Lesson 4

Fabric Filter Material

Goal

To familiarize you with the construction of fabric filter material, fibers used, and problems affecting fabric life.

Objectives

At the end of this lesson, you will be able to do the following:

1. Name two ways filters are constructed
2. List at least seven natural or synthetic fibers used to make filters and identify the conditions under which they are used
3. Define five fabric treatment processes
4. Name three failure mechanisms that reduce filter life
5. Briefly describe four types of fabric tests that are used for troubleshooting bag problems

Filter Construction

Bag filters can be made of woven or nonwoven materials. Nonwoven materials can further be divided as felted or membrane. Most bags are either completely or partially made by weaving since nonwoven fabrics are generally attached to a woven base called a *scrim*. **Woven** filters are made of yarn with a definite repeated pattern. **Felted** filters are composed of randomly placed fibers compressed into a mat and attached to loosely woven backing material. A **membrane** filter is a special treatment where a thin, porous membrane (expanded polyfluorocarbon) is bonded to the scrim, or support fabric. Woven filters are generally used with low energy cleaning methods such as shaking and reverse-air. Felted fabrics are usually used with higher energy cleaning systems such as pulse-jet cleaning. Membrane filters were developed in efforts to achieve high efficiency particle capture and to handle flue gas conditions where high moisture and resulting high pressure drop problems frequently occur.

Woven Filters

Woven filters have open spaces around the fibers. The weave design used will depend on the intended application of the woven filter. The simplest weave is the plain weave. The yarn is woven over and under to form a checkerboard pattern (Figure 4-1). This weave is usually the tightest, having the smallest pore openings in the fabric. Consequently, it retains particles very quickly. This weave is not frequently used, because the bags tend to have a high pressure drop (even without any dust cake).

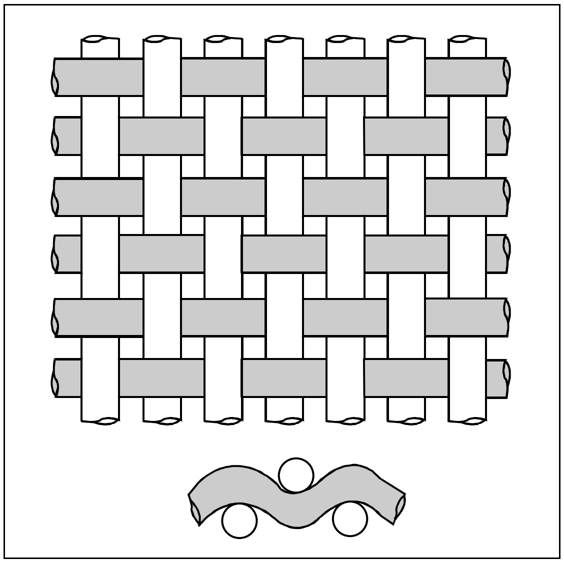

Figure 4-1. Plain weave or checkerboard

Other weaves include the twill and sateen (satin). In the **twill weave**, yarn is woven over two and under one for a 2/1 twill and over three and under one for a 3/1 twill weave (see Figure 4-2).

