7
Other textile applications

7.1 Introduction

This chapter details other textile uses including some of the larger growth areas at the present time, driven by government legislation to improve the safety of cars. The main driving force has been the federal laws passed in the USA relating to airbags and head protection devices. The airbag in particular is experiencing quite spectacular growth and developments continue to improve its action which undoubtedly saves lives, but is believed to have caused the deaths of children and small adults in fairly low impact accidents.

As well as continuing to make the car safer, researchers are continuing to improve the comfort of car interiors. Discomfort contributes to driver fatigue, which in turn contributes to lapses in concentration and judgement causing accidents. Noise and vibration are two factors which engineers strive to control and there is no doubt that modern cars are much quieter than several years ago but the struggle continues to improve further. There are known limitations of both vibration and noise above which human health will suffer. The carpet is a key component in the pursuit of quieter interiors and a smoother ride but as with all other developments associated with the car, cost control and cost reduction are vital.

Textiles provide strength and reinforcement to many other components of the car and involve rubber and plastic composites. Rubber composites are included in this chapter but plastic composites are considered in Chapter 9. Composites are used significantly in other forms of transportation, but are not, at present, used in large components in regular production cars. Much research is being conducted to enable this to happen.

Many of the essential components of the car are made from combinations of yarn, fibre or fabric with rubbers. The best known of these are the tyres, followed by the hoses and drive belts. Tyres are usually associated more with the rubber industry but their physical performance depends to a large extent on the properties of the reinforcing textile within. The textile yarn in all rubber composites has to have good dimensional stability, and as low heat shrinkage properties as possible so they do not move during the vulcanization process or during use. Being embedded in rubber will not prevent the shrinkage, which can distort the article and contribute to premature failure. The general relationship between temperature and shrinkage of polyester yarn appears in Fig. 4.7. Textiles are also used in composite form with specialist rubbers and other materials in seals, diaphragms, gaskets, clutch and brake linings of all types of vehicles, and in recent years have replaced asbestos. Tests involving textile properties are listed in Table 7.1.

7.2 Seat belts

The wearing of seat belts in the United Kingdom only became compulsory for drivers and front seat passengers in January 1983, although all new cars made after 1 July 1964 had to have front seat belts fitted. Studies carried out in the 1970s concluded that seat belts could reduce fatal and serious injury by 50%. The wearing of both front and back seat belts is now compulsory in many countries of the world and all new cars made, contain at least four diagonal and lap seat belts each made from about 250 g of woven fabric. In the USA, although all new cars are fitted with seat belts, individual state laws vary and not all drivers or passengers wear them. This has produced a different situation with airbags compared to Europe, as will be seen.

The narrow fabric is a multiple layer woven twill or sometimes satin, using typically 320 ends of 1100 dtex or 260 ends of 1670 dtex high-tenacity continuous filament polyester yarn. These constructions are chosen because they allow maximum yarn packing within a given area for maximum strength and good abrasion resistance – the trend is to use thicker yarns for even better abrasion resistance. Belts need to be as soft and flexible as possible along the length direction but as rigid as possible in the width direction so they can slide easily through buckles and to retract smoothly into housing. The edges must be scuff resistant but not unpleasantly hard and the material must be resistant to UV degradation and retain its strength for the life of the car – otherwise it must be replaced. Some of the first seat belts were made from nylon but they are now almost exclusively made from polyester because of its superior resistance to UV degradation.

Spun-dyed yarns are used but other colours are produced by pad thermosol dyeing using selected dyes. These dyes must have excellent resistance to light and high wet crocking and perspiration fastness. Loomstate fabric is about 5 cm wide, weighing approximately 50 g per linear metre, but during fabric finishing, some shrinkage is induced in the length direction to improve the energy absorption properties. As a result, finished fabric weight

Table 7.1 Test methods for textile automotive components

These are the main tests involving the textile component. There are many others to evaluate the whole composite item:

Seat belts	BS 3254 Part 1 1988	Restraining devices for adults
	BS 3254 Part 2 1991	Restraining devices for children
	BS AU 183	Specification for passive seat-belt systems
	SAE J114 June 1994	Abrasion test performance requirement
	SAE J339 June 1994	Abrasion test procedure
	SAE J117	Dynamic test for seat belt systems
	BS 2576-86	Breaking strength test
	Also EC regulations – see text	
Airbags	SAE J1538 April 95	Terms and glossary
	SAE K1856 May 89	Identification (at vehicle disposal)
	ASTM D5428-93A	Practice for evaluating performance
	ASTM D5446-94	Physical properties determination
	ASTM D5427-93A	Ageing test
	ASTM D5426-93	Visual inspection of fabric
	ASTM D-3786-87	Bursting strength (diaphragm method)
	ASTM D737-96	Air permeability
	DIN 53 887	Air permeability
Automotive carpets	ASTM D2646-96	Test for backing fabric
	ASTM D-1175	Abrasion resistance
	ASTM D-4723-90	Method and specifications for heat and flammability
	ASTM D-2859-96	FR test method
	ASTM D-5393	Fogging
	AATCC Method 121-89	Visual soiling
	AATCC Method 122-89	Service soiling
	AATCC Method 123-89	Accelerated soiling
	AATCC Method 138-92	Shampooing
	AATCC Method 134	Electrostatic Nature
	SAE J1530 August 94	Test for abrasion and loss of fibre
Tyre cords	ASTM D 885-94	Method of testing tyre cords/tyre cord fabrics
	ASTM D 885-94 (M)	As above – metric
	ASTM D 4974-89	Shrinkage of tyre cords (Testrite Oven)
	ASTM D 2692-89	Air wicking of cords
	ISO 4647	'H-pull' method for adhesion of rubber to cord
	ASTM D2138	Test for adhesion of rubber to cord
	BS 903 Part A48	Test for adhesion of rubber to cord
Hoses and belting	ASTM D413-93	Rubber to textile adhesion test methods
	BS 903 Part A12	Rubber to textile adhesion test methods
	DIN 53530	Rubber to textile adhesion test methods
	ISO 36	Rubber to textile adhesion test methods

is approximately 60 g per linear metre. This controlled limited non-recoverable, i.e. not elastic, stretch reduces some of the deceleration forces on the body being restrained during a collision.[1,2] Some seat belts are lightly coated to improve cleanability, durability, ease of passage in and out of housing and to impart some antistatic properties.

