FOREWORD

Like many other natural products in an increasingly synthetic world, wool felts have experienced both a period of being overlooked and a period, which is here and now, of being rediscovered.

Wool felt must be one of the oldest textile materials and was used for a variety of purposes that would, today, be uneconomic or unappreciated and alternative methods and materials have been evolved. A generation of designers, engineers and specifiers has grown up in the last 25 years, who may never have used wool felts or may be unaware that they were using wool felts. Felt producers themselves have, like many craft based industries, been slow to adapt to the modern need to communicate the merits of their product both effectively and continuously in order to be heard above the increasing background noise. This appears now to be changing.

The intrinsic and often unique properties of wool felts are discussed in these pages and examples are given of wool felts performing cost-effectively in their traditional end-uses and being employed in new products and processes that did not exist until recently. Felt makers have, in several cases, re-engineered their products to the specific needs of new industries, demonstrating the amazing flexibility and adaptability of a material which can be produced in such a wide variety of densities, thickness, textures and shapes, that one could almost think of them as isomorphus of wool.

1: INTRODUCTION

Although wool felt is the world's oldest textile structure and it has been used practically in every industry, generations of engineers and materials scientists/specifiers are growing up without knowing much about this remarkable material.

Over 130 years of continuous industrial development has demonstrated the versatility of wool pressed felt as a material that has far surpassed any other textile material in the depth and breadth of its applications.

''FELT'' is a textile structure composed entirely of fibres physically interlocked and consolidated by the utilization of mechanical work, chemical action and moisture without the use of weaving, knitting, stitching, thermal bonding or adhesives. It is composed wholly of any one or a combination of new or recycled wool fibres. Part-wool felt, is a felt composed of any one or combination of new or recycled wool fibres mixed with one or more man-made fibres, vegetable fibres, etc.

2: FELT SPECIFICATION NUMBERS

Felts are governed, in India, by Specn. IS 1719. In the International market, these are governed by SAE Specifications F-1 to F-55, DIN Specification No. 61200, Federal Specn. CF 206, British Specn. No. BS-4060 and U.S.S.R. Specn. No. Gost 6308-71

3: PROPERTIES OF PRESSED FELTS

An understanding of the specifications and physical and chemical properties of felt is of importance for its successful selection and application. TABLE-I (Page no. 16) contains details about grades of felts and their chemical and physical properties. Specific properties of felts are briefly discussed in this Brochure.

3.1: PHYSICAL PROPERTIES

Felts differ in density and also in construction and the quality of wool fibres used. Distinctions between these inherent characteristics largely distinguish the performance of one type and grade from another. From the stand-point of construction, the relative strength of the piece along the axis of length, width and thickness are principally controlled by the lay of fibres and the degree of fulling; the lay being generated by the carding operation in which the principal web strength is in the direction of the axis of length. Transverse strength in the piece is build up and controlled by crossing alternate layers of the carded fibre webs. Interfacial strength is the result of hardening and fulling, i.e. felting. In general, the longer the felting operation is continued, the tighter the fibre interlocking; hence the greater the number of locked fibres in a given volume and, therefore, the greater is the density.

(a) DENSITY

Felt density means "the weight per unit volume of the felt under test as distinguished from the volume of the fibre". Thus, the values in Tables I under density or specific gravity are in grammes per cubic centimetre. Density is the parameter that affects the mechanical and functional properties of felt.

(b) TENSILE STRENGTH AND ELONGATION

These are related in direct proportion to felt density, but wool fibre quality and fibre lay-up of the felt also influence these properties. In general, each grade of felt has a characteristic stress-strain curve or modulus value that is distinct from that of other grades.

(c) HARDNESS/SOFTNESS

There is a direct relationship between felt density and shore A durometer measurments. The denser the felt, the harder it is.

(d) SPLITTING RESISTANCE

Splitting resistance, which measures the interfacial strength of felt, increases with the density of the material. The dense felt exhibits about 15 times the splitting resistance of the low density felt.

(e) COMPRESSION AND RECOVERY

The laws governing the compressive deformation of felt may be considered objectively by regarding felt as a porous structure in which initial deformation is produced by closing down and decreasing the interstitial spaces of the fibre matrix. This stage is followed by one in which the fibres,
having been brought into contact, are flattened down until the material approaches a solid state. Further deformation beyond this point requires proportionately greater loading. Deformation, expressed as percentage of initial felt thickness, is directly related to density. Other observation from tests to determine the behaviour of felts loaded in compression were that :

(a) the higher-density felts demonstrate less compression set for any given load than the lower density felts;

(b) the lower density felts show less compression set for a given deformation than the higher density felts.

(f) ABRASIVE WEAR RESISTANCE

The wear resistance of wool felt is in direct proportion to density and fibre quality, and in inverse proportion to applied load.

(g) COEFFICIENT OF FRICTION

The coefficient of friction of felt is, for all practical purposes, independent of felt density or felt grade, but highly dependent upon the texture and smoothness of adjacent surfaces as well as the viscosity of associated lubricating oils, if used.

3.2: CHEMICAL PROPERTIES

Extended exposure of felt to lubricating oils and organic solvents has no appreciable effect on the properties of wool felt. Inorganic acids, such as sulphuric and hydrochloric, are not injurious to wool felt in dilute concentrations. Strong alkali attacks wool.

3.3: AGEING

Unlike many other engineering materials, **wool felts do not change much over long periods of time, even measured in decades.** The natural destructive forces of atmospheric moisture, heat, cold sun and ozone have very little effect. Felt is unchanged by temperatures in the range of -15°C to +100°C (-60°F to +212°F). Many plastic materials stiffen in cold weather and soften in hot weather. Polyurethene foam is less expensive than wool felt, but polyurethene foam deteriorates under atmospheric conditions.

Two of the most important features of wool felt as a mechanical and engineering material for specifiers, are that it is long-lived and practically maintenance free. Wool felt pieces have been known to perform in pianos for over 80 years and they have retained their original tonal qualities and other properties during that time with no maintenance other than the normal dusting/cleaning and tuning of the musical insturments.

3.4: GENERAL PROPERTIES

(a) Felt can be made to Engineer's requirements

Wool felt can be manufactured so that it has almost any property required by the design engineer. It can be made to virtually any thickness, weight per unit area, consistency of hardness or softness, with different relative pore volumes, shapes, absorption characterstics and with a fibre diameter gradient through its thickness, if desired. Wool felt can be combined, by felting, with yarns or woven or knitted fabrics to further improve such properties as liquid wicking rate and wicking height and strength and stretch characteristics. Wool felt can be chemically treated or coated or laminated with film, foams, foils, nettings etc. to further extend its range of properties.

(b) Felt is Easy to put into any Desired Shape/Form

Wool felt can be cut to fit any design with a knife, die or a pair of shears. It can be cut, punched, skived, chiselled, lathed, sawed, moulded, ground or otherwise processed by common methods. **It can be cut or machined into solid pads, washers/gaskets, strips, rods, channels, tubes, pen points/nibs, wheels, bobs, rollers or any odd shape.** It cuts with non-fraying Edges and does not ravel or fray. (Fig. 1 on cover page 2)

(c) Non-Glazing

Unlike most synthetic fibre materials, wool felts do not glaze when rubbed vigorously at high speed against various surfaces such as metals, glass, plastic, etc. Therefore, felt is excellent for buffing and polishing applications.

