CHAPTER 3

Non-woven Fabric Media

Whilst in the total world of textile fabrics, woven materials are dominant, by comparison with other forms of textile, the reverse is true in filtration media fabrics, with non-wovens taking an ever increasing share of the fabric component of the filter media market. One reason for this is the continuing demand for finer filtration, of both liquids and gases, which can be met by very finely spun fibres, assembled into ever more complex forms of non-woven materials.

3.1 Introduction

In the form of woollen felts, non-wovens can claim to be the oldest form of textile fabric, and for many centuries represented the only alternative process to weaving, by the combined action of moisture and heat on carded wool fibres. This simple scenario has been radically changed during the last half-century by the development of a continually expanding variety of manufacturing techniques and novel products, based on a similarly continually expanding array of raw materials.

The first significant step recorded in this development process was the production of a few thousand metres of adhesive-bonded fibre webs in the USA in 1942(1), for which the term 'non-woven fabric' was coined. Subsequent years have seen the invention of various other adhesive techniques, including adhesive dispersions, the wet and dry laying of webs, and the integral bonding of thermoplastic fibres. Alternative processes have included mechanical bonding, based on needling or stitch knitting, with or without the use of binding threads. To these became added the increasingly important ability to laminate two or more fabrics together, or to apply a coating to a non-woven product, so as to form a composite fabric.

As these techniques and processes were evolving during the 1960s, there was a considerable amount of international debate over describing them all as 'non-woven fabrics'. In fact, in his book *Manual of Nonwovens*(1), Professor Krcma devoted more than two pages of text to this topic, in addition to a list of 24 literature citations – one of which has the stark heading: 'Wanted: a new name for nonwovens'(2). The point of dispute was the linguistic contradiction inherent in this combination of words, which evidently caused grammatical problems in literal translations into some other languages. Despite these semantic niceties, common usage has long since resulted in the acceptance of this terminology.

Krcma's own definition of the term is all-embracing: 'non-woven fabrics are textile fabrics made of a fibrous layer, which may be a carded web, a fibre web, or any system of randomly laid or orientated fibres or threads, possibly combined with textile or non-textile materials such as conventional [woven] fabrics, plastic films, foam layers, metal foils, etc., and forming with them a mechanically bound or chemically bonded textile product.'

That definition includes paper as a non-woven fabric, which is a usage foreign to the filtration application. Paper is, of course, frequently made, or at least dried on a non-woven belt, but it is covered separately in this Handbook (Chapter 4), because the fibres, made from wood cellulose, are much shorter than the natural or synthetic fibres actually used to make non-woven fabrics. Whilst paper is essentially a wet-laid product, the great majority of non-woven fabrics are dry-laid.

A non-woven fabric, then, is one that is made up from an agglomeration of fibres, and sometimes of continuous filaments, which are held together by some form of bonding, to create a more or less flexible sheet of fabric. This will be as wide as the bed upon which the non-woven material is laid down, and as long as the receiving rolls can accept. In their bulk, as-made, format non-wovens are sometimes referred to as 'roll goods' (as are woven fabrics as they leave the loom), as opposed to piece goods, which might refer to the individual pieces of filter media cut from the roll, prior to their being fitted into or onto a filter.

The chemical properties of a non-woven fabric are dictated almost entirely by the nature of the basic fibre – unless there is a binding adhesive of significantly different properties (such as melting or softening temperature). Accordingly, the chemical properties of non-wovens can be obtained from the same tables of such properties that were given at the start of Chapter 2 for woven fabrics.

3.2 Types of Non-woven Fabric

There is a steadily increasing range of non-woven fabrics, as manufacturers develop new processes for their production. Nevertheless, it is possible to define two broad classifications of such materials, into which almost all non-woven fabrics will fall, and which can then be used as headings for subsequent description. These two classes are, to a large extent, divided by the means utilized to hold the loose fibres together:

- felts, which use the basic characteristics of the fibre to provide mechanical integrity, or which use mechanical processing to create a fabric; and
- bonded fabrics, which use some additional adhesive material to hold the fibres together, or, more commonly, rely upon the thermoplastic nature of the polymer to provide adhesion.

This second group is then further divided in two, according to whether the basic formation of the basic fibre is an integral part of the manufacture of the medium (the dry-laid spun media) or not (resin and thermal bonding).

It should be realized that non-woven fabrics are used in many other fields of industry and commerce besides filtration, and that they are therefore a very important part of the industrial scene. Two major (and related) societies, INDA(3) and EDANA(4), exist to support the non-wovens industry, including the organization of conferences devoted to the use of non-wovens in filtration – annually in the USA, and every third year in Europe.

In its brochure for its 'Index '99' exhibition, EDANA stated that: 'Non-wovens represent 90% of all filter media used in dry and liquid filtration.' Even if paper media are included in the total, this is a high figure, but nevertheless it does indicate the importance of non-wovens to the filter media marketplace.

3.3 Felts

Some fibres, wool especially, have the ability to cling together to form a coherent mass. Most others can be made to adhere by suitable processing. The first step in any felt making process is the unloading of the bulk fibre into a carding machine, where the fibres are drawn out into a thin web, which has its fibre content roughly aligned in one direction. Pieces of such web can then be placed one above the other to provide a felt of the required thickness. The successive layers can all be aligned with the fibres all lying in the same direction, or in different directions to give equal directional strengths. When sufficient thickness has been achieved, the felt is compressed and heated, often after dampening, to produce its final structure.

The distinctive characteristic of felt is that it comprises a mass of individual fibres, which are compacted and locked together to form a cohesive structure. Early civilizations learnt how to felt wool by means of heat and moisture, so as to produce cohesion through the localized breakdown of the complex structure of these natural fibres. Although this process is not applicable to the wide variety of modern synthetic fibres and filaments, they can nonetheless be felted, either by bonding with an adhesive (as discussed in Section 3.4), or by a mechanical entanglement process known as needle punching.

3.3.1 Needlefelts

For some, undemanding, applications, a simple felt can provide suitable performance, without any form of strengthening. However, their low tensile strengths, and the ease with which fibres can become detached from the felt and enter a downstream flow, make simple felts unattractive for most filtration purposes, and some mechanical (or chemical) strengthening is required.

Needle punching is by no means a new technique, since it originated in the 1880s with natural fibres, but it is only since about the early 1970s that it has come into prominence because of its applicability to many synthetic fibres. The first step is to assemble several layers of carded fibre into a 'lofty' (i.e. bulky) web or 'batt'; this is then compressed into a denser structure by needle punching with a mass of special barbed needles reciprocating at speeds up to 2000 strokes/minute, as illustrated in Figure 3.1.

With perhaps 100 or more needle penetrations per square centimetre, the effect is to entangle the fibres and to reduce the thickness of the web substantially, to a degree that is controlled as desired. Punching may be on both sides of the web instead of just the one, as in Figure 3.1; this improves the uniformity of the felt.

Before needling, the web of loose fibres is prepared with great care, using the traditional carding methods of the textile industry: several layers of carded fibre are stacked on top of one another, according to the desired thickness and density of the final needlefelt. Carding aligns the fibres along the length of the machine, so that a stack of layers in parallel produces a felt that is far stronger in the machine direction then transversely. Cross laying of alternate layers can eliminate this directional difference, or even reverse it, depending on the angle between consecutive layers.

Most felts are mechanically strengthened by needling, but an alternative, and more specialized, technique employs a set of high-pressure water jets to fix the fibres in place – a technique known as hydroentanglement.

3.3.1.1 Needlefelt properties

The relatively low tensile strength of a plain felt is significantly improved by needling. Even greater strength can be achieved by forming the needlefelt around an inner scrim, which is a single layer of very open woven mesh, as in Figure 3.2. The scrim layer is placed within the pile of individual webs that make up the felt; some felts are asymmetric in structure, with the scrim located accordingly for optimum abrasion resistance. Formation around a scrim is the more common structure of needlefelts for filtration, although scrimless felts are also sometimes used. A scrimmed needlefelt is essential in the case, say, of filter bags that are cleaned by a reverse jet of air, to expand the bag. The frequent and regular expansions and contractions would be more than a plain needlefelt could tolerate.

The shape of the cross-section of the fibre is a significant factor in determining the strength of a needlefelt. This has accordingly received considerable attention from manufacturers seeking to meet the demanding conditions imposed on their

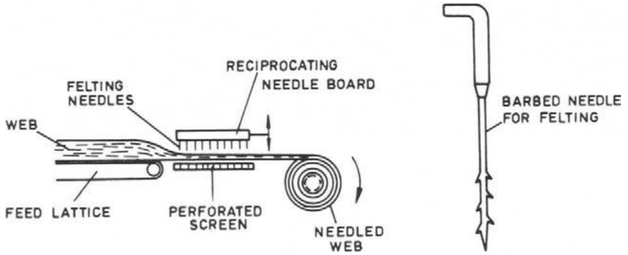


Figure 3.1. Principles of the needle felting process using barbed needles.