BS 3254; 1960 requires a belt to restrain a passenger weighing 90.7 kg (about 14 stone) involved in a collision at 50 km/h (about 30 m.p.h.) into an immovable object. In an actual car accident the front of the vehicle will crumple, usually by design, causing very rapid deceleration forces on the human body. The standard takes this and other factors into consideration and specifies minimum performance requirements for the seat-belt webbing. This first standard was replaced by BS 3254 Part 1 1988, 'Restraining devices for adults' and BS 3254 Part 2 1991, 'Restraining devices for children'. Minimum belt widths are specified, 4.6 cm minimum for the waist strap and 3.5 cm minimum for the shoulder strap for adults. Minimum belt widths are also specified for children depending on their weight, 2.5 cm for the smallest (9 to 18 kg) and 3.8 cm for larger children (18 to 36 kg). The belts should be tested for breaking strength using BS 2576; 1986, breaking strength and elongation-strip method for woven textiles. Minimum breaking forces for adults are 13.3 kN for the waist strap and 10 kN for the shoulder. Some manufacturers however work to a minimum of a straight pull tensile strength test result of at least 30 kN/5 cm. Other tests include accelerated ageing and in the made up form, fastening and unfastening 10 000 times. Seat belts are also governed by standards ECE R16, ECE R44 and EEC 77/561 and Construction and Regulation use 46/47/47A. Seat Belt fabric is scrupulously examined for defects, usually by electronic means and the manufacturers are subject to both national government and European Union regulations. The main textile tests appear in Table 7.1.

A total of about 14 m of seat belt fabric weighing about 800 g are used in each car made, which amounts to about 32 000 tonnes every year. Recycling was believed to be feasible because of uniform composition and ease of removal, but a return scheme has been recently abandoned by one of the major yarn suppliers because of logistical problems.[3] Seat belts are mainly black in Europe, light grey in the USA and Japan, but this is now changing to harmonize with interior colours.

Much research has gone into child restraint systems (CRS) in the USA where individual state laws have been in place since the early 1980s involving various test methods; the Federal Standard is FMVSS 213. CRS development also involves child seat design, suitable washable fabric, seat comfort and ease of use.[4–6] An advanced seat belt material, Securus (AlliedSignal) is claimed to limit the decelerating forces exerted on the human body. Other seat belt developments combine protection with airbags and there is an airbag which inflates from the seat belt away from the body.

The use of seat belts for passengers in coaches is growing following several recent serious coach accidents.

7.3 Airbags and related products

Airbags have only come into widespread use over the last 5 years or so but in fact have been around for more than 30 years. The growth in their was has been quite spectacular, mainly because of legislation in the USA. The federal safety standard, FMVSS 208 requires all passenger cars sold in the USA to have airbags for both the driver and front-seat passenger. A second federal standard FMVSS 201, requires 10% of cars to be fitted with some type of head protection by May 1999.[5,6] The standard does not specify the device by which this should be achieved and so it could be a type of airbag or some kind of padding in the headliner area of the car. FMVSS 201 requires all cars made by May 2003 to be fitted with some head protection facility. There is a higher proportion of vehicles in the USA – SUVs and light trucks – which have a higher centre of gravity than cars, leading to more roll over types of accident and head protection is especially relevant in these circumstances. In Europe BMW introduced a head protection device, an 'inflatable tubular structure' (ITS), sometimes called 'the sausage', and also a side impact airbag in their 7-series which will be extended to their 5- and 3-series of cars. In fact a BMW concept car featured 12 airbags.[7] Rear passenger airbags are being developed as well as side airbags which provide protection in roll-over accidents by shielding the occupants from side window glass and protecting the head.[8,9] Airbags have even been suggested for protection of the knees and legs. Autoliv have three different head protection systems, the combined Head and Thorax bag (HAT-bag), the ITS and the inflatable curtain (IC).[10] Volvo installed an Autoliv side airbag during June 1994, the world's first side airbag and a short time after, Volvo were also the first OEM to use an inflatable curtain, which is held inside the headliner and covers the length of the car interior.

The world market for airbags in 1998 was worth $5.5 billion and is expected to reach $7 billion in 1999 – and there is still room for considerable growth in both front passenger airbags, especially in Europe and Japan and side impact airbags, especially in the USA. Airbags operate by a triggering device, which sets off explosive chemicals when it senses an impact at above approximately 35 km/h is about to happen. This causes the bag to inflate, which cushions and restrains the human body from hitting a harder object. It inflates and deflates all within a fraction of a second – less than the time to blink an eye. The fabric from which the bag is made must be able to withstand the force of the hot propellant chemicals and more importantly they must not penetrate through the fabric to burn the skin of the car occupant.[11] Polyester is not used for airbags because its thermal properties are not suitable. Compared to nylon 66, about 40% less heat is needed to melt polyester and the fabric could allow the penetration of hot gases.[12]

The first airbags were Nylon 66 coated with Neoprene rubber (DuPont), but in efforts to make bags both lighter and thinner to fold up into a compact pack, silicone coatings soon followed.[13] There has been considerable research and development to improve the deployment, the design and also the production efficiency of airbags. The huge volumes involved – not to mention the life preserving factors – justify the effort being put into airbags and all associated safety devices. To save weight and cost, uncoated fabrics have appeared which make use of fabric construction to control air permeability and these appear to be the preferred option for the future. However there are advantages and disadvantages for both coated and uncoated fabrics. Coated fabrics do not fray, are easier to cut and sew and air porosity can be controlled better. Non-coated fabrics are lighter, softer, less bulky and can be recycled more easily. The sizes of air bags vary with the car they are going into and also whether they are to be used for the driver or the passenger. In Europe, driver-side airbags are about 40–65 litre capacity, whereas front seat passenger airbags are a little larger, about 60–100 litre capacity. Airbags in the USA are generally larger than European ones because in Europe, the airbag is designed for use in conjunction with a seat belt, whereas in the USA not all drivers use seat belts and instead rely on the airbag alone for protection.

