEDDING FOR SUBDRAIN SYSTEMS
- 3.2 MANHOLES AND FLUSHING AND OBSERVATION RISERS
  - 3.2.1 Manholes
  - 3.2.2 Flushing and Observation Risers
- 3.3 INSTALLATION OF FILTER FABRIC AND PIPE FOR SUBDRAINS
  - 3.3.1 Installation of Filter Fabric
    - 3.3.1.1 Overlaps on Perforated or Slotted Pipes
    - 3.3.1.2 Installation on Open-Joint Pipe
    - 3.3.1.3 Trench Lining and Overlaps
  - 3.3.2 Installation of Pipe for Subdrains
    - 3.3.2.1 Pipelaying
    - 3.3.2.2 Jointings
- 3.4 INSTALLATION OF AND BACKFILLING FOR BLIND OR FRENCH DRAINS
- 3.5 INSTALLATION OF FILTER MATERIAL AND BACKFILLING FOR SUBDRAINS
- 3.6 TESTS
  - 3.6.1 Pipe Test
  - 3.6.2 JP-4 Fuel Resistance Test

-- End of Section Table of Contents --

\*\*\*\*\*  
USACE / NAVFAC / AFCEC / NASA UFGS-33 46 16 (April 2008)  
-----  
Preparing Activity: USACE Superseding  
UFGS-33 46 16 (July 2006)

## UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2013

\*\*\*\*\*

### SECTION 33 46 16

#### SUBDRAINAGE SYSTEM

04/08

\*\*\*\*\*

NOTE: This guide specification covers the requirements for subdrainage systems for drainage of water from under the ground.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

\*\*\*\*\*

## PART 1 GENERAL

### 1.1 MEASUREMENT AND PAYMENT

\*\*\*\*\*

NOTE: When filter fabric is not used in the drainage system, the requirement for filter fabric will be deleted from this specification.

The paragraph as written contemplates taking bids on a unit-price basis. When it is determined that a lump-sum contract may be more advisable, the paragraph will be deleted.

\*\*\*\*\*

#### 1.1.1 Pipe Subdrains

The length of pipe installed will be measured from end to end along the

centerlines without any deduction for the diameter of the manholes. Pipe will be paid for according to the number of linear **meters feet** of subdrains placed in the accepted work. Payment for bedding and filter materials, except filter fabric, will be included in the payment for the pipe subdrain system.

#### 1.1.2 Blind or French Drains

Blind or french drains will be paid for by the linear **meter foot** and measured from end to end along the centerlines of the completed drains.

#### 1.1.3 Manholes

Manholes to be paid for will be the number of manholes completed with base, rungs or ladders, frames, and covers or gratings (where specified) constructed in the accepted work.

#### 1.1.4 Flushing and Observation Risers

Flushing and observation risers to be paid for will be the number of flushing and observation risers completed with frames and covers (where specified) constructed in the accepted work.

#### 1.1.5 Filter Fabric

Filter fabric shall be measured for payment by the square **[meter yard]** **[meter foot]** in place. Overlapped joints and seams shall be measured as a single layer of cloth.

### 1.2 REFERENCES

\*\*\*\*\*

**NOTE:** This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

\*\*\*\*\*

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS  
(AASHTO)

AASHTO M 190	(2004; R 2012) Standard Specification for Bituminous Coated Corrugated Metal Culvert Pipe and Pipe Arches
AASHTO M 252	(2009) Standard Specification for Corrugated Polyethylene Drainage Pipe
AASHTO M 294	(2011) Standard Specification for Corrugated Polyethylene Pipe, 300- to 1500-mm Diameter

ASTM INTERNATIONAL (ASTM)

ASTM A123/A123M	(2012) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A227/A227M	(2006; R 2011) Standard Specification for Steel Wire, Cold-Drawn for Mechanical Springs
ASTM A229/A229M	(2012) Standard Specification for Steel Wire, Oil-Tempered for Mechanical Springs
ASTM A27/A27M	(2010) Standard Specification for Steel Castings, Carbon, for General Application
ASTM A47/A47M	(1999; R 2009) Standard Specification for Ferritic Malleable Iron Castings
ASTM A48/A48M	(2003; R 2012) Standard Specification for Gray Iron Castings
ASTM A760/A760M	(2010) Standard Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains
ASTM A762/A762M	(2008) Standard Specification for Corrugated Steel Pipe, Polymer Precoated for Sewers and Drains
ASTM B745/B745M	(2012) Standard Specification for Corrugated Aluminum Pipe for Sewers and Drains
ASTM C139	(2011) Standard Specification for Concrete Masonry Units for Construction of Catch Basins and Manholes
ASTM C14	(2011) Standard Specification for Concrete Sewer, Storm Drain, and Culvert Pipe
ASTM C14M	(2011) Standard Specification for Concrete Sewer, Storm Drain, and Culvert Pipe (Metric)

ASTM C150/C150M	(2012) Standard Specification for Portland Cement
ASTM C231/C231M	(2010) Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
ASTM C33/C33M	(2013) Standard Specification for Concrete Aggregates
ASTM C4	(2004; R 2009) Standard Specification for Clay Drain Tile and Perforated Clay Drain Tile
ASTM C412	(2011) Concrete Drain Tile
ASTM C412M	(2011) Concrete Drain Tile (Metric)
ASTM C425	(2004; R 2009) Standard Specification for Compression Joints for Vitrified Clay Pipe and Fittings
ASTM C444	(2003; R 2009) Perforated Concrete Pipe
ASTM C444M	(2003; R 2009) Perforated Concrete Pipe (Metric)
ASTM C478	(2013) Standard Specification for Precast Reinforced Concrete Manhole Sections
ASTM C478M	(2013) Standard Specification for Precast Reinforced Concrete Manhole Sections (Metric)
ASTM C55	(2011) Concrete Brick
ASTM C62	(2012) Building Brick (Solid Masonry Units Made from Clay or Shale)
ASTM C654	(2011) Porous Concrete Pipe
ASTM C654M	(2011) Porous Concrete Pipe (Metric)
ASTM C700	(2013) Standard Specification for Vitrified Clay Pipe, Extra Strength, Standard Strength, and Perforated
ASTM D1751	(2004; R 2008) Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)
ASTM D1752	(2004a; R 2008) Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion
ASTM D2751	(2005) Standard Specification for Acrylonitrile-Butadiene-Styrene (ABS)