4: FUNCTION AND USES OF WOOL FELT

Table II (on page 24) lists the basic functions of felt and some current applications. There are many, many more uses of felt in a host of industries and military and other government agencies than can possibly be listed here. **It is, however, not fully known as to how or where the felt products are used by the customer and thus one purpose of this Brochure is to point out the board range of uses for felt and to present some data on the properties and functions of felt so that the engineers and material specifiers may consider and select felt for their potential needs or new applications.**

4.1: POLISHING AND BUFFING

In most cases, sheet felts are used for polishing and buffing applications. Figure 2 shows sheet felt bobs of different shapes and sizes used for polishing and buffing. Sheet felts for these uses are supplied in a range of densities from 0.34 g/cc and above. A list of buffing/polishing applications includes at least 45 industries from aircraft components to felt hats to silverware and vacuum cleaners. For buffing, particularly for highlighting, the buffing compounds most commonly used are tripoli, rouge, stainless-steel compounds and emery paste. For polishing, the felt component may be "headed" with abrasive grain of 120 grit or finer, using hide glue or cold cement as the matrix. A greaseless compound can be used for deburring. (Fig 2 on Cover No. 4)

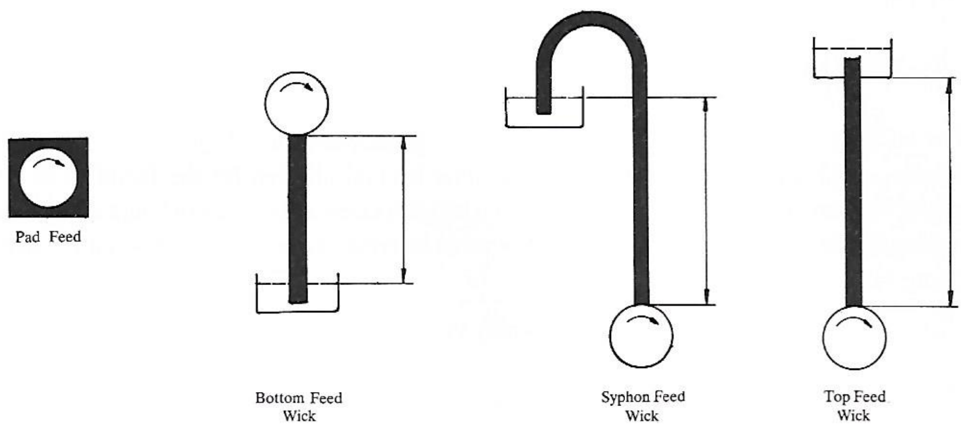
Some advantages of felt wheels are :

- They hold desired edges and shapes for the life of the wheel.
- They do not spread, avoiding streaky polishing.
- Several times more durable than built-up wheels.
- They have uniform density throughout, thus providing for longer "head" life.
- there is less down time than occurs when removing "heads" on built-up wheels.
- They produce a particularly fine surface for plating.

4.2: (I) WICKING AND LUBRICATION

The subject of felt and lubrication embraces the application of felt of wick feed lubricating system for bearing and other mechanical movements, where oil or other coolants are required to be fed in a controlled manner without failure or interruption. Lubricating system of this type may be classified as (1) bottom wicks; (2) syphon wicks; (3) absorbent or pad feed and (4) top feed (Figure 3)

Figure 3 - Configuration of Felt wicks in Lubrication



Syphon and pad feed lubricating or wick systems are the most widely used although bottom wick systems are generally considered the most efficient. They are entirely automatic, require no attention, other than occasional cleaning; and allow a return of the unused liquid to reservoir. In top feed applications, where there is a reservoir, with a wick extending from a bottom outlet, the wick functions as a semi-controlled obstruction. The system to be used for any application is that which satisfies design and operating conditions. In all cases, a first consideration is the selection of proper materials to transport oil based lubricants.

Why felt is Good for oil wicking and Lubrication

Felt is made up of a large number of capillaries which are formed between the fibres. These capillaries hold the oil, and the oil is wicked through them to a metal part. The number and size of the capillaries in a felt are dependent almost entirely on the density of the fibre in the felt. The greater the felt density and the finer the fibres, the greater the number and the finer the capillaries.

Finer capillaries not only transport or wick liquid longer distances and higher heights, they also hold the liquid more tenaciously. This liquid holding capacity makes felt materials both effictive and efficient as liquid reservoirs. Some felt can absorb some four to five times their own weight of oil. In addition, certain felts have good resistance to and good recovery from compression. Thus, they have the ability to maintain their capillary structure under compression and other stresses.

Felt also has ideal surfaces for transferring oil to Axles or other moving metal parts. It does not ravel, it can give up its oil either slowly or quickly depending on the type of felt and the application. Wool felt has particularly good resistance to heat, and will not glaze when properly applied. Lubrication by felt, or any other material is stopped when its capillaries are blocked, either by dirt or by compression or by pinching, etc. In fact, this is one of the disadvantages of woven fibrics for lubrication. Besides their tendency to unravel easily, where the wrap and filling yarns interlace the capillaries are pinched off and flow of the liquid in the yarn is blocked or slowed down.

Some felts are much better than others for the various types of lubrication; the performance of a felt depends on the type of oil lubricant used, the temperature of the oil and on the actual lubrication job the felt has to do. It can be said that no one felt is best for all lubrication purposes. Thus, as much care should be exercised in the selection of felt wick materials, as ir required in the selection of suitable lubricants.

4.2: (II) WICKING

The wicking property of the felt is governed by the height to which the liquid is sucked up a vertically - held sample. This depends on the time interval allowed for the liquid to creep up the sample, but generally the equilibrium (maximum height) occurs after say 2 to 4 hours and thereafter the wicking height (value after 24 hours) was found to increase linearly with increasing felt density (see figure 4).

Figure 4 - Felt Density vs. Wicking Height

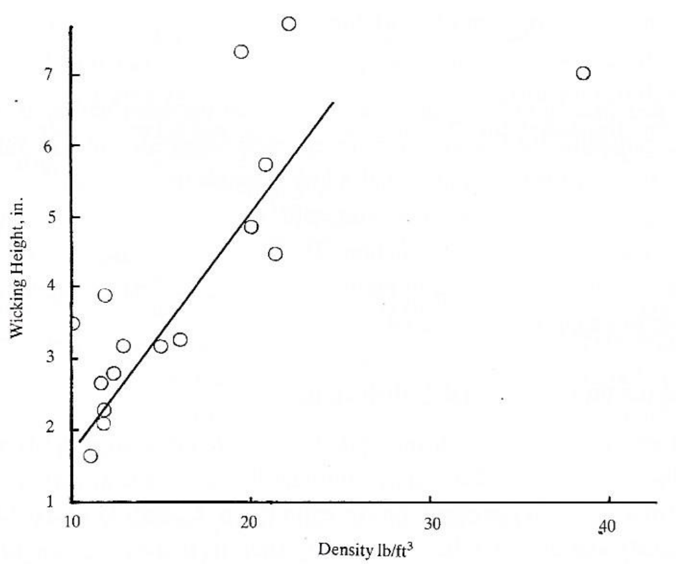


Figure 5-Spinesso 38 Oil
Height and Rise of Oil (ml. Oil/cu. in. Felt) (1 cu. in. ≃ 15.5 ml.)
in each One Inch Section along the length of the
Felt Strip after Wicking 24 Hours at 70°F (21°C)