Airbags are typically woven from high tenacity multi-filament nylon 66 yarns in the approximate dtex range of 210 to 840 with 470 being the most frequently used in Europe and Japan.[14,15] Fabric weights, uncoated are about 170 and 220 g/m^2. A small amount of nylon 6 is used which is claimed to be softer, minimizing skin abrasion and also, to have better packing compactness. Autoliv has developed a 'one-piece weaving' double-layer system which produces airbags directly from the loom.[10] Airbag fabric is not dyed but needs to be stabilized by heat setting and scoured to remove impurities, which could mildew or cause other problems. The fabric must be strong with high tear strength, high anti-seam slippage and needs to have controlled air permeability, usually measured using ASTM D37-75 or DIN 53877.[16] It must be capable of being folded up in a small space for over 10 years or more without deterioration and, in the case of coated fabric, without blocking or sticking together. Some tests specify 75% property retention after 4000 h at 90–120 °C, the equivalent of 10 years UV exposure and also cold cracking down to –40 °C. A selection of the main test methods is in Table 7.1. DuPont have tested two of their airbags in nylon 66, one coated and one uncoated, which were installed in a car in the 1970s and found no loss in performance after 16 years. The new nylon 4.6 recently introduced by AKZO has a melting point of 285 °C and should be well suited for airbags, although its extra cost is a disadvantage. Improved thermal performance can be obtained by coating.

In the USA, the National Highway Traffic Safety Administration (NHTSA) estimates that 4750 people are alive today (9 December 1999) because of their airbags.[17] NHTSA also estimates that the use of an airbag in combination with a lap/shoulder belt reduces the risk of serious head injury by 81% compared with 60% reduction by use of a belt alone. Although airbags undoubtedly save lives they are believed to have caused the deaths, in the USA, of an estimated 148 persons in low-severity accidents since 1990. These included 42 female drivers, out of a total of 56 drivers, 68 children (aged between 1 and 11 years) and 18 infants. Analysis showed that many of these persons were not wearing a seat belt and were sitting close to the steering wheel or airbag. This has resulted in considerable research and development work for reliable 'smart' airbags which can sense the size of the seat occupant or even if the seat is unoccupied and deploy accordingly. Other designs have been put forward including an airbag, which deploys outwards from the seat belt.[18,19] Research is also directed towards gentler inflation and less abrasive fabric material. Injuries caused by airbag inflation include eye damage, fractures, bruises and chemical burns caused by penetration of the inflating material through the fabric. Integrated safety systems especially for children are being developed. Airbags are not yet compulsory in Europe and it has been suggested that tests should be carried out to determine the most suitable for use in conjunction with seat belts which are compulsory and which are in widespread use. Recently there seems to be some progress in the development of airbag fabric from non-woven material.[20]

Statistics compiled by the World Health Organization in 1998 record that world wide 500 000 persons are killed and 15 million injured in traffic accidents every year. This is expected to increase sharply as car ownership increases in the developing nations and also as the young adult populations grow. Traffic accidents are among the main causes of premature death in many of the developed counties and efforts are being made to reduce this by several means including making cars more safe. In the USA there is a whole series of Federal Motor Vehicle Standards (FMVSS) aimed at improving car safety.[5] These include: FMVSS 201–head protection for cars and light trucks, 100% compliance by May 2003; FMVSS 208–airbags for both cars and light trucks, 100% compliance by September 1998; FMVSS 213–child restraint systems, 100% compliance by August 1994; FMVSS 214–side impact for passenger cars and light trucks, 100% compliance by September 1998; FMVSS 581-bumper properties.

Car occupant safety is becoming an electronic 'high tech' industry with the development of sensor systems for the seat belt, for anticipation of type of accident, e.g. roll over, side impact etc. and for the airbag.[21] These sensors activate the relevant components to optimize the protection performance. In the USA, new legislation is expected in the near future to regulate advanced airbags. Continental analysis of airbag deployment has drawn attention to the economic cost of airbags deploying unnecessarily.[22] New fabric structure development continues to improve safety devices.[23] Recent developments with a review of expected NHTSA proposals have been summarized recently, with an account of the latest method of one-piece airbag weaving.[24,25] Airbag technology is summarized in a recent Textile Institute publication.[26]

Both polyurethane foam and polypropylene foam manufacturers are developing grades of foam with optimum properties for absorption of impact energy. Eventually every surface in the car interior will incorporate some kind of energy-absorbing material, which will not only improve comfort and reduce noise levels, but also contribute to safety. In Europe legislation is in preparation for side-impact safety, and in the not too distant future, laws are likely to appear for protection to pedestrians in accidents up to 25 m.p.h. Softer car exteriors, possibly incorporating textiles may contribute to this new challenge. There has been progress in development of external airbags, which deploy on the bonnet for pedestrian protection.

7.4 Carpets

This was once considered a luxury item but is now an essential part of interior trim not only for the aesthetics and sensual comfort but also because of the part it plays in noise and vibration control. There are about 3.5–4.5 m^2 of carpet in each car, made by either tufting or needle-punching with considerable differences depending on where in the world the car is made.[27] In Western Europe approximately one-third of all cars have carpets tufted mainly from bulked continuous filament (BCF) nylon yarns. The rest, about two-thirds and gradually increasing is needle-punched, mainly from polyester but also from increasing amounts of polypropylene. About the same proportion of tufted and needle-punched carpets appear in cars made in Japan, and most of the yarn used in tufting is BCF nylon, with a very small amount of polypropylene. In the USA at present all car carpets are tufted mainly from BCF nylon. The remainder is staple-spun nylon and solution (spun)-dyed fibres are being increasingly used.

The poor compression resilience of polyester prevents it being used in tufted carpets. Recently needle-punched carpets have appeared in the USA and are expected to become more widely used. An increasing trend worldwide is to produce lighter carpets using finer gauge yarn for more covering power towards the lower weights of approximately 12 ounces/square yard for tufted and 450 g/m^2 for needle-punched or even lower. Tufted carpets are generally more resistant to wear and tear but needle-punched carpets have better mouldability. In addition needle-punched carpets have no tendency to exhibit 'grin through' unlike tufted carpets especially around convex curves.