## Sewer Pipe and Fittings

ASTM D3034	(2008) Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings
ASTM D3212	(2007; R 2013) Standard Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals
ASTM D3753	(2012; E 2013) Glass-Fiber-Reinforced Polyester Manholes and Wetwells
ASTM D422	(1963; R 2007) Particle-Size Analysis of Soils
ASTM D4632	(2008) Grab Breaking Load and Elongation of Geotextiles
ASTM F405	(2005) Corrugated Polyethylene (PE) Tubing and Fittings
ASTM F667	(2012) Large Diameter Corrugated Polyethylene Pipe and Fittings
ASTM F758	(1995; E 2007; R 2007) Smooth-Wall Poly(Vinyl Chloride) (PVC) Plastic Underdrain Systems for Highway, Airport, and Similar Drainage
ASTM F949	(2010) Poly(Vinyl Chloride) (PVC) Corrugated Sewer Pipe with a Smooth Interior and Fittings

### 1.3 SUBMITTALS

\*\*\*\*\*

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project.

The Guide Specification technical editors have designated those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the

District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

\*\*\*\*\*

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-04 Samples

Filter Fabric  
Pipe for Subdrains

SD-07 Certificates

Filter Fabric  
Pipe for Subdrains

1.4 DELIVERY, STORAGE, AND HANDLING

1.4.1 Delivery and Storage

\*\*\*\*\*

NOTE: This time restriction applies to pipe containing normal quantities of ultraviolet (UV) inhibitors such as carbon black or titanium dioxide, in geographic areas receiving normal UV exposure. Delays in installation longer than 6 months, from time of manufacturer to time of installation, may be allowed when the Contractor can show that the pipe has been covered or stored indoors for the duration of the additional delay.

\*\*\*\*\*

Inspect materials delivered to site for damage; unload, and store with minimum handling. Do not store materials directly on the ground. The inside of pipes and fittings shall be free of dirt and debris. Keep, during shipment and storage, filter fabric wrapped in burlap or similar heavy duty protective covering. The storage area shall protect the fabric from mud, soil, dust, and debris. Filter fabric materials that are not to be installed immediately shall not be stored in direct sunlight. Install plastic pipe within 6 months from the date of manufacture unless otherwise approved.

1.4.2 Handling

Handle materials in such a manner as to ensure delivery to the trench in sound undamaged condition. Pipe shall be carried and not dragged to the trench.



## PART 2 PRODUCTS

### 2.1 PIPE FOR SUBDRAINS

\*\*\*\*\*

NOTE: The type or types of pipe to be used will be indicated on the drawings. Where a Contractor's option is to be permitted, the types that are acceptable will be included in the specification. Designers' instructions, including required strength of pipe, are in FAA Advisory Circular 150/5320-5C and UFC 3-230-17FA. In specifying pipe for subdrains, pipe of comparable strength for the various sizes and kinds of pipe will be specified.

Perforation and slot sizing is based on embedment gradation, flow requirements, and structural considerations. The embedment material gradation is in turn based on the gradation of the surrounding soil. In order to minimize the migration of fines into the coarser material while maintaining adequate permeability, the following criteria should be met:

All soils (except clays without a sand or silt fraction):

$$\frac{(15 \text{ percent size of drainage or filter material})}{(85 \text{ percent size of material to be drained})} = 5 \text{ (max)}$$

$$\frac{(50 \text{ percent size of drainage or filter material})}{(50 \text{ percent size of material to be drained})} = 25 \text{ (max)}$$

$$\frac{(15 \text{ percent size of drainage or filter material})}{(85 \text{ percent size of material to be drained})} = 5 \text{ (max)}$$

$$(15 \text{ percent size of drainage or filter material}) = 0.4 \text{ (max)}$$

All Soils

$$\frac{(15 \text{ percent size of drainage or filter material})}{(15 \text{ percent size of material to be drained})} = 5 \text{ (min)}$$

$$\frac{(50 \text{ percent size of drainage or filter material})}{(\text{slot width})} = 1.2 \text{ (min)}$$

$$\frac{(50 \text{ percent size of drainage or filter material})}{(\text{hole diameter})} = 1.0 \text{ (min)}$$

\*\*\*\*\*

Submit samples of pipe, and pipe fittings, before starting the work. Pipe for subdrains shall be of the types and sizes indicated. Submit certifications from the manufacturers attesting that materials meet specification requirements. Certificates are required for drain pipe, drain tile, and fittings.

#### 2.1.1 Concrete

\*\*\*\*\*

NOTE: Type II cement normally will be specified, but Type V cement will be specified when the soils contain more than 0.2 percent water-soluble sulfate as SO<sub>4</sub> or the water contains more than 1,000 parts per million sulfates. Type I cement may be permitted when the water-soluble sulfates in the soil are less than 0.1 percent and the sulfates in the water are less than 150 parts per million.

\*\*\*\*\*

Class 1, 2, or 3 as indicated and conform to [ASTM C14M](#) [ASTM C14](#) using [ASTM C150/C150M](#) portland cement Type [II] [V].