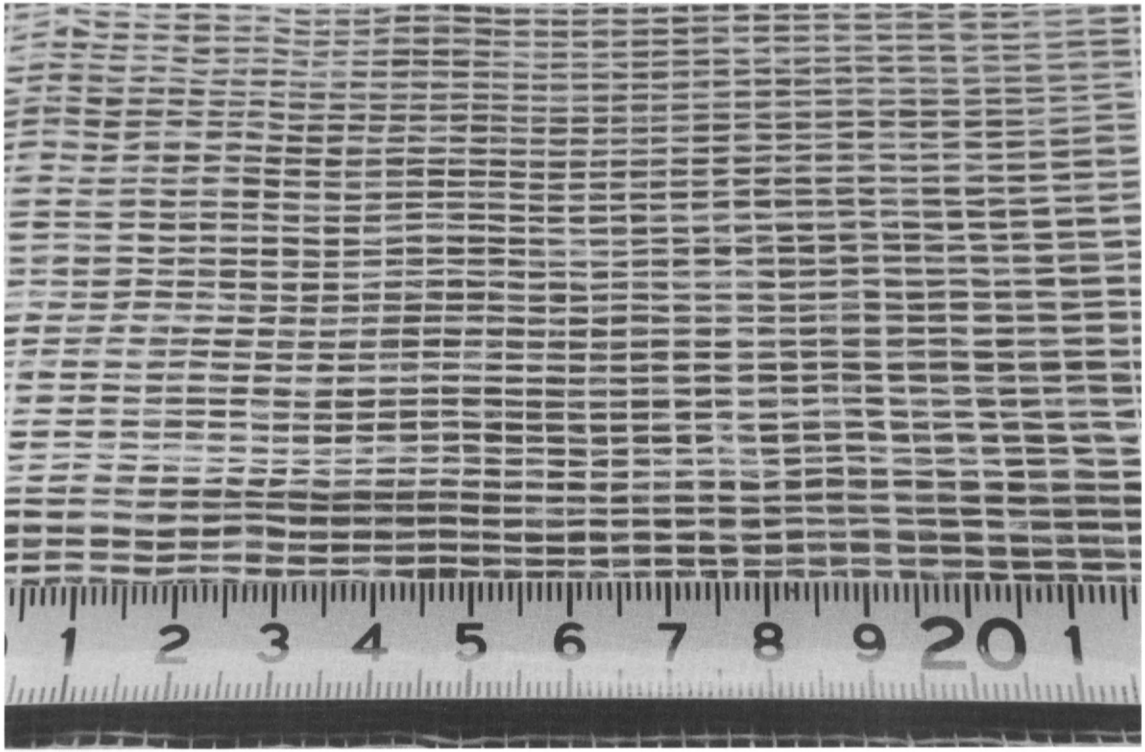


Figure 3.2. A typical scrim around which a felt is formed by needle punching.

products in applications varying from carpets to clothing, with filtration by comparison generally providing a relatively small-scale market. Figure 3.3 shows the highly profiled form of Lenzing's P84 fibres, while various fibre shapes are illustrated in Figure 2.5 of Chapter 2.

The fineness of the fibres in a needlefelt has a significant impact on filtration efficiency, notably in respect of the concentration of particles in the exhaust from bag house fabric filters. A paper by Dilger(5) summarizes the results of a development programme by Du Pont utilizing fine fibres of both Nomex and Teflon. The emission level of a 520 g/m^2 needlefelt of standard 2.2 dtex Nomex fibres was 1.19 g/m^3 higher than that of a 500 g/m^2 felt of 1.1 dtex fibres.

In many ways, needlefelts would appear to be ideal for filtration, combining the possibility of greater flexibility and versatility in construction, including the ability to produce asymmetric forms, by exploiting variations of fibre diameter and shape, plus the final felt density. Thereby it should be possible to achieve a far more uniformly open surface and controlled in-depth structure than with woven fabrics. On both of these counts, however, the reality falls short of the ideal, but still provides a rich source of media of great industrial value, especially in dry filtration for the collection of dusts.

The possibility of optimizing construction of a needlefelt to suit a particular application is, in practice, limited by the practical realities of the textile industry, with its commitments to fields other than filtration. Two factors must be borne in mind: first, felt manufacturers are generally dependent on outside suppliers for the fibres they require, and can only buy grades that the suppliers find it economic to produce on the large scale implicit in their own manufacturing processes; secondly, felting itself is also essentially a large-scale operation, and is therefore inevitably geared to large markets.

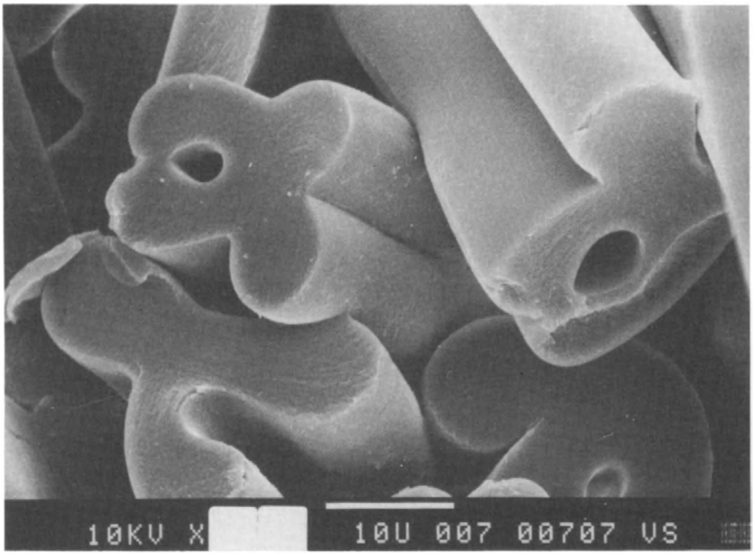


Figure 3.3. Microphotograph showing the cross section of Lenzing's P84 fibres.

As for the uniformity of the surface and control of the in-depth structure of a needlefelt, close inspection under magnification reveals something of the underlying technical difficulties. Figure 3.4 is a microphotograph of a section cut through a felt that has been needle punched on both sides. In Figure 3.4 the points of penetration by the needles are clearly visible, revealing the orientation of fibres imposed at a point of penetration: it also shows the yarns of the scrim along the centre line of the sample. It is very possible that the needle holes may be significantly larger than the pores in the rest of the structure.

For much of the last 30 years, needlefelts have been the dominant material for filter media, especially for gas cleaning. However, they are now steadily being replaced by the thermally bonded spun polymeric media, discussed in Section 3.5, which are capable of much finer degrees of filtration.

Initial enthusiasm for the seemingly endless potential of these then new types of filter media in the early 1970s stimulated Wrotnowski(6) to propose a theoretical model to relate the pore size of a needlefelt to the diameter of the fibres and the density of the felt. For a time, this relationship was used as a guide to the ranges of needlefelt available – as shown for polyester and polypropylene needlefelts in Table 3.1, but subsequent experience and material development led to its being largely discarded in favour of the empirical summary of the available fabrics, as discussed later.

3.3.1.2 Surface coatings

The finishing processes applied to needlefelts are much the same as for woven fabrics, as discussed in Section 2.3.1.2. These include calendering and singeing, the latter being illustrated in Figure 3.5, as techniques to modify the surface finish, rather than adjusting pore size.

The coating of needlefelt fabric surfaces is a little more complex, and sometimes it is difficult to draw the line between coated fabrics and the bonded media discussed in Section 3.4, or between coated fabrics and the membranes

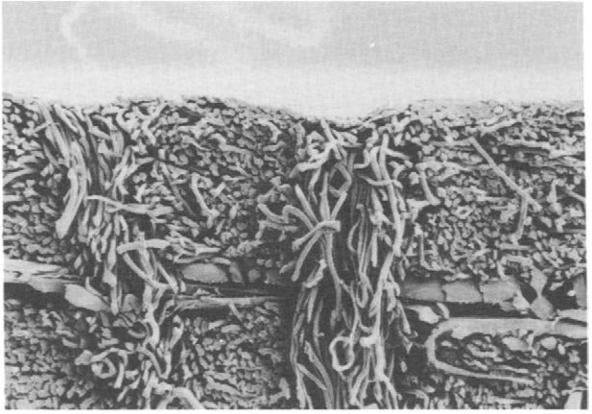


Figure 3.4. Cross section through a needle felt, showing the scrim and also the fibre re-orientation caused by the needling, at ×62 magnification.

made using felts as substrates and discussed in Chapter 8. Coatings can be employed to change the porosity of the surface of the felt, and/or to protect the materials of the fibres from heat or the corrosive effects of gases (or, to a lesser extent, of liquids), or to protect against abrasion. Another major use is to increase the ability of the mesh to release a cake of collected solids, whether this be hygroscopic or oily.

Simple surface coatings include the Ravlex material described in Chapter 2, and illustrated in Figure 3.6, and the Madison 'Primapor' and 'Azurtex' materials also described earlier.

Webron, for example, supplies its Microweb 2000 and Microweb II media as PTFE and acrylic coatings, respectively, on a polyester needlefelt (at 2.1 m wide), with relatively high permeabilities. The company also supplies Supaweb chemical treatments, which can be applied to felts of most synthetic materials, and which are thermally bonded to the basic material. Each treatment conveys a particular additional property upon the felt:

- Supaweb DR improves cake release behaviour;
- Supaweb WR repels water and improves release of hygroscopic dusts;

Table 3.1 Theoretical variation of pore size of needle felt with fibre diameter and felt density

Felt density (g/cm^3)	Polyester			Polypropylene			
	Fibre diameter (μ)			Fibre diameter (μ)			
	12	18	25	15	21	30	48
0.01	41	64	91	42	60	77	134
0.12	36	57	81	37	53	69	118
0.14	33	51	73	33	47	61	106
0.16	30	48	66	30	43	55	96
0.18	27	43	61	28	39	51	88
0.20	25	40	57	25	36	47	81
0.22	24	38	53	24	33	43	75
0.24	23	35	50	22	31	40	69
0.26	21	33	47	21	29	37	65
0.28	20	31	44	19	27	35	61
0.30	19	29	42	18	26	33	57
0.32	18	28	40	17	24	31	54
0·34	17	27	38	16	23	29	51
0.36	16	26	36	15	21	28	48
0.38	16	24	35	14	20	26	46
0.40	15	23	33	13	19	25	43
0.42	14	22	32	13	18	24	41
0.44	14	21	30	12	17	22	39
0.46	13	21	29	12	16	21	37
0.48	13	20	28	11	16	20	35
0.50	12	19	27	11	15	19	33
0.52	12	18	26	10	14	18	32
0.54	11	18	25	10	14	17	30
0.56	11	17	24	9	13	17	29
0.58	10	16	23	9	12	16	28
0.60	10	16	23	8	12	15	26

- Supaweb OR aids release of oily cakes;
- Supaweb CR greatly improves resistance to chemical attack;
- Supaweb FR resists the effects of incandescent particle carry over.