Tufting is a relatively new process, many times faster than weaving, and tufted car carpets first appeared in the USA in the 1950s.[28] The tufts can either be cut or uncut looped pile, but the vast proportion of tufted car carpets are cut pile; uncut looped pile being used only for special effects. The most popular gauge of both cut pile and loop pile tufting is 0.1 inch. Needle-punching of car carpets is an even younger process than tufting and is an even more rapid and economical process. Needle-punching has been much refined in recent years and is now producing very attractive materials that are comparable in quality with tufted carpets. Tufted carpets are standard in up-market cars in Europe, e.g. Audi, BMW, Mercedes, Saab and some Rover cars. Tufting of automotive carpets is carried out on a polyester spun-bonded, non-woven material weighing between 110–120 g/m^2 called the primary backing. Both AKZO (with Colbond) and Freudenberg (with Lutradur) have developed special fabrics for this purpose, which also facilitate moulding to the shape of the car interior. Recently the weight of these fabrics has been reduced by using finer fibres but the stretchability has been increased to allow deeper draw moulding which is especially important for European and Japanese markets. American cars generally have less contoured floors. Both tufted and needle-punched carpets require about 70–100 g/m^2 of a binder coating, usually SBR or acrylic latex on the back to stabilize it and to lock in the fibres. Another layer of a suitable material is then applied to both types of carpet to confer good thermo-mouldable properties. This is important for process efficiency but also to produce a good fit to reduce vibration, and to maximize noise insulation.[29,30] Polyethylene powder is used on both tufted and needle-punched carpets for this purpose and about 250–600 g/m^2 are applied by powder scattering and infra-red heating. The correct thermal characteristics are critical, because no softening must occur at temperatures below 90 °C but softening should occur sharply, in the region of about 110–140 °C, which is the temperature at which moulding is carried out. An alternative to polyethylene powder, used mainly on needlefelt carpets is a layer of thermoformable fibres which is needled on to the back of the needle-punched carpet. These thermoformable fibres must also have the same thermal characteristics already mentioned. In older plants, the thermomouldable layer is a further much heavier coating of SBR latex filled with chalk, (calcium carbonate) or barytes (barium sulphate), a heavy material.

All carpet materials have to be selected for mouldability, good adhesion to the fibre and other substrates and for heat stability to withstand further processing in the car factory and also for durability during the life of the car.[31,32] After the application of the thermomouldable layer the carpet is thermomoulded to the shape of the car to which it is to be fitted. A good fit is essential for good acoustic control and for ease and efficiency in installation and it must be dimensionally stable under all conditions of temperature and humidity.[33,34]

Many cars now have a sound absorption barrier layer of barium sulphate-filled EVA/EPDM polymer, weighing approximately 2000–7000 g/m^2 which is laminated to the thermomouldable layer before thermoforming. The combination of a heavy layer against a flexible padding layer is beneficial to reducing noise inside the car. Up-market cars will also have an extra noise and vibration insulation layer between the carpet and the vehicle floor, see below.

Carpet manufacture is made more complicated by the holes and gaps required for cables and ducting and provision must also be made for the fitting of seats and control consoles. Certain areas of the carpet will have extra heat insulation pads for example the part at the front facing the engine. As well as being an essential item for comfort providing thermal and noise insulation and vibration damping, carpets now contribute directly to safety through the use of energy-absorbing backing foam. In a similar way to the headliner, the car carpet has become a complex module system in its own right.

In addition to fitted car carpets there is also a sizeable market for secondary carpet mats – known as 'thrown in' or 'option mats' totalling perhaps 4 million m^2 in Western Europe alone.

7.4.1 Noise control

Sound is propagated through the air and by vibration of the car body and there are three basic mechanisms for reducing it: by absorption, by damping and thirdly by isolation or insulation.[35] In general a thick piece of material will absorb more sound than a thinner piece of the same material. There are a number of layers of material and permutations of layers of materials used in noise and vibration damping, see Table 7.2. Density, air porosity and thickness of the material influence sound absorbency, but actual frequency of the sound waves is also relevant.[36] Damping can be obtained by putting soft materials next to a harder material such as the metal car-body structure. Efforts to isolate engine vibration and noise are made by special design of engine mounts and the car suspension to isolate it from the passenger compartment. Engineers are also constantly trying to improve the fit of doors and windows and to eliminate all the bangs, squeaks and rattles in cars.[37–43] Flock-covered parts, both plastic and textile are sometimes used for this purpose.[44,45]

Once only luxury cars had a noise insulation pad under the carpet but as in many cases this has become or is becoming a standard requirement.

Table 7.2 Automotive carpet structure

Main elements:
1. Decorative top layer of fibre
2. Thermoplastic material for thermomouldability
3. Acoustic and vibration damping layers

Layer	Materials used
Top decorative layer	Tufted BCF nylon or needle-punched polyester or polypropylene-back, latex coated with SBR or acrylic latex
Thermoforming layer	Polyethylene powder, meldable fibres, EVA or a further thick layer of compounded SBR latex
Acoustic layers	'Heavy layer' of EPDM, shoddy fibres or polyurethame foam

Luxury cars have more than one acoustic layer. Bitumen is also used in many cars as a further layer next to the metal.

Bitumen sheeting is widely used but this is now supplemented with resinated waste or shoddy fibre. These materials generally have to be fitted in small pieces, which is time consuming and produces an insulation performance which is inferior to that of a continuous layer. In some vehicles this insulation layer is formed directly on the back of the pre-formed carpet itself by back injection moulding using polyurethane foam.

A barrier film on the back of the carpet is necessary to prevent liquid foam from penetrating to the carpet surface during moulding.[43] This is considered a more satisfactory method giving more consistent results and the objective is to obtain maximum sound absorption with the lightest material possible. Various types and densities of foam and non-woven fabrics have been evaluated at different vibration frequencies.[36,46]

A method has been developed for adding barium sulphate filler to a polyurethane elastomer which is then froth-coated directly on to the back of the carpet. This produces a sound-insulating 'heavy-layer' in a reduced number of manufacturing steps and with much reduced fogging.[47] Recently developed foams by ICI (now Huntsman) allow the individual noise and vibration characteristics of a vehicle to be selectively damped by tailoring the foam properties to suit the particular vehicle. Large sections of floor covering can be precisely moulded to the shape of the vehicle's floorpan to enhance acoustic absorption as well as contributing to assembly efficiency.[48]

Engineers working in research departments in carpet manufactures, OEMs as well as university departments are applying much effort to reduce noise and vibration. Collins and Aikman have a test dummy in their

Michigan acoustic laboratory, called Oscar, which is equipped with specially designed ears to locate the origin of noises.[29] This laboratory is one of the most up-to-date in the world for the investigation and elimination of noise, vibration and harshness (NVH). Noise frequencies and levels are characteristic of each individual car model and the materials and specific designs have to be individually optimized.[35,38–40,43] The carpet, headliner and parcel shelf are probably the three major items by which interior noise can be controlled. However all the components in a car will influence noise levels, and it is difficult to separate individual contributions. The best tests are done on the car as a whole, on the road – where the ultimate tests will be carried out, by the customer. Noise contributes to driver fatigue, a major cause of accidents and reducing it is a valuable contribution to road safety.