#### 2.1.2 Clay and Perforated Clay

##### 2.1.2.1 Clay

Clay pipe shall be either standard or extra strength as indicated and shall conform to [ASTM C700](#).

##### 2.1.2.2 Perforated Clay

Perforated clay pipe shall be either standard or extra strength as indicated and shall conform to [ASTM C700](#). Plain-end pipe conforming to the strength and perforation requirements of [ASTM C700](#) will also be acceptable if provided with spring wire clips of approved type to maintain a taut but elastic joint between the sections of pipe when laid. Clips shall be constructed of not smaller than No. 9 hard-drawn or oil-tempered steel wire conforming to [ASTM A227/A227M](#) or [ASTM A229/A229M](#), and shall be coated with an approved rust preventive coating. Wire clips shall withstand 25 cycles of alternate loading and unloading using a stressing force of [556 N](#) [125 pounds](#). The permanent set resulting from this test shall be less than 5 percent, based on the original length of the fastener. Compression joints conforming to [ASTM C425](#) will also be acceptable.

##### 2.1.3 Perforated Concrete

Conform to [ASTM C444M](#) [ASTM C444](#), Type [I] [II] perforations and to [ASTM C14M](#) [ASTM C14](#), Class 1, 2, or 3 as indicated.

##### 2.1.4 Perforated Corrugated Steel

\*\*\*\*\*

NOTE: Corrugated steel pipe may be installed in soils with a pH range of 6.0 to 8.0 provided the resistivity is greater than 2,000 ohm-cm. A bituminous coating should be used when soil or ground-water conditions are at or near these limits.

\*\*\*\*\*

Perforated corrugated steel pipe shall conform to [ASTM A760/A760M](#), Type III. Sheet thickness of pipe shall be as indicated.

##### 2.1.5 Perforated Corrugated Steel, Fully Bitumin. Coated

Perforated corrugated steel pipe, fully bituminous coated, shall conform to [ASTM A760/A760M](#), Type III, with a coating conforming to [AASHTO M 190](#), Type A. Sheet thickness of pipe shall be as indicated.

#### 2.1.6 Drain Tile

\*\*\*\*\*  
NOTE: Drain tile will not be used for general airfield or heliport construction, drainage systems for structures, or for drains crossing adjacent to paved areas, and will be used only for subsoil drainage for drill areas, parade grounds, athletic fields, and other areas similarly used that are subject to lightweight vehicle traffic only, and where conditions justify its use. Special quality of drain tile will be specified for tile laid in soils that are markedly acid or that contain unusual quantities of sulfates.  
\*\*\*\*\*

Clay drain tile shall conform to ASTM C4 standard, extra quality or heavy duty as indicated. Concrete drain tile shall conform to ASTM C412M ASTM C412 standard, extra, heavy duty extra, or special quality as indicated.

#### 2.1.7 Porous Concrete

\*\*\*\*\*  
NOTE: Type II cement normally will be specified, but Type V cement will be specified when the soils contain more than 0.2 percent water-soluble sulfate as SO<sub>4</sub> or the water contains more than 1,000 parts per million sulfates. Type I cement may be permitted when the water-soluble sulfates in the soil are less than 0.1 percent and the sulfates in the water are less than 150 parts per million.  
\*\*\*\*\*

Conform to ASTM C654M ASTM C654, standard or extra strength as indicated and using ASTM C150/C150M portland cement Type [II] [V].

#### 2.1.8 Perforated Corrugated Aluminum Alloy

\*\*\*\*\*  
NOTE: Corrugated aluminum pipe without bituminous coating may be installed in soil with pH range of 5.5 to 8.5 if the resistivity is greater than 500 ohm-cm or 5.0 to 9.0 where the resistivity is greater than 1,500 ohm-cm. This type of pipe should not be installed in material classified as OH or OL according to the Unified Soil Classification System as presented in ASTM D2487. Bare aluminum alloy pipe has satisfactory corrosion resistance in clean granular materials even when subjected to sea water.  
\*\*\*\*\*

Perforated corrugated aluminum alloy pipe shall conform to ASTM B745/B745M, Type III, Class [1] [2]. Sheet thickness of pipe shall be as indicated.

#### 2.1.9 Perforated Corrugated Aluminum Alloy, Fully Bitumin. Coated

\*\*\*\*\*  
NOTE: Corrugated aluminum pipe, fully bituminous

coated, may be considered in soils where the pH range is 6.0 to 8.0 and resistivity is greater than 2,000 ohm-cm.

\*\*\*\*\*

Perforated corrugated aluminum alloy pipe, fully bituminous coated shall conform to [ASTM B745/B745M](#), Type III, Class [1] [2] with a bituminous coating conforming to [AASHTO M 190](#), Type A.

#### 2.1.1.10 Precoated Corrugated Steel

Precoated corrugated steel pipe shall conform to [ASTM A762/A762M](#), Type III.

#### 2.1.1.11 Plastic

Plastic pipe shall contain ultraviolet inhibitor to provide protection from exposure to direct sunlight.

##### 2.1.1.1.1 Acrylonitrile-Butadiene-Styrene (ABS)

Acrylonitrile-butadiene-styrene (ABS) piping and fittings shall conform to [ASTM D2751](#), with maximum SDR of 35.

##### 2.1.1.1.2 Polyvinyl Chloride (PVC) and Fittings

Polyvinyl chloride (PVC) pipe and fittings shall conform to [[ASTM D3034](#),] [[ASTM F949](#),] [[ASTM F758](#), Type PS 46].