The corresponding treatment processes employed by Fratelli Testori, a long-established maker of filtration fabrics, include:

- Novates, a coating of polyurethane on polyester or acrylic felts, which is hydrophobic and oleophobic; it resembles a membrane, although the finished pore size is only stated as 'below 15 µm';
- Mantes, a chemical treatment of the felt with a resin containing PTFE, for application to acrylics, and high-temperature fibres such as aramid, polyimide and sulfar (PPS), giving good chemical resistance;
- Kleentes, which involves steeping the fabric in a chemical solution containing PTFE and fluoride resins at high concentrations, following which the fabric is dried and heated to fix the fluorides on the fibres; used

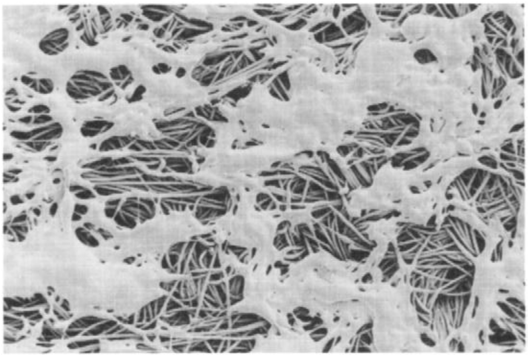


Figure 3.5. The surface of a heavily singed needle felt.

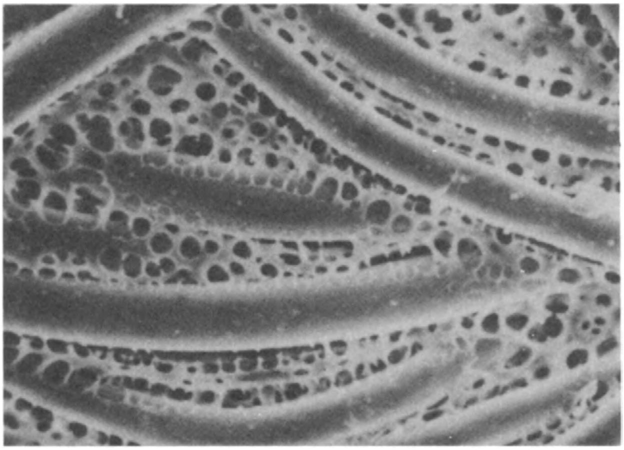


Figure 3.6. 'Ravlex' coating on spunbonded polypropylene needle felt.

on polyester or acrylic fibres to give good cake release and protect from chemical activity;
- Rhytes, which is made in a similar fashion to Kleentes but is applied to higher temperature fibres, to improve the high-temperature performance, and reduce chemical attack.

Madison has also developed an abrasion-resistant coating in its Tuf-tex coatings for polypropylene, nylon and PET substrates (woven as well as nonwoven). These are thermosetting resins sprayed or knifed onto the surface, giving not only abrasion resistance, but also improved dimensional stability.

3.3.1.3 Needlefelt fabrics

The type and range of needlefelt fabrics available are well illustrated by the data of Table 3.2. This shows the main products of Andrew Textile, a long-established needlefelt maker (and sister comapny of Webron Products), in the company's standard range, for four different fibres: polyester, polypropylene, homopolymer acrylic, and copolymer acrylic. A similar table, Table 3.3, shows the corresponding data for a range of higher temperature polymers: aramid, PPS, PTFE and polyimide. These materials have porosities between 72 and 87%, and

Table 3.2 Standard needlefelts[a]

Product	Weight (g/m^2)	Thickness[b] (mm)	Density (g/cm^3)	Air permeability[c]	Breaking strength[d]	Elongation[e] (%)	Lineal (%)	Shrinkage[f], C
Polyester								
T350TFS	350	1.35	0.26	350	1000	3	3	170
T400TFS	400	1.40	0.27	260	1100	3	3	170
T450TFS	450	1.45	0.31	220	1200	3	3	170
T500TFS	500	1.75	0.29	190	1200	3	3	170
T550TFS	550	1.80	0.31	165	1300	3	3	170
T640TFS	640	2.15	0.30	140	1300	3	3	170
Polypropylene								
P400PFS	400	2.00	0.20	225	450	4	3	100
P450PFS	450	2.20	0.20	170	500	4	3	100
P500PFS	500	2.30	0.22	150	500	4	3	100
P550PFS	550	2.75	0.20	130	550	4	3	100
Acrylic HP								
H400HSS	400	1.78	0.22	260	500	4	3	150
H500HSS	500	2.15	0.23	200	600	4	3	150
H550HSS	550	2.33	0.24	165	650	4	3	150
Acrylic CP								
C500HSS	500	2.10	0.24	600	600	4	3	140

[a] Andrew Textile Industries Ltd.

[b] Thickness at 2.2 kPa.

[c] Air permeability, $dm^3/dm^2/min$ @ 20 mm WG.

[d] Minimum breaking strength, N/5 cm.

[e] Maximum elongation @ 50N/5 cm.

[f] Maximum lineal shrinkage after 24 h exposure to dry heat.

Table 3.3 High-temperature needlefelts[a]

Product	Weight (g/m^2)	Thickness[b] (mm)	Density (g/cm^3)	Air permeability[c]	Breaking strength[d]	Elongation[e] (%)	Lineal (%)	Shrinkage[f], C
Aramid								
X407XSS	400	2.00	0.20	265	500	3	3	240
X489XSS	480	2.30	0.21	200	650	3	3	240
X500XSS	500	2.10	0.24	180	650	3	3	240
X550XSS	550	2.30	0.24	165	700	3	3	240
X559XSS	550	2.40	0.23	175	750	3	3	240
X509XSS	500	2.30	0.22	200	650	3	3	240
PPS								
R552RSH	550	1.85	0.30	225	500	3	2	200
R500RSH	500	1.60	0.31	230	600	3	2	200
PTFE								
F702FFH	700	0.96	0.73	145	500	6	3	250
F750FFH	750	1.00	0.75	115	600	6	3	250
F840FFH	840	1.05	0.80	90	600	6	3	250
G800FFH	800	1.40	0.57	110	650	6	3	250
F700FFH	700	1.05	0.67	135	600	6	3	250
Polyimide								
I550ISS	550	2.65	0.21	170	600	4	3	250

[a] Andrew Textile Industries Ltd.

[b] Thickness at 2.2 kPa.

[c] Air permeability, dm^3/dm^2/min @ 20 mm WG.

[d] Minimum breaking strength, N/5 cm.

[e] Maximum elongation @ 50N/5 cm.

pore sizes between 35 and 66 μm. The tensile strengths range from 40 to 100 kgf/5 cm strip.

Two significant recent introductions by Andrew Textile concern scrims and microfibres. The use of a scrim in needlefelt has been traditional in Europe, but it has been less common in the USA. Andrew introduced its Fibre-Locked felts to Europe, to overcome the problems of the weakening of a scrim in the needling process. This material has lower tensile strengths than those of scrim supported felts, but the general filtration performance is better.

Consequent upon the availability of finer, so-called 'microdenier' fibres, Andrew has also introduced its Micro-felt, made 100% from fibres of less than 10 μm in effective diameter. This material is able to achieve much finer degrees of filtration, with mean pore sizes of 12 to 25 μm (from fibres of 0.5 to 2.25 denier).

Figure 3.7 shows an interesting variant of the flat sheet form in which needlefelts are generally produced, this being Webron's Circron circular seamless tubes or sleeves. They are produced by continuously winding and needling a web of fibres around a rotating mandrel, so as to apply a number of layers to build up the required final thickness; the tube thus formed is drawn continuously off one end of the mandrel, so that the length is virtually unlimited. Circron tubes of various fibres are available with inside diameters from 68 to 350 mm, wall thicknesses from 8 to 18 mm, and in materials including

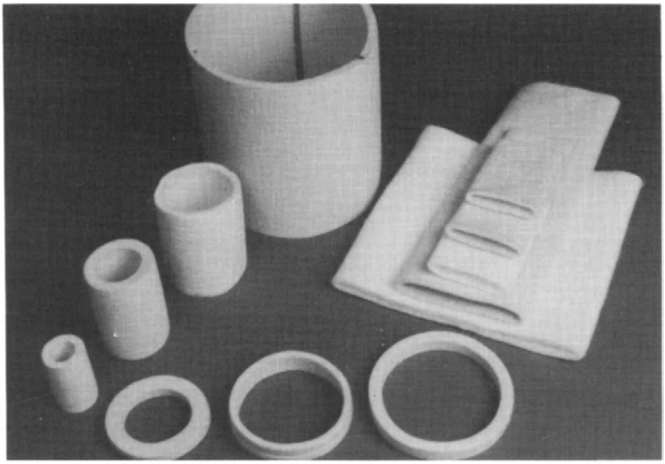


Figure 3.7. 'Circron' seamless needle felt tubes.

polypropylene, polyester, acrylic, aramid and PPS; porosities are 65–90%, with pore sizes up to 400 μm.