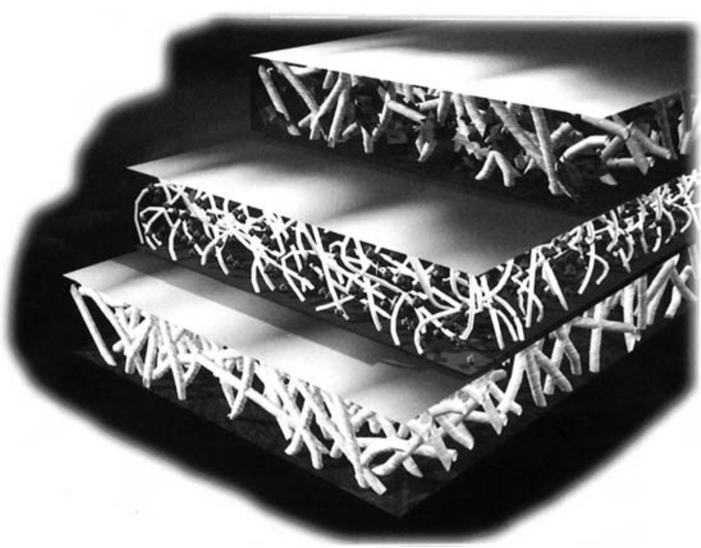
Road noise is now considered a form of environmental pollution. The EU and national governments are applying pressure to OEMs to reduce *external* car noise levels by 3 dB, from 74 to 71 dB, which means by a factor of 50% because noise is measured on a logarithmic scale.[49] Textiles are also contributing to overcome this problem, see the section on wheel-arch liners below.

7.5 Cabin air filters

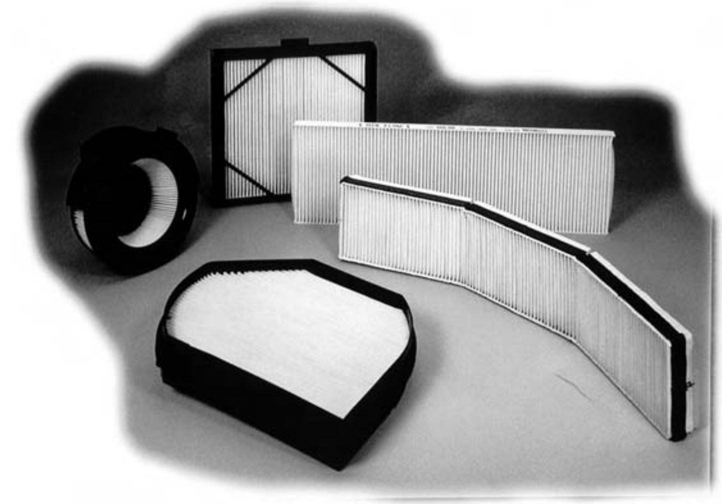
There are about a dozen different kinds of filter used in cars but only about half use textile materials.[50] Paper is used in many applications such as the oil filter and carburettor air filter, although non-wovens are used in some Japanese cars for the latter application. An important potential growth area is the cabin interior air filter. Once again this was once a luxury item which is becoming more and more a standard requirement as living standards improve and competition becomes more intense between the OEMs. Recent research has shown that the air quality inside a car can be several times poorer than the air quality outside, especially if the car is driven closely behind another vehicle. This is referred to as the 'tunnel effect', the consequence being the same as a car driven through a tunnel. The concentration of exhaust gases inside can be as high as six times or more the level of that on the outside. In addition to exhaust gases, car occupants are also exposed to windscreen-washer-fluid odour, agricultural odours of fertilizers and manure, industrial fumes, pollen, spores and even viruses and bacteria.[51]

Dust particles and pollen can cause allergic reactions and diesel fumes and aromatic hydrocarbons can be even more damaging to health. Particle size covers the range from 0.001 micron up to 100 microns. Particles in the region of between 2 and 5 microns originate mainly from combustion and industrial processes, i.e. man-made and comprise heavy metals, carbon and sulphur. Larger particles than this are generally naturally occurring substances including, sand, soil, pollen spores and bacteria. Large particles are deposited in the nose and upper respiratory passages and the particles that are smaller than 10 microns – the PM10s are mainly deposited in the lower respiratory tracts. Studies have shown that the vast majority of particles in the air are smaller than 1 micron, and if breathed in, can remain in the respiratory system for long periods of time. They are therefore potentially, the most damaging to human health. See also Chapter 8.

Cabin filters have been developed in response to consumer requests and have been fitted to up-market production cars for several years, notably in Europe. There are three basic ways in which the filters work. The first is by mechanically filtering out solid particles through fine pores in the nonwoven fabric. The second is by imparting an electrostatic charge to the fibre, which then attracts solid particles electrostatically. The third mechanism, is by the use of activated carbon which adsorbs gases and is therefore also capable of removing odours.[52–55] Activated carbon consists of very small and finely divided particles each with an internal pore structure which presents a very large surface area available for the adsorption of gases. To maximize the effect, activated carbon granules are arranged in the filter to present the maximum surface area and 200 g of the material in theory offers a total surface area of 200 000 m^2 available for gas adsorption. See Figs. 7.1. and 7.2.



7.1 Three layer nonwoven filter material. Airflow is from top to bottom; through the top prefilter, the middle Microfiber filter and through the bottom carrier. Photograph supplied by Freudenberg and reproduced with kind permission.

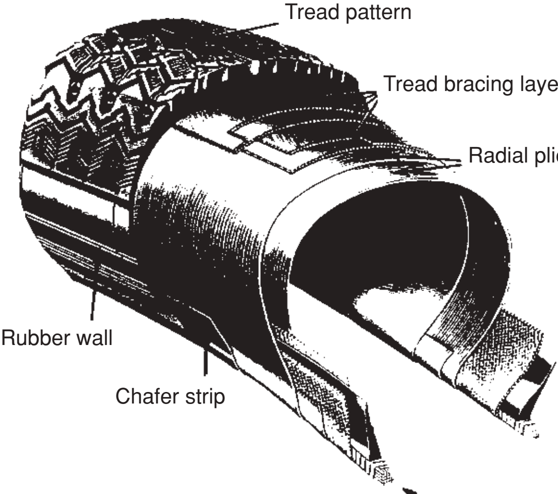


7.2 micronAir brand particle filters; Customer-specific models made with five manufacturing techniques. Photograph supplied by Freudenberg and reproduced with kind permission.