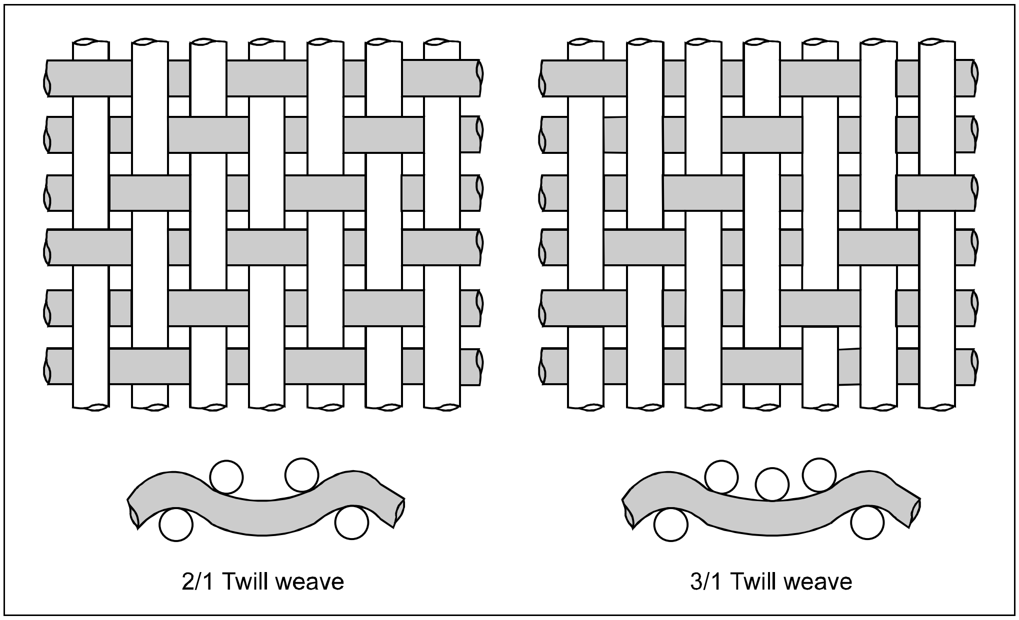

Figure 4-2. Twill weave patterns (2/1 and 3/1)

The twill weave does not retain particles as well as the plain weave, but does not tend to blind as fast. **Bag blinding** is a condition where the particles (dust) becomes embedded in the filter over time and are not removed by the bag cleaning process. The twill weave allows good flow rates through the filter and high resistance to abrasion. In the **satin weave**, yarn is woven over one and under four in both directions. Satin weave does not retain particles as well as the plain twill weave, but has the best (easiest) cake release when the fabric is cleaned (Figure 4-3).

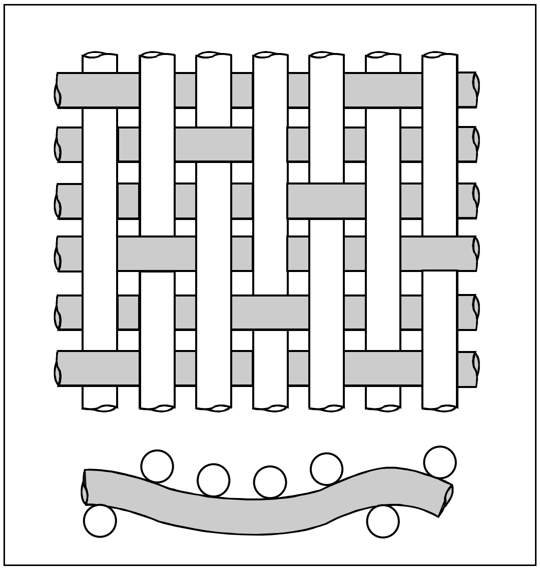

Figure 4-3. Sateen weave (satin weave)

Different weaving patterns increase or decrease the open spaces between the fibers. This will affect both fabric strength and permeability. Fabric **permeability** affects the amount of air passing through the filter at a specified pressure drop. A tight weave, for instance, has low permeability and is better for the capture of small particles at the cost of increased pressure drop.

The true filtering surface for the woven filter is not the bag itself, but the dust layer or filter cake. The bag simply provides the surface for capture of larger particles. Particles are collected by impaction or interception as the open areas in the weave are closed. This process is referred to as **sieving** (Figure 4-4). Some particles escape through the filter until the cake is formed. Once the cake builds up, effective filtering will occur until the bag becomes plugged and cleaning is required. At this point, the pressure drop will be exceedingly high and filtering will no longer be cost effective. The effective filtering time will vary from approximately 15 to 20 minutes to as long as a number of hours, depending on the concentration of particulate matter in the gas stream.

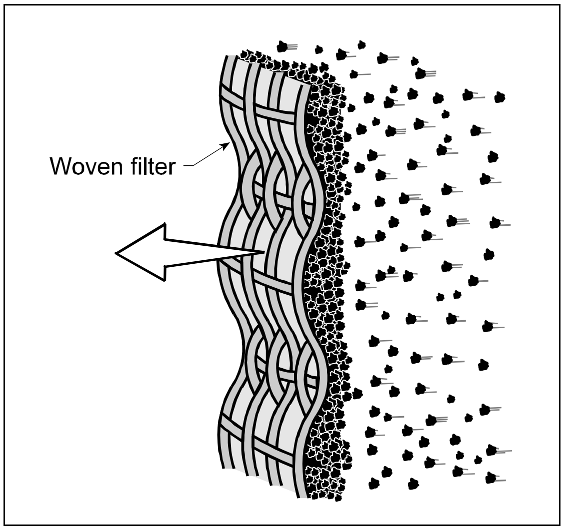

Figure 4-4. Sieving (on a woven filter)

Felted Filters

Felted filters are made by needle punching fibers onto a woven backing called a **scrim**. The fibers are randomly placed as opposed to the definite repeated pattern of the woven filter. The felts are attached to the scrim by chemical, heat, resin, or stitch-bonding methods.