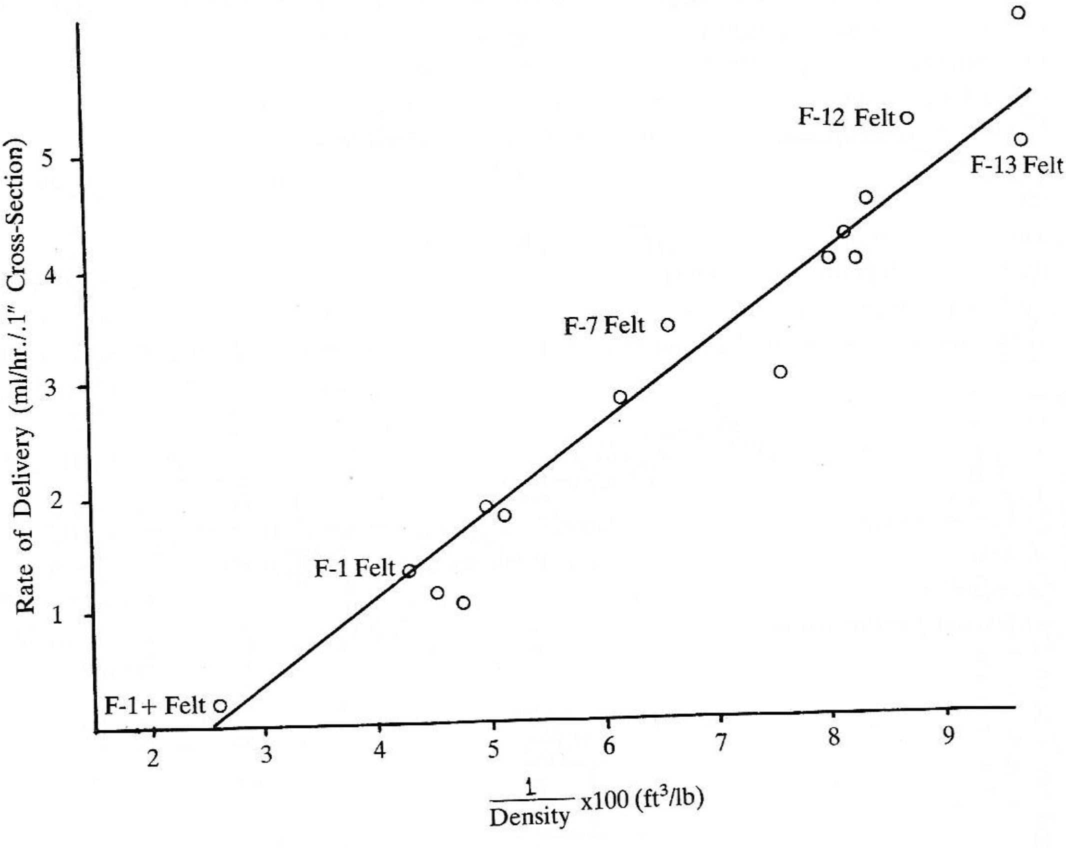
Height of Rise of Oil	F-1+	F-1+	F-1	F-2	F-3	F-6	F-7	F-10	F-10 (1/2)	F-1S	F-1+	F-11	F-12	F-13	F-7	F-14	
9″ (22.5 cm)																	9th
8″ (20 cm)	5.1	0.2															8th
7″ (17.5 cm)	5.6	1.9															7th
6″ (15 cm)	7.0	6.9	4.1	5.5	6.0												6th
5″ (12.5 cm)	7.2	7.6	10.7	8.4	9.1	1.8	3.3								4.3		5th
4″ (10 cm)	7.5	8.0	11.3	10.3	11.1	7.5	9.2								8.0		4th
3″ (7.5 cm)	7.5	8.6	11.8	10.8	12.3	11.8	12.5	9.1	7.2	6.6	0.8	5.0	8.8	1.2	10.2	8.6	3rd
2″ (5.0 cm)	7.9	9.3	12.3	11.7	12.9	12.8	13.7	13.8	12.7	12.2	10.5	13.3	13.4	6.1	10.9	14.6	2nd
1″ (2.5 cm)	8.9	11.6	13.4	12.3	13.6	13.5	15.0	14.4	14.0	13.8	15.6	14.6	15.3	15.6	12.6	15.8	1st

SAE Felt Numbers

Distribution of oil in Felt wicks

Figure 5 shows not only the height of rise of the oil in the wicks, but also the amount of oil, expressed as ml. of oil per cubic inch of felt, in each 1'' section along the length of the felt strips after wicking 24 hours at 21°C (70°F)

Figure 6 - Oil Delivery Rates of Felts by Syphoning Spindle Oil at 20°C



Oil delivery Rates of Felts by Syphoning

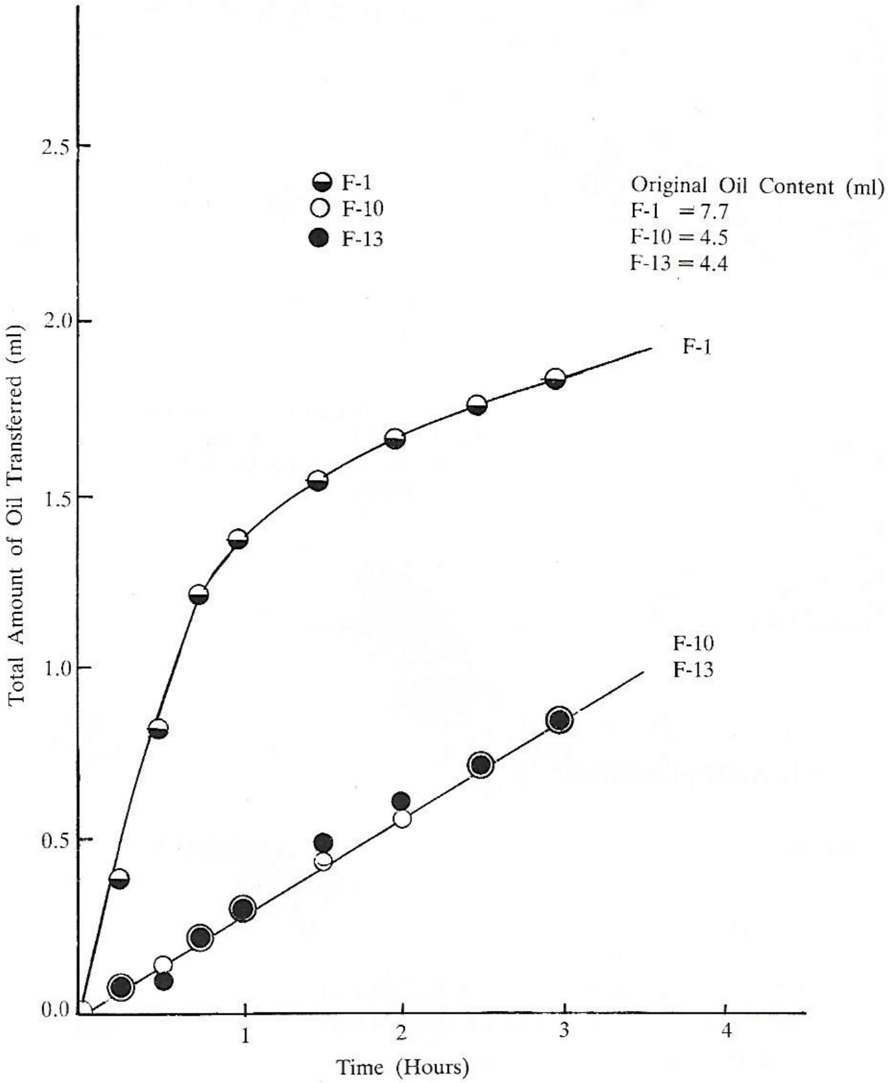
It is realised that as the viscosity of the oil is increased, and/or as the temperature is decreased, the oil delivery rates will be less for all of the felts than the values shown in the graph. When a low viscosity oil is used or the temperature is increased, the delivery rates will be greater. In all cases, the felts that are shown to be best and poorest here will be best and poorest under other syphoning conditions.