The latest advanced filters combine both mechanical filtering through polypropylene non-woven electret fabric with adsorption by activated carbon.[55] Filter fabric is arranged in a pleated form to provide maximum surface area with minimum airflow resistance. The adsorption and retention capacity of the filter for odours in a given airflow rate is a measure of the filter's performance. The non-woven filter fabric itself must be strong when wet, be odour-free, resistant to micro-organisms and resistant to extremes of temperature.[56–59] AlliedSignal recently announced a filter for both particles and odours, which uses a system that is based on microfibres and a special liquid absorber.[60]

The majority of new European cars are equipped with some kind of basic particulate filter whereas in the USA, at present they are only fitted to 10% of cars. The more advanced odour-removing combination-type filter, however, is gaining in popularity because the average person is more readily aware of odour removal than particulate removal. The first cabin filters were fitted in 1993 to luxury standard cars such as the BMW 5 and 7 series and Mercedes 'S' class. This situation has changed quite rapidly. The first high-volume production cars to have a combination air filter fitted as standard were, since 1999, the Volkswagen Golf and the Mercedes C and E class.

One of the main constraints, apart from added cost, is the accommodation of filters into the restricted space in the vehicle but they can be tailored to suit the space available. The filter should have minimum effect on



7.3 Textile components of a car tyre. Simple diagram showing the main textile components. From an illustration provided by the British Rubber Manufacturers' Association and reproduced with kind permission.

the air pressure being drawn into the car and should also have minimum influence on the efficiency of the fan, which has the important task of removing frost and condensation from windows. The filter should also retain its effectiveness for as long as possible, although it can be replaced with a new one during routine servicing. The particulate matter it removes from the air will eventually block a filter, and this will further reduce airflow. The actual life expectancy of the filter will depend on the levels of air pollution; in general present filters last between 15 000 to 40 000 km (i.e. 9500 to 28 000 miles) of use. Further improvements in performance, life-span and fan air pressure drop can be expected as more competitors enter this area. The present market leaders are Freudenberg with their micronAir brand product, which includes polyester, and 3M with their Filtrete brand range using polypropylene. 3M believe their fibrilated filter fibre, which is flat and rectangular in shape, provides a greater charge compared to the more conventional round electrets. A recent comprehensive review of all car filters is available.[59]

7.6 Battery separators

Every battery needs a separator of some description to mechanically separate the anode from the cathode and to prevent short circuits. The general battery classification is into two types; primary cells, which cannot be recharged and secondary cells such as the lead–acid cell which can be recharged.[61–63] Electric lead–acid batteries such as those used in motor cars consist of two plates, an anode (+) and a cathode (–) in dilute sulphuric acid. When discharging, chemical reactions take place, the anode is converted from lead peroxide to lead sulphate and the cathode from pure lead to lead sulphate. There are lead–acid batteries of different design depending on the vehicle in which they will be used. For example ordinary cars require a single high initial load to start the vehicle, for lighting and ignition (SLI), whereas vehicles such as milk floats and fork-lift trucks need a continuous discharge to actually move them. Each battery has a number of cells and the output is about 2 volts per cell. Thus for 12 volts there will be 6 cells. Lead sulphate particles build up on the battery plates and need to be retained, otherwise they would eventually cause a short circuit. This is achieved by a physical barrier or a separator.

Fibreglass was once used extensively, but in the search for more economical materials, polyester has been found to be suitable for this application, which requires stability to acid conditions. The material must allow the flow of electrolyte but prevent actual particles migrating, and in addition it must have some measure of vibration resistance. Actual plates in car batteries are quite small, requiring pieces of fabric about 15 cm × 15 cm but in fork lift trucks, golf carts, milk floats and other electric vehicles they can be 15 cm × 35 cm or much larger.

The Japanese market in 1998 was about 2 million m^2, which could increase to several times this figure if electric vehicles are produced in volume.[63] Tubular-woven polyester fabric is used for some secondary cells. To stabilize it and to help with fabrication the fabric is impregnated in a specialist acrylic resin, e.g. certain Primal grades from Rohm and Haas. An effective well-designed separator is essential for long battery life – 6 years is now a common requirement. With the concern for reduced atmospheric pollution, and the interest in alternative methods of powering vehicles, battery separators offer a potentially significant growth area. The state of California, requires by the year 2003 that 10% of all cars offered for sale must have zero emissions and electric vehicles are likely to have a role to play. Growth in the requirement for general automobile batteries to the year 2000, is believed to be about 5%, whereas that of batteries for electric-powered vehicles is forecast at 7%.[64]

7.7 Bonnet (hood) liners

These are generally made from a laminate material the main function of which is to absorb and dampen engine noise. The main constituent is generally phenolic-resinated waste shoddy fabric or fibreglass usually laminated on both sides with non-woven fabric. The covering side facing the engine needs to be resistant to fluids such as oil, fuel, windscreen-cleaning fluids and water and this can be improved by a fluorocarbon finish. The effectiveness of the sound absorption has to be balanced by increased weight – generally the thicker the liner – the better the noise insulation. Both polypropylene and polyester non-wovens are used in this application. The adhesives used for lamination have to be resistant to fluids and heat and they must be durable to last the life of the vehicle. Polyurethane foams, which have the advantage of lightness, are sometimes used in place of the shoddy material. More recently, bonnet liners are being designed entirely in polyester or entirely in polypropylene to facilitate recycling and to remove the fibreglass, a potential skin irritant. Spun-bonded non-wovens, such as Lutrador (Freudenberg), are well-suited because they allow deep-draw, well-defined moulding to the required shape.

7.8 Wheel-arch liners

These external components are a relatively new application for textiles but are becoming more important in the quest for road noise reduction and increased road safety. As well as significantly cutting down noise, they also reduce spray in wet conditions and protect the bodywork against stone impact and corrosion. Performance and properties are covered by DIN 661151 and DIN 61210.[65] Needle-punched polyester and polypropylene that is coated with specially formulated SBR latex have been found to be suitable material. They replace PVC and EPDM which are stiffer, harder, less flexible and heavier than the textile alternatives, and not as effective in reducing noise or spray. The textile is more effective because of its porous structure, which disperses water into smaller droplets and this helps to reduce road noise. In addition, the use of textile material in place of the heavier plastic reduces car weight by about 3 kg. Wheel-arch liners are also used inside the car to assist with insulation from road noise for the car occupants.