To collect fine particles, the felted filters depend to a lesser degree on the initial dust deposits than do woven filters. The felted filters are generally 2 to 3 times thicker than woven filters. Each individual randomly oriented fiber acts as a target for particle capture by impaction and interception. Small particles can be collected on the outer surface of the filter (Figure 4-5).

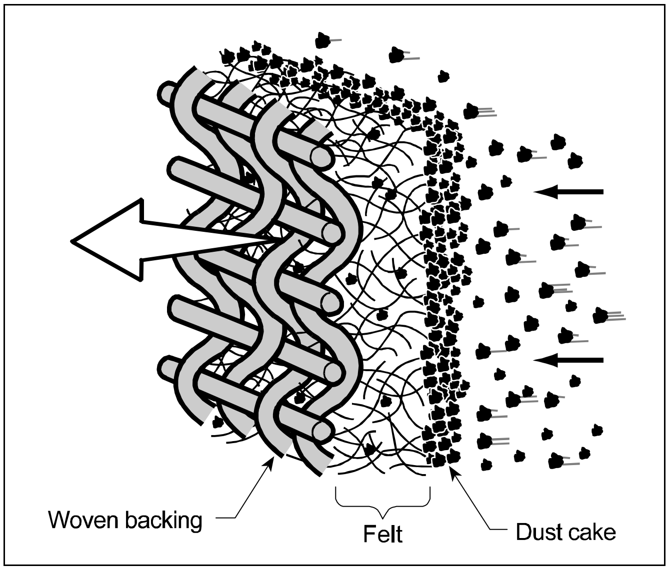

Figure 4-5. Felted fabric filter

Felted filters are usually used in pulse-jet baghouses. A pulse-jet baghouse generally filters more air per cloth area (higher air-to-cloth ratio) than a shaker or reverse-air unit. Felted bags should not be used in high humidity situations, especially if the particles are hygroscopic (these particles have an affinity to absorb moisture and thus become sticky). Clogging or blinding could result in such situations.

Fibers

The fibers used for fabric filters vary depending on the industrial application to be controlled. Early filters were mostly made from natural fibers such as cotton or wool. These fibers are relatively inexpensive but have temperature limitations (< 212°F or 100°C) and only average abrasion resistance. Cotton is readily available making it very popular for low temperature simple applications. Wool withstands moisture very well and can be made into thick felt easily.

Synthetic fibers are more widely used today than natural fibers because they can operate at higher temperatures and better resist chemical attack. The synthetic fiber most often used for high temperature application is fiberglass or glass fibers. Fiberglass is the generic substance found in Fiberglas®. For low temperature applications polypropylene is the most inexpensive synthetic fiber and is used in many industrial applications such as foundries, coal crushers, and food industries. Nylon is the most abrasion-resistant synthetic fiber, making it useful in applications filtering abrasive dusts. Polyesters such as Dacron fibers have good overall qualities to resist acids, alkalines, and abrasion and are relatively inexpensive, making them useful for many industrial processes such as smelters, foundries, and other metal industries.

Nomex fibers are widely used for fabric filter bags because of their resistance to relatively high temperatures and to abrasion. Nomex is used for filtering dusts from cement coolers, asphalt batch plants, ferroalloy furnaces, and coal dryers.

Other registered trademark fibers such as Teflon, Fiberglas, Ryton, and P84, as well as carbon fibers can be used in very high temperature situations. Teflon has very good resistance to acid attack (except fluorine) and can withstand continuous temperatures up to 445°F (230°C).

Fiberglas or glass is often used in baghouses that handle very high temperatures (up to 500°F or 260°C) for continuous operation. About 90% of the baghouses currently operating on coal fired utility boilers use bags made with glass fibers (McKenna and Furlong 1992). Glass fibers are usually lubricated in some fashion so they will slide over one another without breaking or cutting during the cleaning cycle. Graphite is commonly used as a lubricant and will help retain the upper service temperature limits. Glass fibers can break easily and require a very gentle cleaning cycle. Ryton is a felted filter made from polyphenylene sulfide fibers generally attached to a polyfluorocarbon scrim. Ryton can operate at high temperatures (350°F or 177°C) and shows good resistance to acids and alkalis. Fiberglas, Teflon, Nomex and Ryton have been used to remove particulate emissions generated from industrial and utility coal-fired boilers (Belba et al. 1992).