##### 2.1.1.1.3 Corrugated Polyethylene (PE) and Fittings

Use [[ASTM F405](#) for pipes 80 to 150 mm 3 to 6 inches in diameter, inclusive, [ASTM F667](#) for pipes 200 to 600 mm 8 to 24 inches in diameter] [[AASHTO M 252](#) for pipes 80 to 250 mm 3 to 10 inches, [AASHTO M 294](#) for pipes 300 to 600 mm 12 to 24 inches in diameter]. Fittings shall be manufacturer's standard type and shall conform to the indicated specification.

##### 2.1.1.1.4 Pipe Perforations

Water inlet area shall be a minimum of 1,058.4 mm squared per linear meter 0.5 square inch per linear foot. Manufacturer's standard perforated pipe which essentially meets these requirements may be substituted with prior approval of the Contracting Officer.

a. Circular Perforations in Plastic Pipe: Circular holes shall be cleanly cut not more than 9.5 mm 3/8 inch or less than 4.8 mm 3/16 inch in diameter and arranged in rows parallel to the longitudinal axis of the pipe. Perforations shall be approximately 76.2 mm 3 inches center-to-center along rows. The rows shall be approximately 38.1 mm 1-1/2 inches apart and arranged in a staggered pattern so that all perforations lie at the midpoint between perforations in adjacent rows. The rows shall be spaced over not more than 155 degrees of circumference. The spigot or tongue end of the pipe shall not be perforated for a length equal to the depth of the socket, and perforations shall continue at uniform spacing over the entire length of the pipe.

b. Slotted Perforations in Plastic Pipe: Circumferential slots shall be cleanly cut so as not to restrict the inflow of water and uniformly spaced along the length and circumference of the tubing. Width of

slots shall not exceed 3.2 mm 1/8 inch nor be less than 0.8 mm 1/32 inch. The length of individual slots shall not exceed 31.75 mm 1-1/4 inches on 80 mm 3 inch diameter tubing, 10 percent of the tubing inside nominal circumference on 100 to 200 mm 4 to 8 inch diameter tubing, and 63.5 mm 2-1/2 inches on 250 mm 10 inch diameter tubing. Rows of slots shall be symmetrically spaced so that they are fully contained in 2 quadrants of the pipe. Slots shall be centered in the valleys of the corrugations of profile wall pipe.

## 2.2 FILTER FABRIC

\*\*\*\*\*

NOTE: When filter fabric is not used in the drainage system, the requirement for filter fabric will be deleted from this specification.

Design criteria for filter fabrics are based on the equivalent opening size (AOS), percent open area (POA), and filter fabric permeability (Kg). The EOS is defined as the number of the US Standard Sieve having openings closest in size to the largest openings in the filter fabric. The AOS specified should be based on the criteria described below. To perform piping criteria computations, the AOS must be expressed as the equivalent US standard sieve opening in millimeters. The AOS can be used for woven and nonwoven fabrics. Where a designer desires to use "percent open area," the percent open area should be based on the criteria below. The percent open area should be used only for woven fabrics. The permeability test can be used for nonwoven and woven fabrics.

The AOS test is a means of evaluating the piping resistance of a filter fabric, and the percent open area test is intended to assure adequate flow through the fabric and adequate resistance to reduction in permeability over time (clogging). The percent open area test is an indirect test which has been shown to correlate with a woven fabric's long term permeability. The permeability test measures the ability of the filter fabric to pass water without any soil on the fabric. This test does not provide a direct measure of field performance of the filter fabric.

The designer must specify filter fabric properties which will allow retention of the soil being protected, permit sufficient flow through the fabric, and prevent clogging. The designer should select the AOS, POA, and Kg, based on the following criteria:

Protected Soil		Piping (a.)	Woven	
Percent Passing				
Nonwoven	0.075 mm (No. 200) Sieve	Maximum AOS (mm)	Minimum POA	
(d.)	Less than 5 percent (b.)	D85 (c.)	10 percent	Ks
	5 percent to 50 percent (b.)	D85	4 percent	Ks
	50 percent to 85 percent	(a.) D85 (b.) Upper Limit on AOS is AOS = 0.212 mm (No. 70) US Standard Sieve	4 percent	Ks
	More than 85 percent	(a.) = D85 (b.) Lower Limit on AOS is AOS = 0.125 mm (No. 120) US Standard Sieve		Ks

a. When the protected soil contains appreciable quantities (20 to 30 percent) of material retained on the 4.75 mm, (No. 4) sieve, use only the soil passing the 4.75 mm (No. 4) sieve in selecting the AOS of the filter fabric.

b. These protected soils may have a large permeability and thus the POA of Kg may be a critical design factor.

c. D85 is the grain size in millimeters for which 85 percent of the sample by weight has smaller grains.

d. Kg is the permeability of the nonwoven fabric, and Ks is the permeability of the protected soil.

The AOS requirement should be specified as a range to allow for manufacturing tolerances. The smallest sieve opening size of the AOS range should not be smaller than the openings of a 0.125 mm (No. 120) US Standard Sieve. It is preferable to specify a filter fabric with openings as large as allowed by the criteria.

Fabric strength requirements vary with intended use and construction procedures. Experience has shown that when a heavier nonwoven fabric is used, the bedding material can often be reduced in thickness or completely eliminated. Recommended values are:

Type	Minimum	Test
Tensile	444.8 N (100 lbs)	ASTM D4632 grab test 25.4 mm (1 inch) square and 304.8 mm (12 inches) per minute constant rate at traverse.
Elongation	15 percent	ASTM D4632 determine apparent breaking elongation.
Puncture	177.8 N (40 lbs.)	ASTM D3787 except polished steel ball replaced with a 8 mm (5/16 inch) diameter solid steel cylinder with a hemispherical tip centered within the ring clamp.
Tear	111.2 N (25 lbs.)	ASTM D1117 trapezoidal tear strength.