7.9 Hood material for convertibles

A variety of coated fabrics have been used for this application including rubberized cotton fabric and PVC-coated cotton, nylon and polyester. PVC is still used in some volume-production models but more up-market vehicles now use a triple-textile laminate with spun-dyed acrylic fibres in the top layer. This outer material has to be extremely well engineered to be resistant to UV and other sunlight radiation, rain, frost, ozone, micro-organisms, dirt and traffic fumes as well as car-wash chemicals for the life of the car. In addition it needs to be dimensionally stable under all weather conditions and have excellent abrasion resistance.[66] Soil resistance is achieved by application of a fluorocarbon. The market leader is Dolan 25, now being replaced with improved Dolan 65, both made from Acordis acrylic fibre.[67] Aesthetics are important as the vehicle top is very visible and its appearance must be integrated into the rest of the vehicle design.

Cotton is now unsuitable for any part of the convertible top because it will not pass tests for weathering and resistance to micro-organisms. Polyester twill-woven fabric is used for the inner surface of the triple laminate and the middle layer is rubber. The recently improved Dolan 65 now uses acrylic yarns both in the warp and weft of the top layer. Earlier versions of this product used acrylic only in the weft with polyester in the warp, but the polyester warp hydrolysed in subtropical locations of the world. At present only spun-dyed acrylic satisfies all the demanding tests; the latest UV stabilized polypropylene fibres were evaluated but certain processing problems could not be overcome.

The fabric is tested for weather resistance using a test such as DIN 53387 and also specially designed sagging tests at 75 °C with a weight hung on the end of the test strip of material. The percentage of permanent elongation after a 24 h test period is calculated from measurements before and after testing. These laboratory tests are correlated with outdoor exposure tests in the southern states of America. SAE tests for exterior materials include, J1960 JUN 89 (accelerated exposure using water-cooled xenon-arc), J1961 JUN 94 (accelerated exposure using Solar Fresnel-Reflective) and outdoor weathering test J1976 FEB 94.

7.10 Tyres

The modern tyre has its origins in the work of three pioneers, Goodyear who discovered vulcanization of rubber in the USA in 1839, RW Thompson, a Scottish engineer, who developed and patented the concept of the pneumatic tyre in 1845, and Dunlop, who in 1888 first used textiles, a canvas fabric, as rubber tyre reinforcement. Early tyres used woven fabric which was later replaced by a unidirectional arrangement of cords sometimes with a small number of weft threads across them.[68,69] The cords are formed by twisting yarns together to build up a strong cord in two or three separate operations. Twist direction is usually in the same direction for the first two operations and in the reverse direction for the final process. The car radial tyre contains about 4 to 7% of its total weight of textile material; cross-ply tyres contain much more, about 21%.[70] Radial tyres have a steel cord 'breaker' layer between the rubber and the textile ply for added resistance to shock. The force of local impacts, stones for example, are spread out over a wider area. Tyre production in the UK is quite constant at the present time at about 35 million units per year. Of this total, about 5 million tyres are for off-road vehicles and aircraft.[70]

Cotton was replaced by the first man-made fibre rayon but not until the problems of bonding the rubber to rayon were overcome. Cotton, composed of staple fibre with many fibre ends and having a rough surface, stuck quite well to rubber but a resorcinol–formaldehyde latex (RFL) bonding system was required to promote adhesion of the smoother rayon to rubber.[71] Improvements continued and eventually high tenacity rayon yarns were developed. When nylon became available during World War II, it was used first in aircraft tyres where toughness and light weight were the important parameters, but again the fibre–rubber bonding problem needed to be overcome, this time using a modified RFL system. Both nylon 6 and 66 were used but these fibres have the disadvantage of 'flatspotting' which is not generally acceptable for private cars and this has restricted their growth. Nylon however is used in some Japanese cars, which are sold in countries, which have poorer road surfaces than Europe or the USA. In addition nylon is used extensively on tyres for off-the-road vehicles such as tractors and other farm vehicles.

In the years after World War II, intense competition between rayon and nylon led to improvements with both fibres. Steel cords and polyester tyre cords, which appeared during the late 1950s and early 1960s, resulted in the decline of rayon in passenger-car tyres, especially in the USA, although significant amounts are still used in Europe. Some manufacturers still consider rayon to be the most satisfactory tyre cord because of its thermal stability.[72]

Much work needed to be done to develop an effective polyester–rubber bonding system. When this was accomplished polyester tyres became very successful in passenger cars but not for aircraft or heavy goods vehicles. The reason for this, is the poor dynamic performance of polyester at temperatures higher than that normally found in passenger cars, i.e. above 82 °C, the glass transition temperature of polyester. Thermal instability limitations of polyester can also give rise to problems in tyre manufacture, but despite this, polyester is the least expensive material for tyre cord, and so it is the most extensively used fibre throughout the world for car tyres. Steel cords are economical but have the disadvantages of high weight and possible moisture corrosion but they are used in radial tyres for trucks.

Tyre cord development continues with further improvements both in textile cords such as the introduction of high-tenacity, low-shrink polyester yarns and also in the continued development of fibre–rubber bonding techniques.[73–75] Aramids offer the highest strength-to-weight ratios coupled with high temperature resistance and are well suited to speciality cars and aircraft. Some high-performance car tyres and quality bicycle tyres are made using aramids but the limitation for high-volume production cars is cost. Low shrinkage properties are important because yarn movement when the tyre is subject to heat during the vulcanization process or during use, could lead to distortions and reduced performance and durability.

The usual reasons for tyre performance limitations is differing elastic properties between the rubber and the introduced fibre, which in turn give rise to poor fibre–rubber bonds, the build-up of heat and hence poor durability. DuPont have approached the fibre–rubber combination by a novel route by producing very intimate Kevlar short fibre/rubber dispersions which allow the speciality properties of Kevlar, i.e. high tensile strength, high modulus and thermal and flexural performance be transferred to the rubber. The result is a tyre with better resistance to tears and cuts, punctures and actual wear. So far the new technology has been successfully applied to bicycle and motorcycle tyres and is under test for cars and other vehicles.[76] The 'run flat' tyre is being perfected which should in theory make the spare wheel redundant with the benefits of savings in weight and more storage space. Of the existing textile materials used in commercial tyres, rayon has the highest thermal dimensional stability and it may be due for a new lease of life in run-flat tyres in which temperatures can reach 270 °C.[72,77]

In addition to cords, textiles are used in smaller quantities in holding together the bead assembly on the tyre rim. Bead wrap is generally nylon cord or light-weight woven or knitted nylon pre-treated with adhesive to stick to the rubber. Nylon fabric is also used as the chafer material, which protects the tyre during manufacture and helps maintain the shape during curing.