Another material used to make bags is Gore-tex membrane manufactured by W. G. Gore and Associates, Inc. The Gore-tex membrane is an expanded polytetrafluoroethylene (PTFE) membrane that is laminated with a variety of fibers such as Fiberglas, polyester, and Nomex to produce felt and woven filters. Some test reports have indicated very good emission reduction (99.9+%), low pressure drops, increased bag life and higher air-to-cloth ratios using this material in metal industries, chemical industries, food industries, and coal-fired boilers. However, other fabrics have been able to obtain similar results.

Finally, for very high temperature applications (> 500°C), ceramic filters are now available (McKenna and Turner 1989). These filters show promise for high temperature applications such as using the filters ahead of boiler superheater tube sections to remove particles and improve heat transfer in the boiler tubes.

Table 4-1 lists a number of typical fibers used for fabric filters. The properties of the listed fibers include temperature limits, acid and alkali resistance, abrasion resistance, and relative bag costs. Table 4-1 is only a general guide since bag filters can be made of two or more layers of materials to achieve specific effects (i.e. strength, stability, filtering etc.) The cost (1992) of a fiberglass bag 14 feet long and 6 inches in diameter is approximately $35 to $40. From Table 4-1 the price of a Teflon bag of the same size is approximately $115 to $135.

Table 4-1. Typical fabrics used for bags

Generic name	Fiber	Maximum temperature				Acid resistance	Alkali resistance	Flex abrasion resistance	Relative cost
		Continuous		Surges					
		°F	°C	°F	°C				
Natural fiber cellulose	Cotton	180	82	225	107	poor	excellent	average	0.4
Polyolefin	Polypropylene	190	88	200	93	excellent	excellent	good	0.5
Natural fiber protein	Wool	200	93	250	121	good	poor	average	0.8
Polyamide	Nylon	200	93	250	121	poor to fair	excellent	excellent	0.6
Acrylic	Orlon®	240	116	260	127	very good	fair	average	0.7
Polyester	Dacron®	275	135	325	163	good	fair	excellent	0.5
Aromatic polyamide	Nomex®	400	204	425	218	fair	very good	very good	2.0
Fluorocarbon	Teflon®	450	232	500	260	excellent except poor for fluorine	excellent except poor for trifluoride, chlorine, and molten alkaline metals	fair	6.7
Glass	Fiberglas® or glass	500	260	550	288	good	poor	poor to fair	1.0
Polymer	P84®	450	232	500	260	good	fair	fair	2.5
Polymer	Ryton®	375	191	450	232	excellent	excellent	good	2.5-4.0

Sources: McKenna and Turner 1989.
Greiner 1993.

Fabric Treatment

Fabrics are usually pretreated to improve their mechanical and dimensional stability. They can be treated with silicone to give them better cake release properties. Natural fabrics (wool and cotton) are usually preshrunk to eliminate bag shrinkage during operation. Both synthetic and natural fabrics usually undergo processes such as calendering, napping, singeing, glazing, or coating.

These processes increase fabric life, improve dimensional stability (so that the bags retain their shape or fit after long use), and facilitate bag cleaning.

Calendering is the high pressure pressing of the fabric by rollers to flatten or smooth the material. Calendering pushes the surface fibers down onto the body of the filter medium. This is done to increase surface life and dimensional stability and to give a more uniform surface to bag fabric.

Napping is the scraping of the filter surface across metal points or burrs on a revolving cylinder. Napping raises the surface fibers, creating a "fuzz", that provides a large number of sites for particle collection by interception and diffusion. Fabrics used for collecting sticky or oily dusts are occasionally napped to provide good collection and bag cleaning ease.

Singeing is done by passing the filter material over an open flame, removing any straggly surface fibers. This provides a more uniform surface.

Glazing is the high pressure pressing of the fiber at elevated temperatures. The fibers are fused to the body of the filter medium. Glazing improves the mechanical stability of the filter and helps reduce bag shrinkage that occurs from prolonged use.

Coating, or resin treating, involves immersing the filter material in natural or synthetic resin such as polyvinyl chloride, cellulose acetate, or urea-phenol. This is done to lubricate the woven fibers, or to provide high temperature durability or chemical resistance for various fabric material. For example, glass bags are occasionally coated with Teflon or silicon graphite to prevent abrasion during bag cleaning and aid in acid resistance. The Teflon coating is generally applied at 10% of finished weight level.