Oil Transfer

The last lubrication property of felt is of oil transfer. Figure - 7 shows the amount of oil in ml. transferred to the axle at a room temperature of 21°C (70°F) by F-1/F-10 and F-13 felts, initially containing 200% by weight of SAE-10 oil. The vertical axis is the total amount of oil transferred in ml. and the horizontal axis is the period of time in hours during which the felts were in contact with the revolving axle.

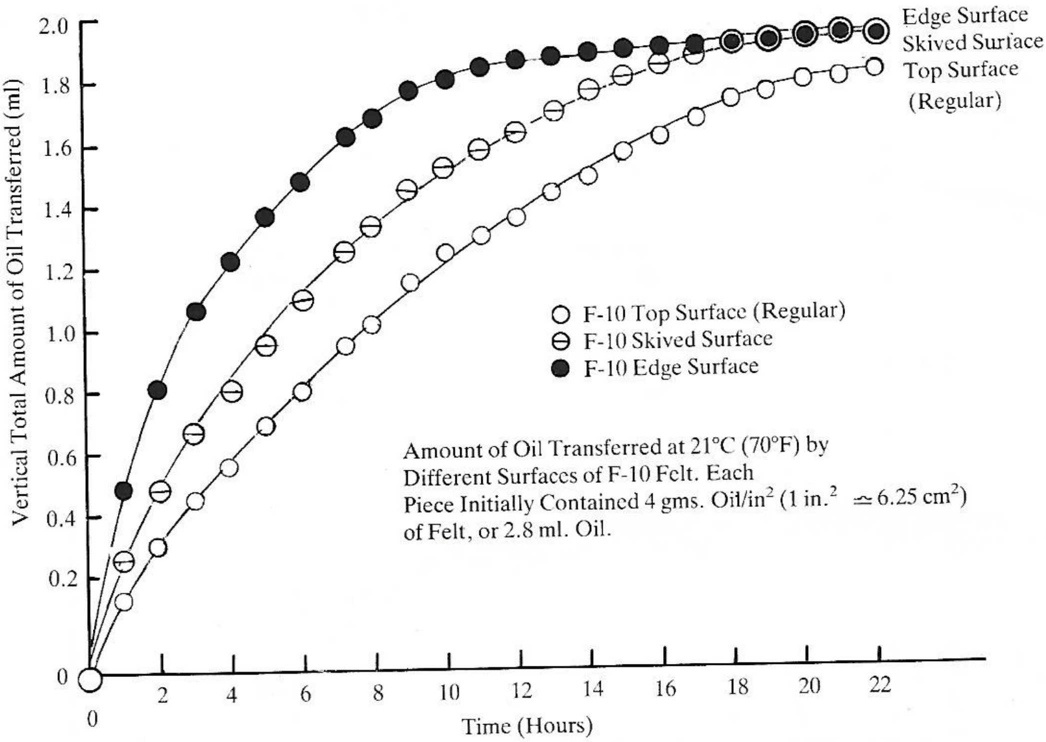
Figure 7 - S.A.E. 10 Oil

Amount of Oil Transferred at 21°C (70°F) by Felts Initially Containing 200% Oil (Weight Basis)



The next graph (Figure-8) shows the effect of the type of surface of a F-10 felt on the amount of oil transferred by that felt. In one case the regular mill finished felt surface was in contact with the axle. In a second case, the regular surface was cut off as the felt piece was skived and the skived surface was rubbed against the axle, and the third case, the edge of the felt was in contact with the axle. All of these felt pieces initially contained the same volume of oil 4 grams of SAE-10 oil per square inch (6.5 cm^2) of felt which was a total of 2.8 ml. of oil in each felt piece.

Figure 8 - Effect of Type of Felt Surface on Amount of SAE-10 oil Transferred



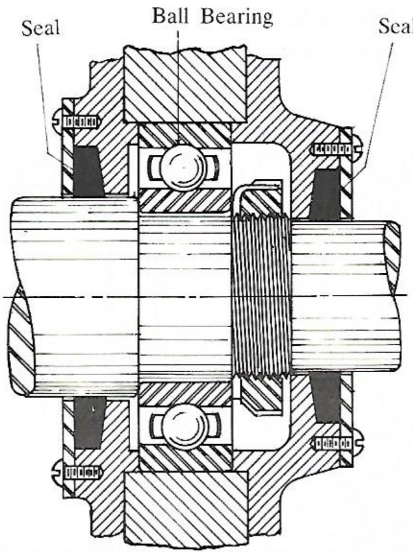
4.3: SPACING AND SEALING

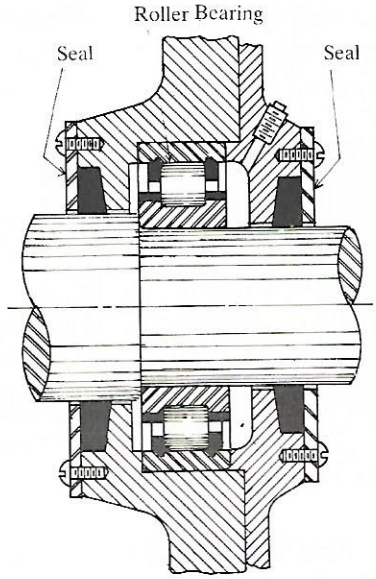
Foremost among the physical properties which recommended felt for washers and gaskets in spacing and sealing applications, are high liquid absorption capacity, low coefficient of friction and excellent resilience.

Because of its resilient character, felt maintains a constant sealing pressure regardless of wear, end play, minor misalignment or cut-of-round conditions of metal assemblies. The coefficient of friction, which averages 0.22 for dry felt against steel is reduced to at least 0.18 when pre-saturated with oil.

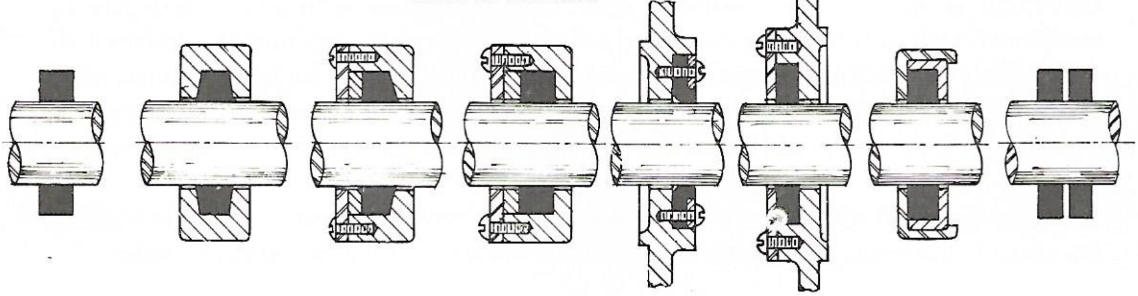
Typical applications for felt seals mounted in machined felt carriers with ball and cylindrical roller bearings on "shaft shoulders" and shaft extensions are shown in the centre of Figure - 9. At the bottom of the same figure is shown a felt ring mounted in a machined groove with an 8 degree taper at the rear. A metal retaining plate is used in this construction to hold the felt ring in place.