Filter fabrics used to wrap collector pipes should be surrounded by at least 150 mm (6 inches) of granular material. If the filter fabric is used to line a trench, the collector pipe should be separated from the fabric by a minimum of 150 mm (6 inches) of granular backfill material.

\*\*\*\*\*

Submit samples of filter fabric, and certifications from the manufacturers attesting that filter fabric meets specification requirements. Provide geotextile that is a [woven] [nonwoven] pervious sheet of polymeric material consisting of long-chain synthetic polymers composed of at least 95 percent by weight polypropylene (PP) or polyester (PET). The use of woven slit film geotextiles (i.e. geotextiles made from yarns of a flat, tape-like character) will not be allowed. Add stabilizers and/or inhibitors to the base polymer, as needed, to make the filaments resistant to deterioration by ultraviolet light, oxidation, and heat exposure. The filter fabric shall provide an equivalent opening size (AOS) no finer than the US Standard Sieve No. [\_\_\_\_\_] and no coarser than the US Standard Sieve No. [\_\_\_\_\_] . AOS is defined as the number of the US Standard sieve having openings closest in size to the filter fabric openings. [The percent open area provided shall not be less than [\_\_\_\_\_] percent and not more than [\_\_\_\_\_] percent. Percent open area is defined as the summation of open areas divided by the total area of the filter fabric and expressed as a percent.] The fabric shall have a grab strength of 160 pounds in accordance with [ASTM D4632](#). The fabric shall be constructed so that the filaments will retain their relative position with respect to each other. [The edges of the fabric shall be selvaged or otherwise finished to prevent the outer material from pulling away from the fabric.] [The fabric shall be woven into a width that may be installed as shown without longitudinal seams.]

## 2.3 SUBDRAIN FILTER AND BEDDING MATERIAL

\*\*\*\*\*

**NOTE:** The thickness and gradation of the filter material for use with pipe subdrains and blind or french drains will be determined by soil conditions

and subsoil drainage requirements. Filter material will be graded in accordance with the requirements of UFC 3-230-06A, as applicable. TABLE I includes the requirements for each specific installation. The filter material placed adjacent to perforated pipe and open joints will be of a size that will prevent the entrance of any of the filter material into the drain. Graded (composite or layered) filters will be used where specified, and cross sections will be as indicated on the drawings. For pipe with perforations, the filter material will extend from a point not less than 150 mm (6 inches) below the pipe to a point up the sides of the pipe not less than 50.8 mm (2 inches) above the horizontal centerline. For bell-and-spigot or tongue-and-groove pipe laid as specified in paragraph EXCAVATION AND BEDDING FOR SUBDRAIN SYSTEMS, additional filter material not less than 150 mm (6 inches) thick and 300 mm (12 inches) wide will be placed entirely around the joints. Sieve sizes and gradation requirement are inserted in TABLE I using the applicable values from TABLE II. Where site conditions require more than one filter gradation, the drawings will indicate areas of different gradation and the table expanded.

\*\*\*\*\*

Subdrain filter and bedding material shall be washed sand, sand and gravel, crushed stone, crushed stone screenings, or slag composed of hard, tough, durable particles free from adherent coatings. Filter material shall not contain corrosive agents, organic matter, or soft, friable, thin, or elongated particles and shall be evenly graded between the limits specified in TABLE I. TABLE II shows values that can be used to complete TABLE I. Gradation curves will exhibit no abrupt changes in slope denoting skip or gap grading. Filter materials shall be clean and free from soil and foreign materials. Filter blankets found to be dirty or otherwise contaminated shall be removed and replaced with material meeting the specific requirements, at no additional cost to the Government.

TABLE I. FILTER GRADATION

Sieve Designation	Percent by Weight Passing		
	Gradation A	Gradation B	Gradation C
_____	_____	_____	_____

TABLE II

[[ASTM D422 Sieve Size]	[[Type I [Gradation E 11 ASTM C33/C33M] [Percent Passing]	[[Type II [Gradation 57 ASTM C33/C33M] [Percent Passing]	[[Type III [Gradation [____] [____]]] [Percent Passing]
37.5 mm	--	100	[____]
25.0 mm	--	90 - 100	[____]



TABLE II

	<u>Type I</u> [Gradation E 11 ASTM C33/C33M]	<u>Type II</u> [Gradation 57 ASTM C33/C33M]	<u>Type III</u> [Gradation [____] [____]]
[[ASTM D422 Sieve Size]	[Percent Passing]	[Percent Passing]	[Percent Passing]
9.5 mm	100	25 - 60	[____]
4.75 mm	95 - 100	5 - 40	[____]
2.36 mm	--	0 - 20	[____]
1.18 mm	45 - 80	--	[____]
300 micrometers	10 - 30	--	[____]
150 micrometers	0 - 10	--	[____]

TABLE II

	<u>Type I</u> [Gradation E 11 ASTM C33/C33M]	<u>Type II</u> [Gradation 57 ASTM C33/C33M]	<u>Type III</u> [Gradation [____] [____]]
[[ASTM D422 Sieve Size]	[Percent Passing]	[Percent Passing]	[Percent Passing]
1.5 inches	--	100	[____]
1 inch	--	90 - 100	[____]
3/8 inch	100	25 - 60	[____]
No. 4	95 - 100	5 - 40	[____]
No. 8	--	0 - 20	[____]
No. 16	45 - 80	--	[____]
No. 50	10 - 30	--	[____]
No. 100	0 - 10	--	[____]

## 2.4 DRAINAGE STRUCTURES

### 2.4.1 Concrete

\*\*\*\*\*

NOTE: Delete the last sentence when exposed-to-view concrete surfaces will not be subjected to the action of deicing chemicals. The required air contents are for concrete that will be subjected to freezing weather and the possible action of deicing chemicals. In climates where freezing is not a factor, but where air entrainment is used in local commercial practice to improve the workability and placability of concrete, concrete having air content of 3 to 6 percent may be specified.