Table 4-2. Summary of pretreatment processes

Pretreatment	Method	Result	Reason for use
Calendering	High pressure pressing by rollers	Flattens, smooths, or decorates	Increases surface life Increases dimensional stability Provides more uniform fabric surface
Napping	Scraping across metal points	Raises surface fibers	Provides extra areas for interception and diffusion
Singeing	Passing over open flame	Removes straggly surface fibers	Provides uniform surface area
Glazing	High pressure pressing at elevated temperatures	Fibers fused to filter medium	Improves mechanical stability
Coating	Immersing in natural or synthetic resin	Lubricates woven fibers	Provides high temperature durability Provides chemical resistance for various fabric material

Source: McKenna and Greiner 1982.

Bag Failure Mechanisms

Three failure mechanisms can shorten the operating life of a bag. They are related to thermal durability, abrasion, and chemical attack.

The chief design variable is the upper temperature limit of the fabric, or **thermal durability**. As shown in Table 4-1, fabrics have upper temperature limits which they can withstand continuously. The table also shows surge limits which are temperatures at which the baghouse can be operated for short durations. Consult the fabric supplier for the length of time that the surge temperature can be tolerated. The process exhaust temperature will determine which fabric material should be used for dust collection. Exhaust gas cooling may be feasible, but the exhaust gas must be kept hot enough to prevent moisture or acid from condensing on the bags.

Another problem frequently encountered in baghouse operation is abrasion. Bag **abrasion** can result from bags rubbing against each other, from the type of bag cleaning used, or where dust enters the bag and contacts the fabric material. For instance, in a shaker baghouse, vigorous shaking may cause premature bag deterioration, particularly at the points where the bags are attached. In pulse-jet units, the continual, slight motion of the bags against the supporting cages can also seriously affect bag life. As a result, a 25% per year bag replacement rate is common. This can be the single biggest maintenance problem associated with baghouses (Greiner 1992).

Bag failure can also occur from **chemical attack** to the fabric. Changes in dust composition and exhaust gas temperatures from industrial processes can greatly affect the bag material. If the exhaust gas stream is lowered to its dew point (either water or acid dew point), the design of the baghouse (fabric choice) may be completely inadequate. Proper fabric selection and good process operating practices can help eliminate bag deterioration caused by chemical attack. Lesson 6 discusses bag failures in more detail.

Fabric Testing

A number of standard ASTM tests can be conducted on bag filters either to verify the bag filter's conformity with purchase specifications or to use as a troubleshooting tool for problem bag failures. As with all measurement techniques, the results of these bag tests are relative. Often for these tests to be useful, they must be conducted over time in order to compare relative degradation. In addition, with some of the newer fabrics, some of these tests may not be meaningful. These tests can be used to indicate bag strength and flow loss. Four of the standard tests performed are: permeability, MIT flex, Mullen burst strength, and tensile strength (McKenna and Turner 1989). These tests can be conducted if the installed baghouse is having problems with bag life or unusually high pressure drop.

Permeability

The permeability test is used to determine the amount of air that can flow through a given cloth area. Permeability is defined in ASTM Standard D-737-69 as the volume of air that can flow through one square foot of cloth at a pressure drop of no more than 0.5 in. w.g. (125 Pa). Because air permeability is not a linear function of the pressure difference measured across fabric surfaces, the ASTM method prescribes that permeability tests be made at a pressure drop of 0.5 in. w.g. (125 Pa). Certain fabrics may be too dense or too open to maintain this pressure drop. In these cases, the ASTM method states that measured pressure drop be given in the test report.

The permeability of clean felts usually ranges between 15-35 ft/min (8-18 cm/s), while lighter-weight woven materials have permeability values greater than 50 ft/min (25 cm/s). Permeability can be measured on clean or dirty bags. Dirty bags are usually tested in the "as received" state. They are then cleaned by vacuuming or washing and retested. These measured values can be compared to the original clean permeability of the fabric to determine if bags that have been in service have become blinded. It is also possible that the pores in the fabric will open wider after extended use, which is shown by permeability values higher than the original values. This condition, however, does not occur as frequently as blinding.

MIT Flex

The MIT Flex Test is used to measure the ability of fabrics to withstand self-abrasion from flexing. This test method is described in ASTM Standard D-2176-69, which is the standard method for testing the endurance of paper with the MIT test apparatus.

The flex test has frequently been used to help determine the rate of deterioration of glass bags used in baghouses installed on coal-fired utility boilers. This test also helps provide insight into the effect of bag tensioning on bag life. Flex testing is occasionally performed after exposing the fabric to heat and/or acid in order to simulate conditions in utility boiler baghouses. The test cannot be done with a continuous dust load on the fabric, which limits the comparison to actual field conditions.