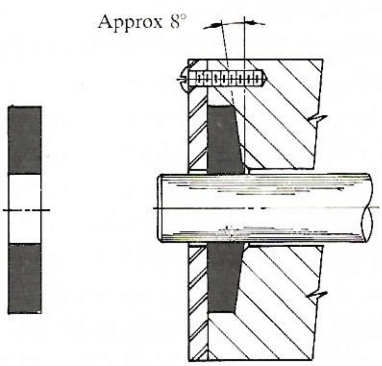
Figure 9 -Felt Seals





Forms of Felt Seals

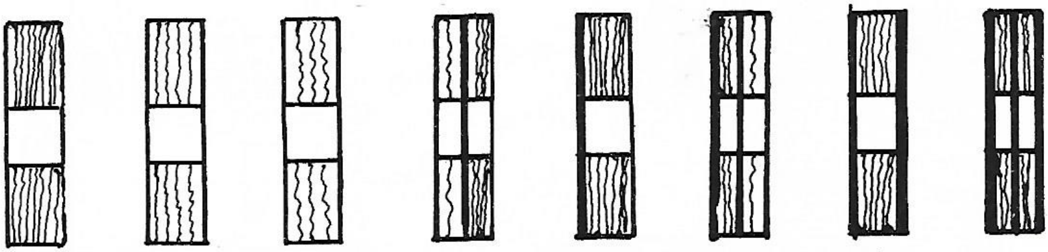




Machined Felt Carrier with Retaining Plate

Felt whashers as applied to oil or grease retention and to dust exclusion are of three general types, plain, impregnated and laminated felt seals.

Figure 10 - Plain and Laminated Felts Seals



F-1 to F-3 F-5 to F-7 F-10 to F-15 a b c d e

Plain felt seals (Figure-10) are precision cut washers fabricated from specified standard grades of felt. Presaturated with lubricants of slightly greater viscosity than those used in the bearing. Plain felt seals, afford positive bearing protection and provide a reservoir for excess lubricant making it available as needed. If run dry, they tend to polish rather than score a shaft and never completely fail through ageing, embrittlement or disintegration. Under normal bearing temperatures and operating conditions the felt seals are highly economical and require replacement only when the machine itself is completely overhauled. Impregnated Felt seals may be either plain or laminated in construction as determined by conditions of use and the severity of the application. Impregnated seals may serve several purposes, e.g.; to further reduce the frictional properties, to impart water repellency etc.

When laminated with synthetic rubber, felt seals also serve as a positive barrier in retaining low viscosity lubricants, or lubricants under pressure, and in preventing the entrance of water.

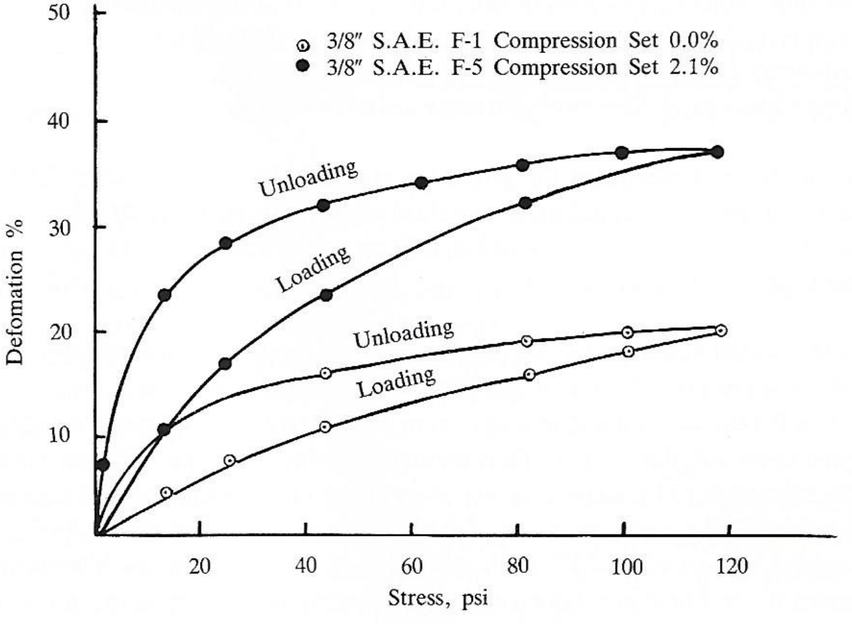
For felt shaft seals, a speed of 2000 rpm is usually considered maximum, but some seals can be used at speeds upto 4000 rpm provided that the shaft is hard and smooth and ample lubricant is present. In general, the higher the peripheral speed of the shaft, the higher the recommended felt density. Both the recommended negative clearance and taper angle decrease with increasing felt density.

4.4: SURFACING, PADDING, CUSHIONING

Because of its non-scratching surface and non revelling edges the wool felt is also ideally suited for surfacing, padding and cushioning applications, some of which are listed in Table II.

Figure 11 shows the compressibility and percent recovery of 3/8'' thick felt (density of 0.34 gmc/cm^3) and felt (0.26 gm/cm^3)) when compressed under loads up to about 8.3 kg./cm^2) (118 p.s.i.) It is seen that the more dense felt deformed only about 20% in thickness and had zero compression set whereas the medium density felt compressed 36.5% and had a compression set of 2.1%. The felt (density of 0.18 gms/cm^3) deformed 51-54% and had compression sets of 9-10%. The higher degree of compressibility and resiliency of the lower-density felts under light loads make them particularly adaptable to cushioning and padding applications. Where high load-bearing capacity is a requirement, as in the vibration-mounting of heavy machines, the higher-density felts, with their low compression set deformation characteristics, are well suited.

figure 11 - Compressibility and Recovery



4.5: SOUND ABSORPTION AND VIBRATION ISOLATION

No sharp distinction can be made between sound-absorption, vibration isolation and shock absorption characteristics. Shock implies a single, sharp displacement that may or may not be resonant vibration. In general, periodic oscillation up to about 50 cycles per second is considered vibration; above that frequency it is considered sound or, if it includes a mixutre of frequencies not harmonically related, noise. since the effectiveness of vibration/sound absorption increases with frequency, it can be assumed that, as felt is effective at very low frequencies, it is even more effective at higher frequencies.

Felt when properly selected for machine load conditions, can reduce the vibrational energy transmitted from a machine to its foundation. Studies indicate that, under the most suitable conditions, isolation of vibration can be made up to 85 percent effective. Similarly, felt mountings under precision instruments afford equal protection against externally generated noise and vibration.

Felt is durable and is stable in the presence of moisture, lubricating oils and greases, detergents, salts, and many other chemicals. Its ability to conform to uneven surfaces prevents the unwanted intrusion of dirt, oil, and other foreign substance beneath the load-bearing area.

Felt provides near permanent resilience, as it is composed of millions of individual wool fibres, selected, blended, and felted to provide a material with maximum vibration energy absorption and isolation characteristics. The naturally resilient construction is maintained under the compressive stresses of heavy static and dynamic loads without deterioration. An important feature is that felt retains its resilience at low temperatures where some other materials become hard and brittle. The impact absorption capacity limits rebound, reducing wear and tear on equipment. Impact and flexural strength remain constant over years of use, assuring dependable performance. Because of this mechanism it is' understandable that a very open (low density) felt will not cause enough frictional heat to be dissipated and, therefore, it will be a poor sound absorber, On the other hand, too dense a felt will not allow enough fibre motion to occur and will, therefore, be a poor absorber.

Sound insulation is preventing the generation of sound. For this, the higher the felt surface density the better the sound insulation. If a machine vibration frequency is 1½. times greater than the natural vibration frequency of the wool felt, then such a felt material should perform adequately from the point of view of sound insulation.