\*\*\*\*\*

Except for precast concrete, reinforcement shall conform to the requirements for [21] [\_\_\_\_] MPa [3,000] [\_\_\_\_] psi concrete in Section 03 30 00.00 10 CAST-IN-PLACE CONCRETE. The concrete mixtures shall have air content, by volume of concrete, based on measurements made immediately after discharge from the mixer of [5 to 7] [3 to 6] percent when coarse-aggregate maximum size is 38.1 mm 1-1/2 inches or smaller. Air content shall be determined in accordance with ASTM C231/C231M. The concrete covering over steel reinforcing shall be not less than 25.4 mm 1

inch thick for covers and not less than 38.1 mm 1-1/2 inches thick for walls and flooring. Concrete covering deposited directly against the ground shall be at least 76.2 mm 3 inches thick between the steel and the ground. Expansion-joint filler material shall conform to ASTM D1751 or ASTM D1752. Exposed concrete surfaces, such as drainage structures that form a continuation of concrete curbs and gutters, shall be given a protective coating of linseed oil as specified in Section 32 16 13 CONCRETE SIDEWALKS AND CURBS AND GUTTERS.

#### 2.4.2 Mortar

Mortar for pipe joints and connections to other drainage structures shall be composed of one part by volume of portland cement and two parts of sand. The quantity of water in the mixture shall be sufficient to produce a stiff workable mortar. Water shall be clean and free of injurious acids, alkalies, and organic impurities. The mortar shall be used within 30 minutes from the time the ingredients are mixed with water.

#### 2.4.3 Manholes and Appurtenances

##### 2.4.3.1 Precast Reinforced Concrete Manhole Risers and Tops

Conform to ASTM C478M ASTM C478.

##### 2.4.3.2 Precast Concrete Segmental Blocks

Precast concrete segmental blocks shall conform to ASTM C139 and shall be not more than 203.2 mm 8 inches thick, not less than 203.2 mm 8 inches long, and of such shape that the joints can be effectively sealed and bonded with cement mortar.

##### 2.4.3.3 Precast Concrete Manhole Bases

If precast concrete manhole bases are used, the bases shall conform to ASTM C478M ASTM C478 and shall be of such a design as to effect suitable connection with influent and effluent lines and to provide a suitable base structure for riser sections.

##### 2.4.3.4 Brick

Brick shall conform to ASTM C62, Grade SW, or ASTM C55, Grade S-I or S-II. Mortar for jointing and plastering shall consist of one part portland cement and two parts fine sand. Lime may be added to the mortar in the amount of not more than 25 percent by volume of cement.

##### 2.4.3.5 Prefabricated Corrugated Metal

Steel manholes and risers shall be fabricated of at least [\_\_\_\_\_] gauge galvanized [and bituminous coated] corrugated metal.

##### 2.4.3.6 Glass Fiber-Reinforced Polyester (FRP)

FRP manholes shall conform to ASTM D3753.

##### 2.4.3.7 Frames and Covers or Gratings

Frames and gratings, or frames and covers, except as otherwise permitted, shall be of either cast iron with tensile strength test not less than ASTM A48/A48M Class 25 or steel conforming to ASTM A27/A27M, Class 65-35.

Weight, shape, and size shall be as indicated. Frames and covers not subjected to vehicular traffic or storage may be of malleable iron where indicated. The malleable-iron frames and covers shall conform to **ASTM A47/A47M** and shall be of the weight, shape, and size indicated.

#### 2.4.3.8 Steel Ladder

A steel ladder shall be provided where the depth of a manhole exceeds **3.66 m 12 feet**. The ladder will be not less than **400 mm 16 inches** in width, with **19.1 mm 3/4 inch** diameter rungs spaced **304.8 mm 12 inches** apart. The two stringers shall be a minimum **9.5 mm 3/8 inch** thick and **50.8 mm 2 inches** wide. Ladder shall be adequately anchored to the wall by means of steel inserts spaced not more than **1.83 m 6 feet** apart vertically, and shall be so installed as to provide at least **152.4 mm 6 inches** of space between the wall and the rungs. Ladders and inserts shall be galvanized after fabrication in conformance with **ASTM A123/A123M**. The wall along the line of the ladder shall be vertical for its entire length.

### PART 3 EXECUTION

#### 3.1 EXCAVATION AND BEDDING FOR SUBDRAIN SYSTEMS

Trenching and excavation, including the removal of rock and unstable material, shall be in accordance with Section **31 00 00 EARTHWORK**. Bedding material shall be placed in the trench as indicated or as required as replacement materials used in those areas where unstable materials were removed. Compaction of the bedding material shall be as specified for cohesionless material in Section **31 00 00 EARTHWORK**.