Mullen Burst Strength

The Mullen burst strength test, described in ASTM Standard D-231, is designed to show the relative total strength of fabrics to withstand pulsing or pressure.

For new glass fabrics, the Mullen burst test provides a good indication of whether the fabric has been weakened by the heat cleaning given the fabric before coating it with materials such as Teflon or silicon graphite.

Tensile Strength

The tensile strength test provides data on fabric stretch, elongation, and tear. This test method is described in ASTM Standard D-1682-64 for breaking load and elongation of textile fabrics.

Tensile strength varies, depending on fabric type and weight. Synthetic fabrics generally tend to stretch or show greater elongation than natural fabrics. Glass materials usually have high tensile strengths. The tensile test, used in combination with the Mullen burst test to compare strengths of new and used bags, can indicate the deterioration in strength of used bags.

Review Exercise

1. Bag filters (bags) are made from ____________________ materials.
   a. Woven
   b. Felted
   c. Membrane
   d. All of the above
2. ____________________ filters are made from yarn with a definite repeated pattern.
3. The ____________________ and ____________________ weaves have better cake release than the simple weave.
4. In a woven filter, the woven material is not the true filtering surface. The dust ____________________ provides the surface for filtering particles.
5. ____________________ filters are made by needle punching fibers onto a woven backing called a scrim.
6. The layer of woven material used for strength and support of felted or membrane material is referred to as the ____________________.
7. Two natural fibers used for fabric filters are ____________________ and ____________________.
8. Wool and cotton are inexpensive but are susceptible to failure at ____________________ ____________________.
9. The fabric that is most often used in high temperature (> 200°C) industrial processes is:
   a. Fiberglas
   b. Nylon
   c. Cotton
   d. Polypropylene
10. True or False? Fabrics are pretreated to improve their mechanical and dimensional stability.
11. The filter surface of fabric material is sometimes scraped with metal points or burrs on a revolving cylinder to create a "fuzz" on the material. This treatment is called:
    a. Singeing
    b. Glazing
    c. Napping
    d. Resin treating
12. True or False? Glass bags are occasionally coated with Teflon or silicon graphite to prevent abrasion during bag cleaning.

13. When fabric material is passed over an open flame to remove straggly fibers, the treatment is called ____________________.

14. Failure mechanisms that shorten bag operating life are:
    - a. Abrasion
    - b. Temperature excursions
    - c. Chemical attack
    - d. Varying particle size in flue gas
    - e. a, b, and c only

15. True or False? The chief design variable for prolonged bag life is the upper temperature limit of the bag.

16. The amount of air that can flow through a given cloth area is the ____________________ of the cloth.

Review Answers

1. **d. All of the above**
   Bag filters (bags) are made from woven, felted, or membrane materials.

2. **Woven**
   Woven filters are made from yarn with a definite repeated pattern.

3. **Twill**
   Sateen
   The twill and sateen weaves have better cake release than the simple weave.

4. **Cake**
   In a woven filter, the woven material is not the true filtering surface. The dust cake provides the surface for filtering particles.

5. **Felted**
   Felted filters are made by needle punching fibers onto a woven backing called a scrim.

6. **Scrim**
   The layer of woven material used for strength and support of felted or membrane material is referred to as the scrim.

7. **Wool**
   Cotton
   Two natural fibers used for fabric filters are wool and cotton.

8. **High temperature**
   Wool and cotton are inexpensive but are susceptible to failure at high temperature.

9. **a. Fiberglas**
   The fabric that is most often used in high temperature (> 200°C) industrial processes is Fiberglas.

10. **True**
    Fabrics are pretreated to improve their mechanical and dimensional stability.

11. **c. Napping**
    The filter surface of fabric material is sometimes scraped with metal points or burrs on a revolving cylinder to create a "fuzz" on the material. This treatment is called napping.

12. **True**
    Glass bags are occasionally coated with Teflon or silicon graphite to prevent abrasion during bag cleaning.

13. **Singeing**
    When fabric material is passed over an open flame to remove straggly fibers, the treatment is called singeing.

14. **e. a, b, and c only**
    Three failure mechanisms that shorten bag operating life are abrasion, temperature excursions, and chemical attack.

15. **True**
    The chief design variable for prolonged bag life is the upper temperature limit of the bag.

16. **Permeability**
    The amount of air that can flow through a given cloth area is the permeability of the cloth.

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