When felt is used as a vibration-isolation material, the greatest isolation efficiency is obtained by using the smallest possible area of the softest felt, in maximum thickness under a static load that the felt will withstand without excessive compression or loss of structural stability. It has a high damping factor and, thus, is particularly useful in reducing amplitude of vibration at resonance. The amplification factor at resonance is almost independent of amplitude and load and is about 4 for soft wool felt. For general purposes, felt mounting of 1 to 2.5cm (½. to 1 inch) thickness is recommended with an area of 5% of the total area of the base if the machine has a felt bed. In installations where vibration is not excessive, no bounding is necessary between the felt and the machine.

Felt pads are used for applications when an isolation material with good cementing characteristics is important. Felt has found widespread use in the textile machinery field and it is recommended when machinery movement or rebound must be closely controlled.

4.6: FILTERATION :

Wool felt filters are an efficient medium for the mechanical filteration of air, gases and liquids where maximum retention efficiency, high permeability, low plugging rate and long life are primary design requirements. The use of felt in respirators for filtering dust, has resulted in the development of a range of all-wool filter felts.

Wool felt is adaptable to all types of filter construction such as plug, accordion-pleated cartridge, sewn bag, drum head, step design, etc. An application of wool felt in gas filteration merits particular mention because it occurs in so many industries; the removal of entrained oil droplets from a stream of compressed gas, which is nearly unavoidable in the discharge from air and refrigerant compressors.

Another important application of wool filter felt, beside those noted above and in Table II, is for all types of oil fired heating equipment to protect the fuel pump and burner nozzle from water, solids and other impurtities in the oil.

The particle size retention of wool filter felt depends on many factors, including; felt density, whether or not the felt has been treated with a resin, such as zinc resinate, and electrically charged (for air filtration), the force of the air or liquid flowing through the filter, whether or not a "cake" builds up on the surface of the filter, the fibre type, the fibre diameter distribution through the thickness of the filter as well as fibre diameter.

It has long been known that wool felt containing 60's to 70's grade wool fibres (24 to 20.5 microns) and carrying electrically charged resinous particles is a very efficient filter for removing submicron (less than 1 micron) particulate matter from the air, and such filter have been widely used in respirators to protect against fine dusts, mists, smoke, organic vapours, acid gases and other hazards.

4.7: FRICTIONAL APPLICATIONS :

As with other materials, the friction coefficient of felt is greatly influenced by surface films such as lubricants and oxide layers and by the texture and smoothness of adjacent surfaces. Behaviour under different conditions can be quickly determined by tests.

4.8: THERMAL INSULATION :

While thermal insulation is directly proportional to the thickness of any material it also varies inversely according to the intrinsic thermal conductivity of the material itself. While the conductivity of wool felt is noticeably low among insulating materials, the superior insulating properties of still air mean that less dense felts are more effective insulators.

4.9: PERCUSSION CONTROLS :

Vital to the manufacture and continued uniform performance of pianos, wool felt hammers, backchecks, wedge veneers, stops and dampers demonstrate the extremely long life, impact resistance and vibration absorption of high-quality wool felts. Sheet felts are used for piano hammers and the felt density is increased progressively and controlled for the bass, tenor and treble sections. Generally, the tonal qualities of the felts remain constant throughout the life of the pianos.

4.10: DECORATION :

A final function of pressed wool felts, to be noted in this article, is decoration. Wool felt can be dyed to hundreds of beautiful, bright and fast colours. It can be printed or embossed. It can be sanded to give a smooth, soft, suede-leather-like surface. Colourful wool felt is used for decorating interiors of homes; apparel from head to foot; toys and novelties; office, walls of hotels and hotel lobbies, cocktail lounges, corporate board rooms; cutlery and jewellery boxes; pennants and ribbons; Christmas and greetings cards.

Table 1. Wool Felts-Roll[a]

Grade →	18R 1	16R 1	16R 2	16R 3	12R 1	12R 2
SAE Spec. No. →		F-1	F-2	F-3	F-5	F-6
general properties						
wool content (fibre basis), % min	100	100	100	95	100	100
standard thickness range, in.	1/8-1	1/8-1	1/8-1	1/8-1	1/8-1	1/8-1
standard width, in.	60	60	60	60	60	60 or 72
texture	fine	fine	medium fine	medium	fine	medium fine
colour[b]	white	white	any, except grey or black	grey	white	grey
physical properties						
specific gravity	0.384	0.342	0.342	0.330	0.262	0.262
operating temperature range, °F[c]	-80 to +200	-80 to +200	-80 to +200	-80 to +200	-80 to +200	-80 to +200
thermal conductivity, 70°F, Btu/(hr)(ft^2 /°F) (in.) [d]	0.39	0.36	0.36	0.35	0.30	0.30
coefficient of thermal expansion, per °F	0	0	0	0	0	0
air permeability, 1/16 in., (ft^3 /min)/(ft^2 /0.5 in. H_2O)	5-15	10-30	10-30	15-35	20-50	20-50
liquid absorption						
wt % (1.0 sp gr liquid)	>125	>175	>175	>190	>250	>225
vol. %	71	74	74	76	80	80
Capillarity, (wicking height, 575 SSU, 70°F), in.	4.5	4.0	4.0	4.0	3.0	3.0
coefficient of friction[e]	0.37	0.37	0.37	0.37	0.37	0.37
vibration absorption[f]						
static load bearing cap, per unit area	high	high	high	high	medium	medium
dynamic stress endurance	high	high	high	high-medium	high	high
coefficient of noise reduction (1 in. thick)[d]	0.45	0.50	0.50	0.52	0.58	0.58
mechanical properties						
tensile strength	600	500	500	400	400	275
elongation, at 100 psi, %	9	13	14	16	16	18
Mullen burst strength (1/8 in. thick), psi	300	250	225	200	175	150

split resistance, lb/2-in width, min	35	33	28	22	18	16
hardness range, Shore A	40-50	30-40	30-40	20-30	20-30	
compressibility (at 10% defl), psi	37	21	21	13	6	6
recovery (within 1 min after 10% defl), %	99	99	99	99	99	99
vibration disintigration	none	none	none	none	none	none
collapse when wet	none	none	none	none	none	none
abrasion resistance[g]	excellent	excellent	excellent	excellent	good	good
flexibility (fold endurance)	1/4-in. thick felt exceeds 3 million 180° flexes					
chemical and environmental properties[h]						
effect of sunlight and oxidation	none	none	none	none	none	none
solvent resistance, stability in oil	excellent	excellent	excellent	excellent	excellent	excellent
acid resistance						
dilute	excellent	excellent	excellent	excellent	excellent	excellent
concentrated	good-fair	good-fair	good-fair	good-fair	good-fair	good-fair
alkali resistance						
dilute	fair	fair	fair	fair	fair	fair
concentrated	poor	poor	poor	poor	poor	poor
fabricating methods	can be fabricated by die cutting, stripping, skiving; laminating, coating, impregnating; stitching, stapling, perforating, cementing; machining, grinding, drilling; and molding and shaping; all grades except 12R1 and 12R2 can be extruded.					
typical uses	bearing seals, ink rolls, polishing, printing, wick lubrication and precision uses where dense high grade felt with max durability is required		vibration mounts, precision channels, oil seals, bumpers, gaskets	automotive, aircraft machine components. Similar to 16R1, and 16R2, where lower	lubricators, wipers, shock dampeners, etc., where durable resilent felt is required density is acceptable	grease retainers, spacer strip seals, vibration mounts, weather strip, journal lubricators.