3.3.2 Electrostatic effects

The filtration of solids from fluids can create electrostatic effects, or can benefit from the existence of electrostatic charges on the filtration media. Especially in the case of the filtration of dusts, the presence or absence of such charges can make a great difference to the filtration performance.

3.3.2.1 Electrically charged non-wovens

Many particles in fluid suspension carry a small electric charge, and so will be more effectively removed from suspension if the filter medium carries an opposite charge. This effect is utilized in the media known as 'electrets', and the phenomenon of 'zeta potential'. The effects are covered in detail in Chapters 4 and 5.

3.3.2.2 Anti-static media

A well-known problem in applying needlefelts to dust filtration is the hazard that can arise from the build-up of electrostatic charges on the filter surface. To guard against this, the system must be well earthed, which is only possible if the fabric of the filter bags has a sufficiently high electrical conductivity. By contrast with this requirement, the synthetic polymers from which needlefelts are made have a high electrical resistance, and are therefore very susceptible to becoming highly charged with static electricity.

The solution to this difficulty is to increase the conductivity of the fabric, either by chemical treatment, so that the polymeric fibres become coated with metal salts, or by incorporating into its structure a small quantity of other fibres that are themselves highly conductive. It is worth emphasizing the importance of ensuring that, in use, filter bags of anti-static cloth are properly earthed; if they are not earthed, they will actually increase the static hazard since their much higher capacitance will enable correspondingly high static charges to accumulate.

Chemical treatment has the disadvantage that it is not durable, since the coating is likely to abrade and disintegrate in use, especially if filter bags are occasionally laundered. By contrast, the inclusion of conductive fibres provides permanent protection. Examples of conductive fibres are DuPont's Epitropic and Bekaert's Bekinox. The latter are of a special grade of stainless steel that is of extremely high purity, so as to avoid the risk of inclusions within the very fine 6.5, 8, 12 or 22 μm diameter fibres.

Epitropic fibres are primarily polyester, with an outer sheath of polyester isophthalate copolymer, which is impregnated with particles of carbon black, as illustrated in Figure 3.8. The sheath has a melting point 35°C lower than the core; it can be softened by controlled heating so that the carbon particles become embedded in it, to be an integral part of the fibre surface. The electrical conductivity of these fibres is 50 times higher than that of stainless steel; this, combined with their significantly lower density, is claimed to give them a significant cost advantage for lower temperature applications suited to polyester.

An alternative approach is to make the scrim conductive as well as having stainless steel fibres among those of the felt. This feature is exemplified by Andrew Textile's conductive felts, listed in Table 3.4.

3.4 Bonded Media

The fibres in felted media or needlefelts are held together by the natural interlocking of the staple fibre, or by the additional entangling of needling or hydroentanglement, coupled with a small effect of temperature at the points of contact of the fibres. Another group of non-woven materials achieve their

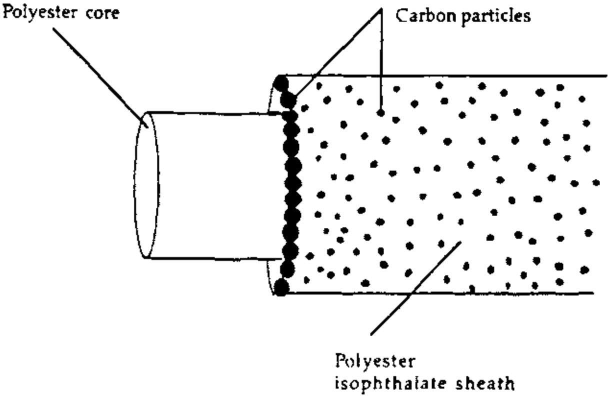


Figure 3.8. The structure of 'Epitropic' fibres.

Table 3.4 Anti-static needlefelts[a]

Product	Weight (g/m^2)	Thickness[b] (mm)	Air permeability[c]	Breaking strength[d]	Elongation[e] (%)	Lineal (%)	Shrinkage[f], C
Conductive							
XS550XKS	550	2.40	150	750	3	3	230
TS500TKS	500	1.55	180	1100	2	3	170
TS550TKS	550	1.70	160	1100	2	3	170
TE500TFS	500	1.65	175	1100	2	3	170
TE640TFS	640	1.90	125	1250	2	3	170
HS500HKS	500	2.30	250	650	5	3	140
PS502PKS	500	2.60	210	1000	2	2	100

[a] Andrew Textile Industries Ltd.

[b] Thickness at 2.2 kPa.

[c] Air permeability, $dm^3/dm^2/min$ @ 20 mmWG.

[d] Minimum breaking strength, N/5 cm.

[e] Maximum elongation @ 50N/5 cm.

[f] Maximum lineal shrinkage after 24 h exposure to dry heat.

cohesion by a specific bonding process of the fibres in the felt, either by means of the addition of a separate bonding agent, or by localized melting of thermoplastic fibres at the points of contact.

3.4.1 Resin-bonded media

Historically the first of the bonded materials to come into use, the *chemically* or *resin-bonded* materials employ an adhesive resin of some kind, impregnated throughout the bulk of the felt, to provide the required degree of cohesion to the fibres. The web of fibres, staple or artificial, would be formed in exactly the same way as felts, by carding and layering, and then a quantity of resin, usually in liquid form, would be sprayed or otherwise distributed throughout the fibre mat, followed by some kind of curing process, to set the resin to achieve both the required level of permeability and also of material strength.

By far the greater amount of bonded material is made by *dry laying*, but there are some specialized media made by *wet laying*. Wet-laid media are produced by the ancient art of papermaking: short staple fibres, whether natural or synthetic, are dispersed in water to produce a slurry; this slurry is then fed continuously onto a moving screen or array of wires, and the slurry dewaters by gravity drainage, sometimes assisted by pressure or vacuum. The resultant web of uniform, but randomly orientated, fibres is then dried over a series of heated rollers. An adhesive or binding agent can be incorporated in the original slurry, or sprayed on the web after its formation; the drying process will then set the binding agent as required. Almost all wet-laid media are made from wood cellulose or glass fibre, and are used as filter papers or related formats – which are discussed in detail in Chapter 4.

Dry-laid media are so called because the first step in their manufacture is the formation of a web of short fibres, directly from the raw fibre material, by means of the conventional bundle opening and carding methods and machines of the textile industry. Multiple layers or sandwiches of the carded fibres are then laid mechanically, with successive layers having the same or different directions of orientation of the fibres, according to the required strengths of the finished material in its individual directions. The layering may be done by cutting the web into strips as it is formed, and then depositing these strips, one above the other, or by using several carding machines in series, as in Figure 3.9.

Less frequently, the opened fibre is transported and dispersed pneumatically by *air laying*, thereby forming a non-directional web, which is usually bulkier ('loftier') than carded webs.

If the fibres are of suitable material, the web may be heat-sealed by means of hot rolls. If not, then the web may be treated with a binding resin, either by spraying onto one or both sides of the web, or by immersion in a bath of the resin, before it is finally dried and cured.

The web of fibre, mixed with bonding agent, can be laid down on a cylindrical former, to produce a cartridge element, as described in Chapter 9.

3.4.2 Thermally bonded media

If the web of fibre is of a thermoplastic polymer, and is not too thick, then the fibres can be bonded by passing the felt between pairs of heated rolls, which have a dimpled surface, with raised areas opposite one another, to compress the fibres and heat them in localized spots across the width of the roll.

Freudenberg, one of the world's largest makers of non-wovens for filtration, has a set of such 'point-sealed' media, shown in Table 3.5, relating to polypropylene and used for industrial liquid filtration.

3.5 Dry-laid Spun Media

Probably the most exciting developments in non-woven media have come from a series of combined extrusion and layering processes that exploit the

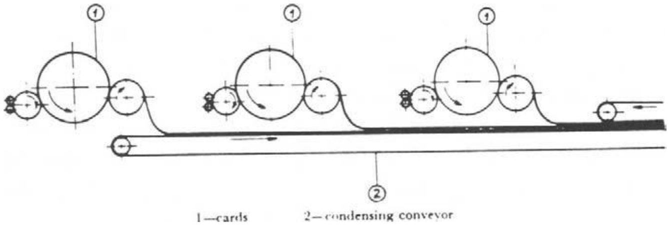


Figure 3.9. Forming a multi-layer web by simultaneously dry laying a sequence of webs from several carding machines in tandem(1).

Table 3.5 Freudenberg point-sealed media[a]

Grade	Weight (g/m^2)	Thickness (mm)	Air permeability ($l/m^2/s$)[b]	Water permeability[c]	Tensile strength[d]	Bubble point (μm)	Mean flow pore (μm)
FFK3423	23	0.23	2350*	671	53	150	80
FFK3440	40	0.38	1180	198	106	100	45
FFK3460	60	0.48	855	144	170	90	43
FFK3470	70	0.50	600	101	188	84	40
FFK3480	80	0.56	560	94	210	78	37
FFKH3410	100	0.64	396	67	250	69	27

[a] Freudenberg Viesstoffe KG, Filter Division.
[b] At 100 Pa (* 50 Pa).
[c] $l/m^2/s$ @ 200 mmWG.
[d] N/5 cm in machine direction.

thermoplastic nature of many synthetic polymers. From small beginnings only a relatively short time ago, the dry-laid spun media have now increased to the state where they are of comparable importance in the filter media market place with woven media and needlefelts.