#### 3.2 MANHOLES AND FLUSHING AND OBSERVATION RISERS

\*\*\*\*\*  
NOTE: The details indicating size, shape, materials, thickness of various sections, the finish required, and amounts or reinforcing, if any, for inlets, catch basins, walls, headwalls, and manholes will be shown in the drawings. Also, the shape, size, thickness of sections, kind of materials, and weight for frames, covers, and gratings for inlets, catch basins, and manholes, as well as the amount of waterway opening for inlet and catch basins will be indicated in the drawings. The covers and gratings will be designed to have ample strength for the traffic conditions to which they may be subjected. Fixed ladders or ladder rungs will be provided for manholes **3.66 m (12 feet)** or deeper measured from top of grate to invert of outlet pipe.  
\*\*\*\*\*

##### 3.2.1 Manholes

Manholes shall be installed complete with frames and covers or gratings at the locations and within the limits and sizes indicated. Manholes shall be constructed of one of the materials specified for manholes in paragraph **DRAINAGE STRUCTURES**. Joints shall be completely filled and shall be smooth and free of surplus mortar or mastic on the inside of the structure. Brick manholes shall be plastered with **12.7 mm 1/2 inch** of mortar over the entire outside surface of the walls. Brick for square or rectangular structures shall be laid in stretcher courses with a header course every sixth

course. Brick for round structures shall be laid radially with every sixth course laid as a stretcher course. Ladders shall be installed in manholes as indicated. Base for manholes shall be either precast or cast-in-place concrete.

### 3.2.2 Flushing and Observation Risers

Flushing and observation riser pipes with frames and covers shall be installed at the locations indicated. Risers shall be constructed of precast concrete, vitrified clay, or [galvanized] [bituminous coated] corrugated metal pipe. Joining of riser pipes to the subdrain system shall be as indicated.

### 3.3 INSTALLATION OF FILTER FABRIC AND PIPE FOR SUBDRAINS

\*\*\*\*\*  
NOTE: Outlets for subsoil drains and for blind drains, if possible, within reasonable costs, will be designed so that severe rainstorms will neither submerge the drains nor back up water into the drains. Where outlets are not subject to backwater or flooding, the outlets will be provided with grates or heavy screens to prevent acts of vandalism or entrance by rodents. If suitable outlets for blind or french drains into pervious strata of gravel or sand with a lower water table are not obtainable, pipe outlets may be required. The open joint or perforated pipe will extend into the filter material of the blind or french drain a sufficient distance to provide ample waterway openings for the particular drain and will extend through the impervious material, usually with closed joints, to a suitable outlet. Outlets subject to flooding will be provided with suitable and properly installed check valves or flap gates. If outlet pipes are necessary for blind or french drains, and are to be paid for as a separate item, such requirement will be clearly specified, giving the various kinds and sizes of pipe required.  
\*\*\*\*\*

#### 3.3.1 Installation of Filter Fabric

\*\*\*\*\*  
NOTE: When filter fabric is not used in the drainage system, the requirement for filter fabric will be deleted from this specification.  
\*\*\*\*\*

##### 3.3.1.1 Overlaps on Perforated or Slotted Pipes

\*\*\*\*\*  
NOTE: When the permeability of the backfill material is sufficient so that only a single-stage filter is required between the backfill and perforated pipe, filter fabric may be used for this single-stage filter. In this case the filter fabric should wrap the collector pipes, and permanent devices to secure the fabric to the pipe are not

needed since the fabric will be held in place by the backfill material once the installation is completed. Filter fabric has been satisfactorily secured to pipes with tape or string placed at about 300 mm (1 foot) intervals along the overlap. The free ends of the cloth have been folded and stapled. Prefabricated filter fabric sheaths have also been used successfully. The seams for such sheaths need not be sewn with a permanent type of thread. When a two-stage filter is required, filter fabric may be used in place of the finer filter material.

\*\*\*\*\*

One layer of filter fabric shall be wrapped around perforated or slotted collector pipes in such a manner that longitudinal overlaps of fabric are in unperforated or unslotted quadrants of the pipes. The overlap shall be at least 50 mm 2 inches. The fabric shall be secured to the pipe in such a manner that backfill material will not infiltrate through any fabric overlaps.

#### 3.3.1.2 Installation on Open-Joint Pipe

One layer of filter fabric shall be wrapped around open joints. The overlap should be at least 50 mm 2 inches. The fabric shall be secured to the pipe in such a manner that backfill material will not infiltrate through the overlap or the edges of the fabric to either side of the open joint.

#### 3.3.1.3 Trench Lining and Overlaps

\*\*\*\*\*

NOTE: Overlaps of fabric used to line drainage trenches should be from 150 to 300 mm (6 to 12 inches). The strength properties of most filter fabrics composed of plastic materials are adversely affected by ultraviolet rays. Consequently, the fabric should be exposed to sunlight as little as possible, and preferably should be covered the same day as installed. When filter fabric is used to separate the filter material from the soil being drained, the gradation ratios of filter material to protected soil given in UFC 3-230-06A, do not apply; however, the filter fabric must be sized to filter the protected soil.

\*\*\*\*\*

Trenches to be lined with filter fabric shall be graded to obtain smooth side and bottom surfaces so that the fabric will not bridge cavities in the soil or be damaged by projecting rock. The fabric shall be laid flat but not stretched on the soil, and it shall be secured with anchor pins. Overlaps shall be at least [\_\_\_\_\_] mm inches, and anchor pins shall be used along the overlaps.

#### 3.3.2 Installation of Pipe for Subdrains

##### 3.3.2.1 Pipelaying

Each pipe shall be carefully inspected before it is laid. Any defective or damaged pipe shall be rejected. No pipe shall be laid when the trench

conditions or weather is unsuitable for such work. Water shall be removed from trenches by sump pumping or other approved methods. The pipe shall be laid to the grades and alignment as indicated. The pipe shall be bedded to the established gradeline. Perforations shall be centered on the bottom of the pipe. Pipes of either the bell-and-spigot type or the tongue-and-groove type shall be laid with the bell or groove ends upstream. All pipes in place shall be approved before backfilling.