Table 1 (continued)

Grade →	12R 3	9R 1	9R 2	9R 3	9R 4	9R 5
SAE Spec. No. →	F-7	F-10	F-11	F-12	F-13	F-15
general properties						
wool content (fibre basis), % min	85	100	100	90	80	60
standard thickness range, in.	1/8-1	1/8-1	1/8-1	1/8-1	1/8-1	1/8-1
standard width, in.	72	72	72	72	72	72
texture	medium	fine	medium fine	medium fine	medium	medium
colour[b]	grey	white	grey	grey	grey	grey
physical properties						
specific gravity	0.262	0.181	0.181	0.181	0.181	0.181
operating temperature range, °F[c]	-80 to +200	-80 to +200	-80 to +200	-80 to +200	-80 to +200	-80 to +200
thermal conductivity, 70°F, Btu/(hr)(ft^2/°F) (in.)[d]	0.30	0.30	0.24	0.24	0.24	0.24
coefficient of thermal expansion, per °F	0	0	0	0	0	0
air permeability, 1/16 in., (ft^3/min)/(ft^2/0.5 in. H_2O)	20-50	75-150	75-150	75-150	75-150	75-150
liquid absorption						
wt % (1.0 sp gr liquid)	>225	>400	>375	>350	>350	>350
vol. %	80	88	88	88	88	88
Capillarity, (wicking height, 575 SSU, 70°F), in.	3.0	2.4	2.4	2.4	2.4	2.4
coefficient of friction[e]	0.37	0.37	0.37	0.37	0.37	0.37
vibration absorption[f]						
static load bearing cap, per unit area	medium	low	low	low	low	low
dynamic stress endurance	medium	high	high-medium	medium	low	low
coefficient of noise reduction (1 in. thick)[d]	0.58	0.58	0.64	0.64	0.64	0.64
mechanical properties						
tensile strength	250	225	200	100	75	75
elongation, at 100 psi, %	21	33	35	35	37	39
Mullen burst strength (1/8 in. thick), psi	125	75	60	55	50	40
split resistance, lb/2-in width, min	12	8	6	3	2	2
hardness range, Shore A	20-30	15-25	15-25	15-25	15-25	15-25

compressibility (at 10% defl), psi	6	4	4	3	3	3
recovery (within 1 min after 10% defl), %	99	99	99	99	99	99
vibration disintigration	none	none	none	none	none	none
collapse when wet	none	none	none	none	none	none
abrasion resistance[g]	good	fair	fair	fair	fair	fair
flexibility (fold endurance)	1/4-in. thick felt exceeds 3 million 180° flexes					
chemical and environmental properties[h]						
effect of sunlight and oxidation	none	none	none	none	none	none
solvent resistance, stability in oil	excellent	excellent	excellent	excellent	excellent	excellent
acid resistance						
dilute	good	excellent	excellent	good	fair	fair
concentrated	fair	fair-good	fair-good	fair-good	fair	fair
alkali resistance						
dilute	fair	fair	fair	fair	fair	fair
concentrated	poor	poor	poor	poor	poor	poor
fabricating methods	can be fabricated by die cutting, stripping, skiving; laminating, coating, impregnating; stitching, stapling, perforating, cementing; machining, grinding, drilling; and molding and shaping; Grade 12R3 can also be machined, ground, and drilled.					
typical uses	dust shields, oil and grease retainers; similar to 12R1 and 12R2 where a lower grade may be used	fluid storage and delivery, resilient pading, plug filterns for gas and air	dryer drum seals, impregnated paking, insoles insulation; oil, a dust and mud shields	chassis strips, spacers, dashliners, antisqueak strips and pads; sound deadeing	grease and oil retention, protective lining and insulation for freight cars, trucks, dunnage; uses similar to 9R2 and 9R3 where less durability and lower grade felt is suitable	

Table 1 (continued)

Grade →	8R 5	16R IX	16R 3X	12R 3X	32S 1, 32S 2	32S 3, 32S 4
SAE Spec. No. →	F-26	F-50	F-51	F-55		
general properties						
wool content (fibre basis), % min	50	100	100	80	100	100
standard thickness range, in.	1/8-1	3/64-3/32	3/64-3/32	1/16-3/32	1/8-3	1/8-3
standard width, in.	72	60 OR 72	60 OR 72	60 OR 72	36x36	36x36
texture	medium	fine	medium fine	medium	fine-extra fine	medium coarse
colour[b]	grey	white	grey	grey or black	white	white
physical properties						
specific gravity	0.154	0.330	0.330	0.256	0.682	0.682
operating temperature range, °F[c]	-80 to +200	-80 to +200	-80 to +200	-80 to +200	-80 to +200	-80 to +200
thermal conductivity, 70°F, Btu/(hr)(ft^2 /°F) (in.) [d]	0.25	0.32	0.32	0.30	0.91	0.91
coefficient of thermal expansion, per °F	0	0	0	0	0	0
air permeability, 1/16 in., (ft^3 /min)/(ft^2 /0.5 in. H_2O)	100-200	15-25	15-40	20-50	>1	>1
liquid absorption						
wt % (1.0 sp gr liquid)	>400	>180	>170	>225	>50	>50
vol. %	92	75	75	81	48	48
Capillarity, (wicking height, 575 SSU, 70°F), in.		4.0	4.0	3.0	5.5	5.5
coefficient of friction[e]	0.37	0.37	0.37	0.37	0.37	0.37
vibration absorption[f]						
static load bearing cap, per unit area	very low				ultra high	medium high
dynamic stress endurance	very low				high	high
coefficient of noise reduction (1 in. thick)[d]	0.65	0.55	0.55	0.58	0.05	0.05
mechanical properties						
tensile strength		500	200	200	800	800
elongation, at 100 psi, %		8	9	25	2	2
Mullen burst strength (1/8 in. thick), psi	25	225	225	200	over 500	over 500
split resistance, lb/2-in width, min					48-50	40-46
hardness range, Shore A	5-15				75-85	75-85

compressibility (at 10% defl), psi	1				121	121
recovery (within 1 min after 10% defl), %	99	99	99	99	99	99
vibration disintigration	none	none	none	none	none	none
collapse when wet	none	none	none	none	none	none
abrasion resistance[g]	poor	excellent	excellent	good	excellent	excellent
flexibility (fold endurance)	1/4-in. thick felt exceeds 3 million 180° flexes					
chemical and environmental properties[h]						
effect of sunlight and oxidation	none	none	none	none	none	none
solvent resistance, stability in oil	excellent	excellent	excellent	excellent	excellent	excellent
acid resistance						
dilute	fair	excellent	excellent	good	excellent	excellent
concentrated	poor	fair-good	fair-good	fair	fair-good	fair-good
alkali resistance						
dilute	fair	fair	fair	fair	fair	fair
concentrated	poor	poor	poor	poor	poor	poor
fabricating methods	can be fabricated by die cutting, stripping, skiving; laminating, coating, impregnating; stitching, stapling, perforating, cementing; machining, grinding, drilling; and molding and shaping; Grades 32S 1 and 32S 2 can also be machined ground, drilled, or extruded.					
typical uses	packing or padding when held between other materials; not recommended for machenical use	ball and roller bearing precision seal, strip wicks, industrial filters and uses requiring thin precision flet	gaskets, liners, bearing seals, where precision tolerances, life and quality are not as exacting	anti-squeak strips, anti drumming and insulation lining cemented to metal or other type panels	extra-hard density polishing wheels and buffs in dental, jewelary, glass and lapidary polishing; also hard washers, bumpers, and casters	