Since the late 1960s, these novel manufacturing processes have developed rapidly, to give the resulting materials this commanding position in the filter media business. The development has been so rapid that a standard set of terms has not yet been agreed on an industry-wide basis – some refer to all such materials as 'spunbonded', others differentiate between spunbonded and 'meltblown', while terms such as 'melt spun' and 'flash spun' are also used.

The earliest such processes were those first called melt spinning, now generally known as spun bonding, and which remain important to the present day. They produced relatively coarse filaments, while the newer developments, such as melt blowing, have enabled the production of much finer fibres.

The key feature of these processes is that a molten polymer is extruded through a series of holes in a spinneret, and the resultant filaments are laid down in various ways on a moving belt running under the spinnerets. The final bonding of the filaments or fibres is achieved by various combinations of heat, pressure and chemical activation, although the thermoplastic nature of the polymer is the prime structural feature. It is this integral production of filament or fibre followed immediately by its laying down as the medium that distinguishes the spun media from the felts – which are made, usually, from bundles of fibre bought in from a separate supplier.

Thus, diverging from the usage of the first edition of this Handbook, where all of these materials were classed under the general heading of spunbonded media, they are here classed as dry-laid spun media. The essential difference between spunbonded and meltblown materials is recognized and described in the following notes.

The differences between the two main classes of dry-laid spun material are significant in terms of filtration behaviour, but both are available with the same range of finishing processes as are used for woven and needlefelt materials: calendering, singeing and coating. The lamination of different materials is also an important feature of dry-laid spun media.

3.5.1 Spunbonded media

In the production of spunbonded media, conventional synthetic fibre technology is used to extrude molten polymer through the orifices of a set of spinning heads or spinnerets, mounted above, and across the width of, a moving screen belt. This produces a multiplicity of continuous filaments, which are first quenched by a cross flow of air, and then drawn downwards by concurrent air streams, through an aspirator jet. The spinnerets oscillate from side to side, and the result is that the filaments, kept apart by electrostatic charges, are randomly laid down on the belt (which has a suction box underneath it).

The fineness of the filaments depends directly upon the size of the capillary nozzles in the spinnerets, and is therefore relatively coarse. Spunbonded media are therefore not capable of very fine degrees of filtration, but are relatively strong in mechanical terms.

The continuous roll of spunbonded material is finally consolidated to the required performance specification, usually by some form of calendering. The majority of spunbonded materials are made from polypropylene and polyester melts.

The name Reemay was originally the registered trademark of Du Pont for the company's spunbonded polyester material. The name lives on, now within the BBA Nonwovens Group, which provides an extensive range of spunbonded media, all produced in the manner described above. The range includes the Reemay polyester media, as well as the polypropylene Tekton media (known as Typar within North and South America), and other polyester media such as Synergex, Typelle and QualiFlo.

Table 3.6 lists the properties of filtration-grade Reemay, made from fine polyester fibres with diameters of 16 or 23 μm; the filaments may be of round or trilobal cross-section, and, as shown in Figure 3.10, they may be straight or crimped. Corresponding grades of Tekton/Typar polypropylene media are summarized in Table 3.7; their thicker 25 and 39 μm fibres, together with a modification to the process to introduce directional orientation of the filaments, provide high material strength.

Another extension of the spunbonding process is to add a needle punching stage. BBA's Typelle has a polyester web formed by spunbonding, which is then partially consolidated in the normal way for spunbonds, prior to being needle punched. Data for Typelle are given in Table 3.8.

3.5.2. Meltblown media

Melt blowing was reported by Meyer$^{(7)}$ as having been pioneered in a programme aimed at developing microfibres capable of collecting radioactive particles in the upper atmosphere. The process was refined and licensed for commercial use by Exxon, and is now one of the most important production routes for filtration media.

Table 3.6 'Reemay' polyester spunbonded media[a]

Style No.	Filament		Weight (g/m)	Thickness (mm)	Grab tensile N (MD×XD[c])	Trap tear N (D×XD[c])	Bursting pressure (kg/cm^3)	Permeability to air[d]	% Filtration efficiency	
	Size[a]	Shape[b]							In air[e]	In water[f]
Straight fibres										
2004	4	T	14	0.13	36×27	11×14	0.62	6830	35	25
2005	4	T	17	0.18	41×32	18×23	0.48	6590	40	28
2055	4	T	19	0.15	50×41	18×18	0.69	5514	73	25
2006	4	T	20	0.18	45×36	18×23	0.76	4880	33	30
2011	4	T	25	0.18	63×50	23×27	0.83	5124	66	30
2014	4	T	34	0.28	86×72	27×32	1.17	4294	66	37
T-667	4	T	34	0.23	99×90	32×32	n/a	3780	80	50
2015	4	T	37	0.25	99×95	45×45	1.58	3540	61	40
2016	4	T	46	0.28	162×122	41×50	2.20	2560	65	40
2024	4	T	71	0.30	275×212	41×50	3.58	1708	92	70
T-679	4	T	81	0.36	277×212	38×47	3.58	n/a	90	80
2033	4	T	100	0.43	459×351	68×77	5.78	1220	96	83
2044	4	T	136	0.56	563×450	63×86	7.36	927	99	88
2250	2.2	R	17	0.13	45×36	19×23	0.48	5670	60	30
2275	2.2	R	25	0.15	68×63	27×32	0.69	4150	83	60
2200	2.2	R	36	0.20	95×86	31×32	1.03	3170	98	48
2214	2.2	R	46	0.25	144×135	42×44	1.93	2560	85	75
T-608	2.2	R	54	0.28	162×153	59×63	n/a	n/a	88	70
T-609	2.2	R	61	0.25	180×167	54×54	n/a	1830	86	81
2295	2.2	R	100	0.48	338×320	101×101	5.23	1220		
Crimped fibres										
2410	4	T	39	0.46	68×51	n/a	0.62	4760	50	15
2415	4	T	45	0.43	106×79	n/a	1.10	3415	63	30
2420	4	T	63	0.46	133×97	n/a	1.24	3170	68	30
2430	4	T	81	0.48	196×152	68×81	1.99	2074	75	35
2440	4	T	98	0.53	251×187	n/a	2.61	1708	88	45
2470	4	T	203	0.76	612×450	167×212	5.64	732	95	91

[a] BBA Nonwovens. [b] Denier values listed. Diameters are 16 and 23 µ. [c] T=trilobal cross section; R=round cross section. [d] MD=machine direction; XD=across machine. [e] Air permeability, l/dm^2 min^{-1} @20 mmWG. [f] Based on 8–18 µ particles. [g] Based on 50–60 µ particles.

Table 3.7 'Tekton' polypropylene spunbounded media[a]

Style no.	Filament size[b]	Weight (g/m)	Thickness (mm)	Grab tensile N (MD×XD[c])	Trap tear N (MD×XD[c])	Bursting pressure (kg/cm^3)	Permeability to air[d]	% Filtration efficiency	
								In air[e]	In water[f]
Low Denier									
T-867	3	34	0.18	120×67	31×27	1.65	1757	40	25
T-244	4	42	0.23	90×54	54×32	1.93	1757	45	25
T-135	4	54	0.25	122×68	68×41	2.41	1219	60	70
T-1161	4	136	0.41	540×360	158×90	7.29	144	94	79
T-198	4	203	0.51	765×495	270×158	12.17	77	94	90
Standard									
3121	8	42	0.20	162×167	81×90	2.41	3629	56	15
31417	8	47	0.20	167×167	90×90	2.61	3139	40	15
3151	10	54	0.20	212×203	104×104	2.75	2438	31	15
3201	10	64	0.23	360×333	167×153	3.78	1949	43	20
3251	10	85	0.25	500×477	185×167	n/a	998	45	20
3301	10	102	0.30	639×617	198×221	6.33	730	65	16
33541	20/10	115	0.36	585×657	216×225	6.39	n/a	38	15
3351	10	119	0.36	666×648	293×324	n/a	730	83	88
3401	20/10	136	0.38	648×720	329×351	8.59	461	75	41
3601	10	203	0.46	1071×1170	428×464	14.64	240	93	60
3801	10	271	0.53	1490×1557	495×572	19.94	n/a	90	96
LF Series[f]									
T-509	10	68	0.25	329×302	99×104	2.89	2198	70	55
T-511	10	136	0.36	617×657	180×198	6.46	490	70	73
T-513	10	169	0.43	761×792	212×252	8.04	336	76	79
T-515	10	203	0.48	905×927	234×279	9.56	336	80	85
T-517	10	271	0.58	122×1296	252×342	n/a	125	87	97

[a] BBA Nonwovens. [b] Denier values listed. Diameters mostly 39 μ but 25 and 39 for T series. [c] MD=machine direction; XD=across machine. [d] Air permeability, l/dm^2 min^{-1} @ 20 mmWG. [e] Based on 8–18 μ particles. [f] Based on 50–60 μ particles. [g] LF=ultra low fuzz, designed for efficient cake release.