#### 3.3.2.2 Jointings

a. Nonperforated Concrete and Clay Pipe: Pipe shall be laid with 3.2 to 6.4 mm 1/8 to 1/4 inch opening between the ends of the pipe or as required by spacing lugs constructed in the pipe. Mortar shall be placed in the joint at three points and pressed firmly into place to hold the pipe securely in line. The mortar shall be the full depth of the bell or groove and approximately 25.4 mm 1 inch in width, and shall be located at the third points around the joint with the top point at the center of the pipe. The inside of the pipe shall be free of excess mortar.

b. Perforated Concrete and Clay Pipe: The pipe shall be laid with closed joints with positive provision for centering each section of the pipe in the bell or groove of the previously placed section. Plain-end perforated clay pipe sections shall be securely fastened together with spring wire clips furnished by the pipe manufacturer.

c. Perforated Corrugated Metal Pipe or Bituminous Coated, Perforated Corrugated Metal Pipe: The sections of perforated corrugated metal pipe or bituminous coated, perforated corrugated metal pipe shall be securely fastened together with standard connecting bands furnished by the manufacturer of the pipe.

d. Drain Tile: Drain tile shall be bedded as provided for bell-and-spigot or tongue-and-groove types of pipe and laid with open joints of approximately 3.2 mm 1/8 inch width but not over 6.4 mm 1/4 inch width. Drain tile shall be protected against the entrance of filter material into the line by the use of filter fabric.

e. Porous Concrete Pipe: Porous concrete pipe shall be installed with mortar joints.

f. Perforated Asbestos-Cement Pipe: Couplings shall be of the sleeve type suitable for holding the pipe firmly in alignment without the use of sealing compounds or gaskets. Tapered couplings will be acceptable.

g. Bituminous Coated or Uncoated Semicircular Steel Pipe: Coupling bands shall consist of an uncorrugated top and bottom section fabricated to fit around two adjacent pieces of pipe. Coupling bands shall be bolted together with four bolts.

h. Bituminous Coated or Uncoated Corrugated Aluminum Pipe: If aluminum pipe is to be connected to dissimilar metal, the connection shall be insulated by bituminous coating or other nonconductive material. Standard joints between corrugated aluminum pipe shall be securely fastened with standard connecting bands furnished by the manufacturer of the pipe.

i. Acrylonitrile-Butadiene-Styrene (ABS): Solvent cement or elastomeric joints for ABS pipe shall be in accordance with ASTM D2751.

Dimensions and tolerances shall be in accordance with TABLE II of  
ASTM D2751.

j. Polyvinyl Chloride (PVC) Pipe: Joints shall be in accordance with the requirements of ASTM D3034, ASTM D3212, or ASTM F949.

k. Perforated Corrugated Polyethylene Pipe: Perforated corrugated polyethylene drainage pipe shall be installed in accordance with the manufacturer's specifications and as specified herein. A pipe with physical imperfections shall not be installed. No more than 5 percent stretch in a section will be permitted.

### 3.4 INSTALLATION OF AND BACKFILLING FOR BLIND OR FRENCH DRAINS

\*\*\*\*\*

NOTE: Outlets for subsoil drains and for blind drains, if possible, within reasonable costs, will be designed so that severe rainstorms will neither submerge the drains nor back up water into the drains. Where outlets are not subject to backwater or flooding, the outlets will be provided with grates or heavy screens to prevent acts of vandalism or entrance by rodents. If suitable outlets for blind or french drains into pervious strata of gravel or sand with a lower water table are not obtainable, pipe outlets may be required. The open joint or perforated pipe will extend into the filter material of the blind or french drain a sufficient distance to provide ample waterway openings for the particular drain and will extend through the impervious material, usually with closed joints, to a suitable outlet. Outlets subject to flooding will be provided with suitable and properly installed check valves or flap gates. If outlet pipes are necessary for blind or french drains, and are to be paid for as a separate item, such requirement will be clearly specified, giving the various kinds and sizes of pipe required.

\*\*\*\*\*

Filter material shall be placed as indicated and compacted as specified for cohesionless materials in Section 31 00 00 EARTHWORK. Filter material shall extend to a suitable outlet or to an outlet through a pipeline as indicated. Overlying backfill material shall be placed and compacted as specified in Section 31 00 00 EARTHWORK.

### 3.5 INSTALLATION OF FILTER MATERIAL AND BACKFILLING FOR SUBDRAINS

After pipe for subdrains has been laid, inspected, and approved, filter material shall be placed around and over the pipe to the depth indicated. The filter material shall be placed in layers not to exceed 200 mm 8 inches thick, and each layer shall be [saturated by flooding] [thoroughly compacted by mechanical tampers or rammers] to obtain the required density. Compaction of filter material and the placement and compaction of overlying backfill material shall be in accordance with the applicable provisions specified in Section 31 00 00 EARTHWORK.

### 3.6 TESTS

#### 3.6.1 Pipe Test

Strength tests of pipe shall conform to field service test requirements of the Federal Specification, ASTM specification, or AASHTO specification covering the product (paragraph PIPE FOR SUBDRAINS).

#### 3.6.2 JP-4 Fuel Resistance Test

\*\*\*\*\*  
NOTE: Delete this paragraph when filter fabric will  
not be exposed to JP-4 fuel.  
\*\*\*\*\*

Five unaged fabric samples, 97 to 107 mm by 147 to 157 mm 4 (plus or minus 0.2) by 6 (plus or minus 0.2) inches shall be immersed in JP-4 fuel at room temperature for a period of 7 days. Each sample then shall be tested for tensile strength and elongation in accordance with ASTM D4632. The strength of the fabric in any direction shall be no less than 85 percent of the strength specified in paragraph FILTER FABRIC.

-- End of Section --