Table 1 (continued)

Grade →	20S1, 26S2, 20S3, 26S4,	20S1, 20S2, 20S3, 20S4	16S1, 16S2,	16S3, 16S4,	12S1, 12S2,	12S3, 12S4,
general properties						
wool content (fibre basis), % min	100	100	100	100	100	100
standard thickness range, in.	1/8-3	1/8-3	1/8-3	1/8-3	1/8-3	1/8-3
standard width, in.	36x36	36x36	36x36	36x36	36x36	36x36
texture	coarse extra fine	coarse extra fine	fine extra fine	medium coarse	fine extra fine	coarse medium
colour[b]	white	white	white	white	white	white
physical properties						
specific gravity	0.555	0.426	0.342	0.342	0.256	0.256
operating temperature range, °F[c]	-80 to +200	-80 to +200	-80 to +200	-80 to +200	-80 to +200	-80 to +200
thermal conductivity, 70°F, Btu/(hr)(ft^2 /°F) (in.) [d]	0.63	0.45	0.36	0.36	0.30	0.30
coefficient of thermal expansion, per °F	0	0	0	0	0	0
air permeability, 1/16 in., (ft^3 /min)/(ft^2 /0.5 in. H_2O)	>5	>15	>25	>35	>40	>60
liquid absorption						
wt % (1.0 sp gr liquid)	>75	>100	>175	>175	>250	>250
vol. %	58	66	74	74	81	81
Capillarity, (wicking height, 575 SSU, 70°F), in.	5.0	4.5	4.0	4.0	3.0	3.0
coefficient of friction[e]	0.42	0.42	0.37	0.37	0.37	0.37
vibration absorption[f]						
static load bearing cap, per unit area	very high	high	high	high	medium	medium
dynamic stress endurance	meduim-high	meduim-high	meduim-high	meduim-high	meduim-high	meduim-high
coefficient of noise reduction (1 in. thick)[d]	0.28	0.41	0.50	0.50	0.58	0.58
mechanical properties						
tensile strength	700	600	500	500	400	400
elongation, at 100 psi, %	4	9	12	12	28	28
Mullen burst strength (1/8 in. thick), psi	>400	>325	>250	>250	>150	>150
split resistance, lb/2-in width, min	30-48	32-44	28-32	20-22	16-18	10-12
hardness range, Shore A	55-65	45-55	30-40	30-40	20-30	20-30
compressibility (at 10% defl), psi	86	58	32	32	18	18
recovery (within 1 min after 10% defl), %	99	99	99	99	99	99
vibration disintigration	none	none	none	none	none	none

collapse when wet	none	none	none	none	none	none
abrasion resistance[g]	excellent	excellent	excellent	excellent	good	good
flexibility (fold endurance)	1/4-in. thick felt exceeds 3 million 180° flexes					
chemical and environmental properties[h]						
effect of sunlight and oxidation	none	none	none	none	none	none
solvent resistance, stability in oil	excellent	excellent	excellent	excellent	excellent	excellent
acid resistance						
dilute	excellent	excellent	excellent	excellent	excellent	excellent
concentrated	fair-good	good-fair	good-fair	good-fair	good-fair	good-fair
alkali resistance						
dilute	fair	fair	fair	fair	fair	fair
concentrated	poor	poor	poor	poor	poor	poor
fabricating methods	die cutting, stripping, skiving; laminating, coating, impregnating; stitching, stapling, perforating, cementing; machining, grinding, drilling, molding and shaping; extruding.					
typical uses	medium-hard density wheels and buff for polishing lenses, mirrors and glass, metals, wood, and marble and granite; fluid transfer rolls, ink rolls, drilled wicks, bearing seal washers, stamp pads, cushioning under sandpaper, caster boot and shoe soles, artificial limbs.		medium-density polishing wheels and buffs for precious metals and plastics, rough optical polishing, metal wiping; drum beaters, drilled wicks, bearing seals, shoe rolls (shank), fluid transfer rolls, oil and fluid wicks grease and oil retaining washers, ink rollers, vibration mounts, bumpers, plugs, glass channels		soft-density polishing wheels and buffs for polishing plastics and polishing wiping brass; also piano wedges, surgical pads, punched wicks, dampeners, absorbent pads, oil and fluid retainers, fluid transfer rolls, bearing seals, washers, wicks, shim and spacer pads, shoe insoles, dust shields.	

[a] Industrial, mechanical and filter felts; three-dimensional fibrous structure.
[b] Colours available on special order.
[c] Felts are flameproofed to meet government and industrial specifications.
[d] for 1-in felts. Felts blended with kapok fibre have a k factor of 0.21 and a coefficient of sound absorption of 0.80 at 512 cps.
[e] Depends upon condition of contact surface, but can be moderately controlled by altering surface finish of the felt.
[f] Up to 85% under appropriate design conditions.
[g] Increases with density.
[h] Treated to resist moths, fungus, mildew and vermin.

TABLE - II

BASIC FUNCTIONS OF FELT AND SOME CURRENT APPLICATIONS

Polishing and De-burring	Finishing optical and opthalmic lenses; polishing plate glass plastics, felt hats, etc.; Buffing wheels for shoe machinery.
Storing, Wicking, Syphoning, Transferring Liquids, Lubricating	Felt-nib, marking pens and ink reservoirs, Stamp pads, Journal lubricating wicks for armature shafts, spindles, and many other iaccessible machie parts, Wicking material for copying machines, Cosmetics, Transfer rollers, Wiping devices.
Spacing-Washers, Gaskets, Packing	Gaskets for auto, arc and flood lights. Gaskets in home clothes dryers, refrigerators, Glass covered electric meters. Gland packing for fuel and supply pumps. Washers in nuclear reactor equipment.
Sealing	Rotating/obturating bands for gunlaunched projectiles, plain and laminated felt seals to protect ball and roller bearings. Weather striping. Power seals for military rockets. Gaskets in cryogenic equipment.
Surfacing Padding, Cushioning	Covers for bases of lamps, fan and trays, etc. Card table covers. Lining and in soles for shoes, wadding boots. Saddle pads, Cushioning material in mechanical processes. Padding under batteries in vehicles. Corn and callous foot pads. Knee pads for horses. Display. Jewellery silverware and other cases.
Vibration Isolation Shock Absorption and Sound Absorption	Felt pads for heavy textile and other machinery. Hi-fi speaker enclosure. Computers. Isolating sensitive/delicate instruments from vibration/shock during shipments or from floor or building vibrations. Wall coverings. Computer and typewriter pads.
Filtration	Respirators. Oil fired heating equipment. Air compressors. Separating water from gasoline. Filtering electroplating solutions, organic solvents, oils, photographic emulsions, etc. Gasoline filters for chain saws.
Frictional	Provides traction to pull strip brass through the cleaning bath in rolling mills and in "jacking" hides in a tannery. Black Board Dusters. Auto window channels.
Thermal Insulation	Insulating refrigerators and cold piping. Boot linings. Military Arcitc weather boots.
Pecussion Controls	Percussion pads, hammers, dampers, back checks, wedges, venners, stops, etc. for pianos. Beater balls for drum sticks, stickers for chimes.
Clothing and Decoration	Skirts, weskits, hats, caps, berets, garment interlinings. Wall and office panel coveringe. Valance covers. Toys, novelties pennants, printed calendars, lettering, insignia/brassards, slippers, handbags. Background for displaying/exhibiting products, etc.