Table 3.8 'Typelle' needle punched polyester spunbounded media[a]

Style no.	Filament size[b]	Weight (g/m)	Thickness (mm)	Grab tensile (N MD×XD)[c]	Trap tear (N MD×XD[c])	Bursting pressure (kg/cm)^2	Permeability to air[d]	% Filtration efficiency	
								In air[e]	In water[f]
5150	2.2	51	0.38	144×104	63×54	1.17	3264	86	61
5154	4	51	0.36	86×68	32×86	0.89	4426	80	52
5200	2.2	60	0.38	194×144	81×99	1.44	2774	75	70
5204	4	68	0.56	140×108	54×68	1.65	3820	71	78
5300	2.2	102	0.51	185×171	75×78	1.79	1699	99	72
5450	2.2	153	0.79	293×270	113×113	4.13	1142	97	86
5600	2.2	203	1.17	340×311	130×133	6.53	826	94	89
5900	2.2	302	1.78	567×441	140×180	9.21	634	94	94
5120	2.2	338	2.26	635×468	149×207	11.28	451	97	95

[a] BBA Nonwovens.

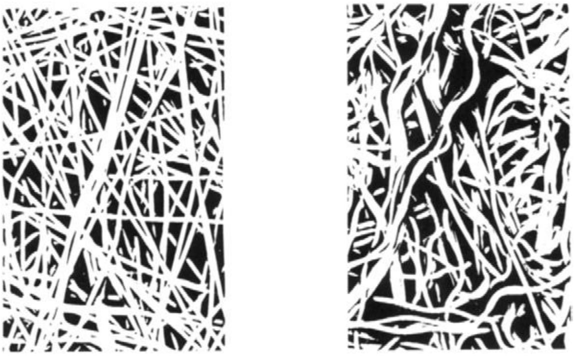
[b] Denier values listed. Diameters 16 μ.

[c] MD=machine direction XD=across machine.

[d] Air permeability, $l/dm^2\ min^{-1}$ @ 20 mm WG.

[e] Based on 8–18 μ particles.

[f] Based on 50–60 μ particles.



Straight Fibers

Crimped Fibers

Figure 3.10. Reemay polyester fibres.

Molten polymer is once again extruded at high temperature from spinneret orifices to form continuous filaments. Now, however, these filaments are impacted by high-velocity air streams, which cause the filaments to fibrillate, and to break into fine, moderately short fibres, some 10 to 20 cm in length. These fibres are then collected, in random orientation, on a moving screen belt, with a suction box underneath it. Because the fibres are both finer and shorter, the meltblown media are less strong than, for example, spunbonded material, and so they are most often used in combination with other stronger media (see Section 3.6).

Meltblown fibres have a relatively high surface area per unit weight (1 m^2/g), and a smaller diameter (5–10 μm) than spunbonded materials. They are thus able to filter to a finer degree than spunbonded materials. The most common material used for melt blowing is polypropylene.

3.5.3 Other spun media

The production of materials by extrusion of polymeric filaments has been taken a stage further by Du Pont in its flash spinning process to produce Tyvek high-density polyethylene sheet products. Like the other spinning processes, flash spinning involves extrusion through a spinneret; but whereas pure molten polymer is extruded in the other processes, with flash spinning the extrudate is a partially separated two-phase mixture of pure solvent droplets and a highly saturated polymer/solvent mixture. The decompression across the spinneret capillaries induces flash evaporation and the formation of fibrils; voids are created within the fibrils as ruptures are caused by expanding globules of solvent vapour. The fibril webs are collected on a moving belt, and are then subjected to a combination of heat and pressure to promote self-bonding. This forms sheets of continuous strands of very fine interconnected fibres, with very high specific surface areas (30 m^2/g), and a high bursting strength.

Because Tyvek is an exceptionally tough material, its primary fields of application are in packaging and construction materials, for which purposes the Tyvek name is still used. In its basic form, its permeability is too low for use as filter media, so the process has been extended, to produce filtration grades, now marketed under the name SoloFlo. This development was also reported by Meyer(7–9), a particularly interesting aspect of these reports being the variety of wastewaters successfully processed by the combination of the SoloFlo filter media and the Oberlin automated pressure filter. Pertinent data on the SoloFlo material are given in Table 3.9, together with those for other grades of DuPont media that have some filtration uses (mainly as membrane substrates). The higher permeability for the SoloFlo grade is shown in its lower pressure drop figure.

A material being developed(10) for military use, for the protection of personnel against chemical and biochemical attack, updates a 70-year-old technique called electrospinning, to produce a mat of nanofibres. As well as in the form of a flat sheet, this mat can be laid down upon any surface – from a model of a human body to the core of a filter cartridge – and promises to be a very good filtration medium.

3.5.4 Extruded meshes

Other forms of extruded polymer are used in filtration in the form in which they are made. There are several suppliers of extruded plastic mesh materials, all deriving from the original Netlon patents, which could be formed into non-woven media. However, the process is mainly used for single layers of mesh, and accordingly is discussed in detail in Chapter 6.

3.6 Composite Non-wovens

Non-wovens of all types are used frequently as part of a composite material, with the various component layers chosen to give the right combination of filtration properties and material strength characteristics.

Special composites have been developed within the range of spun media. One of these is what is now known as SMS, namely a triple-layered material

Table 3.9 DuPont 'SoloFlo' flash spun media*

Property	SoloFlo	1058D	1059D	1073D
Mean flow pore size (μm) (at psi)	5.2 (1.3)	1.7 (4.0)	2.3 (2.9)	1.8 (3.7)
Bubble point (μm) (at psi)	11.0 (0.6)	4.9 (1.4)	5.4 (1.2)	7.1 (0.9)
Void volume (%)	66.3	56.1	58.7	45.6
Liquid efficiency (%)	99.98	98.41	99.63	99.92
Permeability (psid)	1.3	10.0	4.1	4.3
Basis weight (g/m^2)	42.4	54.3	64.4	74.6
Thickness (mm)	0.13	0.14	0.17	0.19

*E I du Pont de Nemours Inc.

consisting of a central meltblown layer, with spunbonded materials top and bottom. SMS media are typified by BBA's UltraFlo range, which is made in polypropylene, in six grades, ranging from 17 to 88 g/m^2 in weight, 0.1 to 0.48 mm thick, and 1575 to 255 l/m^2/s permeability.

There are two contrasting styles of laminated structure, depending on whether the filter medium is intended to function by depth filtration or by surface filtration. With depth filtration, the medium should be graded so as to increase in fineness in the direction of flow. The upper, coarser layers will act as a pre-filter, in which the larger particles are retained, with the smaller particles then being trapped subsequently in the finer layers. This will maximize the dirt-holding capacity per unit area of medium, and hence its life before it is discarded.

Typical of this type of laminated medium is BBA's range of spunbonded composite material called Synergex, formed from several layers of polyester filaments. Some typical data are given in Table 3.10. There are two versions, depending on whether the calendering rolls are smooth, so as to generate 'flat bonded' material, or embossed, so as to generate 'pattern bonded' products.

By definition, surface filtration ideally involves the collection of all particles on the surface, or upstream face, of the medium, with none passing into its depth; thereby the efficiency of the medium is totally dependent on the pores in this surface being sufficiently small for the required purpose. Surface filtration has, of

Table 3.10 'Synergex' composite spunbonded media[a]

Style no.	Filament size[b]	Weight (g/m)	Thickness (mm)	Grab tensile N (MD×XD[c])	Bursting pressure (kg/cm^2)	Permeability to air[d]	% Filtration efficiency	
							In air[e]	In water[f]
Flat bonded								
6110	2.2	34	0.13	104×72	1.65	2630	70	50
6115	2.2	51	0.18	104×131	2.27	1536	75	80
6120	2.2	68	0.20	234×189	3.23	1094	80	85
6125	2.2	85	0.25	320×234	4.95	826	90	85
6130	2.2	102	0.30	342×297	5.02	710	91	90
6140	2.2	136	0.36	500×383	7.01	365	98	97
Pattern bonded								
6215	2.2	51	0.25	162×126	2.48	1584	89	80
6220	2.2	68	0.33	216×171	3.71	1296	95	70
6230	2.2	102	0.41	392×288	5.91	874	100	93
6240	2.2	136	0.46	536×401	8.18	442	99	99
6250	2.2	169	0.64	666×486	9.56	442	99	96
6260	2.2	203	0.74	770×567	11.76	413	99	97

[a] BBA Nonwovens.

[b] Denier values listed. Diameters 16 μ.

[c] MD=machine direction XD=across machine.

[d] Air permeability, l/dm^2/min^{-1} @ 20 mm WG.

[e] Based on 8–18 μ particles.

[f] Based on 50–60 μ particles.

course, been practised for as long as filtration has been in use, and suitable media can be found to provide efficient separation by this means, according to the nature of the particles to be removed.

However, the modern emphasis on extremely high-efficiency removal of very fine particles has led to the demand for very finely porous surface layers, and this demand has been met by the lamination of a membrane on to a suitably robust substrate. Non-woven materials have proved to be very suitable as substrates, especially for the support of PTFE membranes. Depending upon the intended application, substrates range from lightweight spunbonded polypropylene or polyester, to substantial fabrics such as thick needlefelts. These materials, which are effectively membranes as far as filtration is concerned, are more fully discussed in Chapter 8.

In the same way that woven media can be made with combined filtration and chemical treatment behaviour, combination media exist in the non-woven field as well. Typical of these are BBA's Qualiflo media, made from polyester fibres, which are resin bonded. Qualiflo are thick media, internally graded to provide efficient filtration (99% against 2–3 μm particles) and high dust-holding capacity (658 g/m^2). In addition, they can be custom engineered to incorporate a wide range of powders for specific applications; for example, grade EH-AC-980 incorporates activated carbon granules to provide odour control as well as filtration. The recent purchase by BBA of AQF Technologies has added extra capability in combination media.

3.7 Selecting Non-woven Media

A wealth of information exists to guide the prospective user of a fabric, woven or non-woven, as a filtration medium. Most suppliers of filter media issue such guidance, but completely independent advice is not so easily come by. The notes here are intended to give as balanced a view as possible. (Since much of the data is fibre material dependent, the following notes relate as much to woven media as to non-woven.)

The three main parameters in the choice of a medium are: filtration performance, mechanical performance and cost. As far as cost is concerned, the rough figures of Table 1.5 can be used to compare woven and non-woven fabrics. There it can be seen that, on a unit filter area basis, needlefelts and woven fabrics are about the same price, but thermally bonded materials are significantly lower in cost.

In terms of application, and in the broadest possible terms, woven media are used for liquid filtration, and non-woven media for gas filtration – but there are almost as many exceptions to this general rule as there are agreements. It is perhaps more correct to say that non-wovens have successfully displaced wovens from a large number of gas cleaning applications, but have been less successful in displacement in liquid filtration (although the membrane has taken a large share of the market here). One reason for this is that all the mechanically complicated filter equipment (such a belt or a tower press) are used for liquid filtration, and these need the strength in their belts that only woven fabrics can provide.

3.7.1 Non-woven media applications

An early classification of non-woven media by Sandstedt(11) listed a number of applications for dry-laid, wet-laid and spunbonded materials. This was updated for the first edition of the Handbook, and is included here, largely unchanged, as Table 3.11, because it is still largely relevant. The updating included expansion to cover meltblown and needlefelt media. Table 3.11 shows which medium is suitable for which of a number of industrial, commercial and domestic applications. What has changed, of course, is the overall importance of the spun media, at the expense of other dry- and wet-laid materials.

3.7.2 Woven fabrics and needlefelts

The following tables are intended only as a preliminary selection guide. They are based primarily on the experience and product range of P & S Filtration, now part of Madison Filter Group. The tables consider only woven fabrics and needlefelts, with one pair of tables summarizing information in respect of liquid filters, and a second pair similarly devoted to dust filters, but, in the latter case, supplemented by a table relating the recommended fabric weight to the vigour of the cleaning method.

3.7.2.1 Dust filters

A total of 16 different groups of fabrics are identified in Table 3.12, each one being allocated a number, and described briefly in terms of its type. Table 3.13 is

Table 3.11 Overview of markets for basic types of non-woven media[a]

Market segment	Type of non-woven media				
	Needle felt	Bonded media			
		Dry laid	Wet laid	Spun media	
				Spunbonded	Melt blown
HVAC air filter		x		x	x
Fabric dust filters	x				
Tea bags			x		
Coffee bags		x			x
Machine tool coolant			x	x	
Milk		x			x
Vacuum cleaner bags	x		x		x
Edible oil			x		x
Face masks	x	x			
Food and beverage			x	x	
Cartridges			x	x	
RO/UF			x	x	x

[a] Original table by Sandstedt(9) updated with assistance from Lutz Bergmann, Filter Media Consulting Inc.

based on specific industries, with subdivision in terms of the operating temperature of named categories of process: in cross-linking these to suitable groups of fabric, a distinction is made according to the filter cleaning option. It must be remembered that these tables do not take account of the availability of spun media nor of membrane media, both of which are increasingly being used for dust cleaning.

Understandably, heavier needlefelt fabrics are advisable for use with the more intensive methods of cleaning. Table 3.14 distinguishes among five categories of cleaning mode, ranging from infrequent shaking, up to pulse jet cleaning at a pressure of 7 bar.

The type of filter, and especially the mode of cleaning, broadly determine the type of fabric that is appropriate. Bergmann(12) comments that US practice is generally to use needlefelts for pulse jet filters requiring outside cleaning, but woven fabrics for the inside cleaning of shaker and reverse air filters.

The chemical and physical properties of the fabric are also of crucial importance, as described in Chapter 2. Table 2.6 is an important summary of media materials for higher temperature dust filtration applications.

3.7.2.2 Liquid filters

A total of 18 groups of fabric are identified in Table 3.15, slightly more than in the corresponding table for dust filters (and with a noticeable preponderance of woven fabrics). A much greater expansion occurs in considering the media applications in Table 3.16, to allow the inclusion of a variety of vacuum and pressure filters, as well as a substantial number of relevant process variables.

Table 3.12 Types of cloths for dust filters[a]

Filter cloth group/cloth type		Air permeability		
		Weight (g/m^2)	m^3/m^2/min at 12.7 mm WG	l/dm^2/min at 20 WG
1	Woven staple polyester	305–480	9–30	140–475
2	Woven multifil polyester	185	6	95
3	Woven multifil warp, staple weft polyester	405	19	300
4	Woven multifil glass	295–460	10–18	155–285
5	Woven staple acrylic copolymer	460	6.5	105
6	Woven staple acrylic homopolymer	375	8	125
7	Woven multifil warp, staple weft polyaramid	340	16	250
8	Woven staple polyaramid	300	6	95
9	Woven multifil PTFE	290	9	140
10	Needlefelt with base fabric. Polyester	340–640	7.5–17	120–270
11	Needlefelt with base fabric. Acrylic copolymer	405–460	10–33	155–270
12	Needlefelt with base fabric. Acrylic homopolymer	600–650	7–12	110–190
13	Needlefelt with base fabric. Polyaramid	340–500	12–25	190–395
14	Needlefelt with base fabric. Glass	950	10.5	165
15	Needlefelt with base fabric. PTFE	750–840	6–9	95–140
16	Needlefelt with base fabric. Polyphenylenesulphide	500	10–15	155–235

[a] Madison Filter.

Table 3.13 Dust filter applications[a]

Industry	Process	Process Operating Temperature (°C)	Moisture or acidic conditions	Filter cloth group	
				Reverse air/shake cleaned filters	Pulse cleaned filters
Cement	Raw meal crushing, drying	Up to 130°C	Moisture possible	1, 3, 6, 10	10, 11, 12
	Kiln gases and clinker handling	Up to 200°C	Moisture possible	4	14
	Packing transport	Ambient	No	1, 3, 10	10
Iron and steel	Furnace fume	Up to 110°C	No	1, 2, 3, 10	10
	Alumina handling	Ambient	No	1, 3	10
Aluminium	Carbon anode preparation	Up to 200°C	No	7, 8	13
	Potline fume	Up to 120°C	No	1	10
Carbon black	Carbon black	Up to 200°C	Moisture possible	1, 4	13, 14
Non-ferrous smelting zinc, lead, tin	Collection of fume	Up to 190°C	Acidic conditions possible	1, 3, 5, 6, 7, 8, 9	10, 11, 12, 16
Gypsum	Kettles	Up to 150°C	Moisture	5, 6, 11	
Perlite	Perlite production	Up to 170°C	Moisture	4, 7, 8, 10	10, 13
Plastics PVC, A.B.S., polyethylene, polypropylene	Recover	Ambient	No	3	10
Quarry and asphalt	Crusing, grinding, drying aggregate	Up to 120°C	Moisture possible	1, 6	10, 11, 12
	Asbestos milling and drying	Up to 120°C	Moisture	1, 3	10
	Asphalt production	Up to 200°C	Moisture possible	6, 7, 8	12, 13
Coal fired boilers	Fly ash collection	Up to 220°C	Acid possible	4, 6	12, 14, 15, 16
General dust handling including flour, cereal, provender	Dust handling	Ambient	No	1, 3	10

[a] Madison Filter.

3.7.3 Spunbonded media

Table 3.17 summarizes application data supplied for some of BBA Nonwovens' materials: the spunbonded Reemay and Tekton, the needled spunbonded Typelle, and the laminated Synergex.

Table 3.14 Needle felts to suit cleaning mode of fabric filters[a]

Cleaning mode	Basis weight (g/m^2)	Permeability to air (l/dm^2/min^{-1} (@20 mm WG)
Infrequent mechanical shaking	235–270	390–660
Periodic shaking	270–370	390–660
Shaking plus reverse air cleaning	370–500	245–390
Low pressure reverse air cleaning	340–475	245–390
Pulse jet cleaning at up to 7 bar	500–680	50–170

[a] Filter Media Consulting Inc.

Table 3.15 Cloth types for liquid filters[a]

Filter cloth group	Cloth type	Weight (g/m^2)	Air permeability (m^3/m^2/min at 12.7 mm WG)	Max continuous operating temperature (°C)
1	Woven monofilament polyester	350–550	30–150	120
2	Woven multifilament polyester	150–650	1–5	120
3	Woven staple polyester	450–700	1–5	120
4	Needled polyester	640	2	120
5	Woven monofilament polyamide	250–400	25–60	100–110
6	Woven multifilament polyamide	100–250	1–5	110
7	Woven staple polyamide	400–800	1–5	110
8	Needled polyamide	600–1000	2–6	110
9	Woven monofilament polypropylene	200–350	40–120	95
10	Woven multifilament polypropylene	350–700	0.5–5	95
11	Woven staple polypropylene	200–650	1–20	95
12	Woven multifilament warp Staple weft polypropylene	450–600	1–8	95
13	Needled polypropylene	400–600	1–5	95
14	Woven monofilament polypropylene	200–330	30–80	85
15	Woven monofilament Polyvinylidine chloride (Saran)	500–600	Over 200	85
16	Woven staple modacrylic	430	Negligible	85
17	Woven cotton/nylon combination	800	0.5	100
18	Woven cotton	500–650	0.5–2.0	100

[a] Madison Filtration Ltd.

Table 3.16 Liquid filter cloth applications[a]

Industry	Process	Filtration equipment	pH	Process operating temperature (°C)	Particle type	Particle size	Filter cloth group	Filter media features
Sugar	1st and 2nd carbonation	Filter leaf					7, 11	High throughout and resistance to blinding
		Candle filter					11	
	Mud desweetening	Rotary vacuum drum	6–10	95	Amorphous	Medium	7, 11	Good mechanical resistance and cake discharge
		Filter press					6, 7, 11	Good mechanical resistance, dimensional stability and seal
		Automatic pressure filter					12	Good dimensional stability, tracking and high strength
	Juice filtration	Filter press					7, 11, 18	Good mechanical resistance, dimensional stability and seal
	Cane sugar refining	Filter leaf					2, 7, 11	High throughput and resistance to blinding
Phosphoric acid	Removal of calcium sulphate	Horizontal rotating pan filter	Up to 6	100	Crystalline	Coarse	1, 9	Resists abrasion and blinding by crystal formation. Good dimensional stability
		Travelling band filter					1	Dimensional stability to ensure good tracking

Table 3.16 *(continued)*

Industry	Process	Filtration equipment	pH	Process operating temperature (°C)	Particle type	Particle size	Filter cloth group	Filter media features
Alumina	Red mud overflow	Filter leaf	13		Amorphous	Fine	9, 10, 11	Resistance to red mud blinding. High throughput
	Ref mud underflow	Rotary vacuum drum				Medium	5, 9, 14	Resistance to blinding and good cake discharge
	Hydrate product and Seed	Rotary vacuum disc			Crystalline	Coarse	5, 9, 14	Resists stretch and abrasion. High throughput and good cake discharge
Edible oils and fats	Expelled oil	Filter press		120	Amorphous	Coarse	3, 7	Good mechanical resistance and retention
	Bleaching						2, 3, 7	Resistance to heat
	Hardening						7, 17	Excellent retention of catalyst
	Winterizing						7, 17	Resistance to blinding from fats. High throughput
Ceramics and china clay	Clay slip dewatering	Filter press	7	40	Crystalline	Coarse	6, 7, 10, 12, 13	Good mechanical resistance and seal. Consistent cake density
	China clay						6, 10, 12	Fine particle retention. Resistance to pin holding
Sewage and effluent	Municipal	Filter press	5–10	30	Amorphous	Fibrous	1, 5, 7, 11, 14, 15	Good resistance to blinding and mechanical damage. Good cake discharge
		Travelling band filter					1	High stability for good tracking. Strong belt joining high mechanical resistance

Table 3.16 (*continued*)

Industry	Process	Filtration equipment	pH	Process operating temperature (°C)	Particle type	Particle size	Filter cloth group	Filter media features
	Industrial	Filter press				Variable	1, 5, 7, 12	Good cake discharge, fine particle retention and high throughout
Dyestuff, pigments and intermediates		Filter press	1–13	90	Crystalline	Fine	2, 10, 11, 12, 13	Fine particle retention and suitable for cake washing
		Automatic pressure filter					10	Dimensional stability to ensure good tracking
		Vacuum filter					2, 3, 9, 11, 12	Good resistance to chemical conditions and blinding
Viscose	Gel filtration	Filter press	12	20	Amorphous	Gelatinous	8	Optimum gel retention. High throughput. Ideal for off-machine and back washing
Starch products	Starches, glucose and gluten dewatering	Filter press	5–8	30	Amorphous	Coarse	7	Good resistance to blinding, ease of washing
							2, 6	Good throughput
Coal	Coal dewatering	Rotary vacuum belt	5–8	20	Crystalline	Coarse		
		Rotary vacuum belt					1	Dimensional stability to ensure good tracking
		Rotary vacuum disc					5,9	Abrasion resistant and good cake discharge
	Clay tailings				Amorphous		1, 5, 14	Dimensional stability for large presses. Good cake discharge. Resists blinding

Table 3.16 (*continued*)

Industry	Process	Filtration equipment	pH	Process operating temperature (°C)	Particle type	Particle size	Filter cloth group	Filter media features
Metal concentrates	Non-ferrous concentrates	Rotary vacuum disc	5–8	25	Variable	Coarse	7, 13	Good resistance to blinding, high throughput and low moisture content
	Iron ore		5–8	40		Coarse	5, 14	Good resistance to blinding, high throughput and low moisture content
Brewing	Mash	Sparging press	5–8	80	Amorphous	Coarse	9	Maintains high throughput
	Yeast	Filter press		20		Fine	3, 12	Fine particle retention at high throughput
	Roughing	Filter press		20		Fine	8	Maintains high throughput, regenerable
Non ferrous metal refining		Filter press					3, 12, 13	Fine particle retention and resistance to blinding
	Hydrometallurgy	Rotary vacuum drum	1–14	100	Variable	Variable	1, 2, 5, 9, 13	Good blinding resistance, mechanical resistance and cake discharge
		Filter leaf					2, 11	High throughput with good filtrate clarity
	Electrometallurgy	Diaphragm					2, 10, 16	Controlled permeability and low voltage drop
Titanium dioxide	Clarification	Filter leaf	3–11	25	Crystalline	Fine	2, 9	Good resistance to blinding. High throughput
	Removal of iron and treatment	Vacuum leaf	5				3, 11, 18	Good cake pickup. Resistance to blinding and good retention efficiency

Table 3.16 (*continued*)

Industry	Process	Filtration equipment	pH	Process operating temperature (°C)	Particle type	Particle size	Filter cloth group	Filter media features
	Washing and dewatering	Rotary vacuum drum					2, 3, 4, 11	Low moisture content consistent with throughput. Good cake discharge
Cement dewatering	Raw meal dewatering prior to kiln	Filter press	5–8	25	Variable	Coarse	1, 5	Good dimensional stability, mechanical resistance and discharge. High throughput

[a] Madison Filter.

Table 3.17 Application for BBA Nonwovens spunbonded media

	Food and beverage	Swimming pool	Machine coolant	Industrial cartridge	Air filters	Membrane substrate
Reemay						
2004					x	
2005					x	
2055						
2006	x		x			x
2011	x		x		x	x
2014	x		x		x	x
T-667						
2015			x		x	x
2016	x		x		x	x
2024	x		x			x
T-679						
2033	x	x	x	x		
2040	x	x	x	x		
2250	x		x		x	x
2275	x		x		x	x
2200	x		x			x
2214	x		x			x
T-608						
T-609						
2295	x	x		x		x
2410						
2415						
2420						
2430						
2440						
2470	x	x		x		
Tekton						
T-867						
T-244	x			x	x	x
T-135	x			x	x	x
T-161	x			x		x
T-198	x			x		x
3121						x
3141						x
3151	x			x	x	x
3201	x			x	x	x
3251						
3301						
3341						
3351						
3401						
3601						
3801						
T-509	x				x	
T-511	x					
T-513	x					
T-515	x					
T-517	x					

Table 3.17 *(continued)*

	Food and beverage	Swimming pool	Machine coolant	Industrial cartridge	Air filters	Membrane substrate
Typelle						
5150					x	
5154					x	
5200					x	
5204					x	
5300					x	
5450						
5600					x	
5900					x	
5120						
Synergex						
6110	x		x		x	x
6115	x		x		x	x
6120	x		x			x
6125						
6130			x			
6140			x			
6215					x	
6220						
6230						
6240	x					
6250	x					
6260	x					

3.8 References

1. R Krcma (1971) *Manual of Nonwovens*, Textile Trade Press, Manchester, UK
2. Anon. (1959) 'Wanted: new name for nonwovens', *Amer. Text. Rep.*, 12 March
3. INDA (Association of the Nonwoven Fabrics Industry), 1001 Einstead Drive, Suite 460, Cary, NC 27502, USA (PO Box 1288, Cary, NC 27512)
4. EDANA (European Disposables and Nonwovens Association), 157 avenue Eugène Plasky, B-1030 Brussels, Belgium
5. F Dilger (1994) 'Lowering emissions – more effective air pollution control with fine fibre filter media', *Filtration & Separation*, **31**(2), 125–7
6. A C Wrotnowski (1976) 'Felt straining technology', *Filtration & Separation*, **13**(5), 487–92
7. E Mayer and H S Lim (1989) 'New nonwoven microfiltration membrane material', *Fluid/Particle Separation Journal*, **2**(1), 17–21
8. E Meyer (1993) 'Heavy metal removal with Du Pont/Pberlin microfiltration technology', *Fluid/Particle Separation Journal*, **6**(1), 20–6
9. E Meyer (1994) 'Combined wastewater concentration and sludge metals stabilization with Gore backpulse and Du Pont/Oberlin microfiltration technology', *Fluid/Particle Separation Journal*, **7**(4), 160–5

10. D Adam (2001) 'Made to measure and protect' *Sunday Times, Doors Supplement*, 2 Sept., pp. 16–17
11. H N Sandstedt (1980) 'Non-wovens in filtration applications', *Filtration & Separation*, **17**(4), 358–61
12. L Bergmann (1990) *Condensed Manual & Handbook: Filter Media & Filter Fabric Aspects*, Filter Media Consulting Inc