The disposal of old tyres is a serious environmental problem and mention is made of the issues associated with landfill in the next chapter. The Environmental Agency has made a detailed study of this and has published its findings and recommendations.[70] These include, the development of longer lasting tyres which promote energy efficiency, producing road surfaces and tyres which reduce noise pollution, and also by encouraging better care of tyres by more careful driving and less use of the car. Recommendations are also made for environmentally sustainable ways of recovering old tyres as a useful resource.

The frequency of rubber symposia, many featuring textile–rubber bonding provides some indication of the amount of research being conducted in this area. Tyre makers strive to further reduce rolling resistance, reduce weight, road noise and improve wet performance. One estimate states that a 35% reduction in rolling resistance of all tyres would save 5% of fuel consumed – equal to five billion litres of fuel in Germany alone.[78] A new all-steel cord tyre development recently announced developed by Goodyear using their new Ultra-Tensile-Steel reinforcement in a new process, termed 'Impact Technology', is reported to produce a tyre of better quality than all existing tyres.[72]

7.11 Hoses and belts – general considerations

The performance of these articles also relies very much on the bond strength between the textile and the rubber matrix. Development work continues to improve this using both chemical methods and also newer surface-treatment methods.[73–75] In a similar way to tyres many benefits have been made possible by the invention of high-performance fibres which continue to be improved. Both hoses and belts rely almost entirely on the textile component for actual physical strength and various fibres have been used, including cotton, rayon, glass, nylon and polyester.

Rayon loses strength when wet and the rest have certain other limitations. At present specialist polyester yarns are the most frequently used; aramids are used when extra performance is needed and cost can be justified.[79,80] General requirements are dimensional stability, moisture, oil, chemical and temperature resistance, strength and of course good adhesion to the rubber. Similar to tyres low shrinkage and heat stabilized yarns are essential to withstand temperatures of vulcanization and conditions of use. As in all transport applications, weight saving is important and in under-the-bonnet components, space saving is especially relevant. Hoses and belts are only small items but their high performance, without deterioration over several years in extremely demanding conditions is essential to the reliability of the vehicle.

The type of rubber used depends on the application and the conditions of use it will have to withstand. A summary of rubber types appears in Table 9.3 in Chapter 9 plus some comments on compounding. The types most used in automotive components are chloroprene (best known is Neoprene, (DuPont), which has good oil and heat resistance, acrylonitrile–butadiene (ABS) rubber, which is probably the best high volume rubber for oil resistance and butyl rubber, which has good strength-to-weight ratio and excellent heat and chemical resistance.

Compounding the various ingredients together is a highly specialized operation – there are many dozens of different recipes with a minimum of perhaps eight components – each one tailored for a different application and customer. The textile rubber composite needs to be resistant to the materials the hoses or belts come into contact with and also oxygen, moisture and all the various ingredients in the compound mix. These will include, chemical stabilizers, vulcanizing (cross-linking) agents and other additives – some of which themselves sometimes initiate premature breakdown. The chlorine in some chlorine-containing polymers can, with ageing, form hydrochloric acid, which is capable of degrading the textile.

Tests applied to belts and hoses include heat ageing, low-temperature resistance, weathering, fatigue and flex cracking, resistance to swelling in relevant liquids and rubber–textile adhesion determinations.[81,82] The latter property is assessed by ply-separation as detailed in BS 904 or ASTM D413. An account of belts and hoses is included in a recent review of textile progress.[83]

7.11.1 Hoses

A variety of different fabric manufacturing techniques are used; knitting, circular weaving, wrapping, and for high-pressure uses, filament spiralling and braiding. Cotton was first used but this has been replaced with synthetic fibres, which provide higher strength, more durable flex and abrasion resistance and better rot resistance. High-tenacity yarns allow weight reductions and less bulk. For the highest performance of heat and strength, aramid fibres such as Nomex and Kevlar (both DuPont) are used.

Automotive hose products include fuel, oil, radiator heaters, hydraulic brakes, power steering, automatic transmission and air conditioning pipes. Nylon is not generally used in hoses because of its high extensibility but this specific property is useful in the expanding part of power steering hoses. These items are only small but reliability is extremely important and testing to the highest standards is essential. The manufacturers have designed special test rigs, which simultaneously measure performance to high-pressure, ambient temperature, fluid temperature and vibration.

7.11.2 Belts

Again cotton was first used but was replaced as soon as synthetic fibre–rubber bonding difficulties were overcome, and now synthetic-fibre specialist high tenacity yarns are used in cord form. High tensile strength, excellent flex resistance, excellent shock resistance and low extensibility are amongst the requirements for a long belt life. The V-belt is shaped for maximum friction grip as well as high strength with compactness and is composed of cord made from HT yarn such as the Trevira 700 series and rubber, usually chloroprene, covered with a fabric/rubber jacket.

Textile-toothed belts have almost completely replaced chain drives in cars because they are quieter, weigh less, need no lubrication and allow a more compact design. Textile belts are more flexible and smaller pulleys can be used compared to chain drives. Testing of belts needs to be carried out thoroughly to simulate wear in the shortest possible time. This is no easy task because there are mechanical, chemical and physical factors to consider.

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8
Automotive textiles and the environment

8.1 Introduction

The car is a primary concern for environmentalists. It is high profile because of traffic fume pollution and the construction of roads from virgin countryside. There are in fact three main groups of environmental factors, which concern the car; manufacture, actual use, and problems regarding disposal. All three have significant effects on the environment and all concern textiles. The textile industry uses processes, which are potentially highly environmentally polluting, i.e. dyeing and finishing, lamination and other joining operations. As soon as the car is first driven from the showroom, it begins to emit polluting fumes and this continues throughout its working life. Efforts are being made to reduce this by catalytic converters and by other improvements. In addition the engine has been made more efficient so that it uses less fuel, and cars have become more aerodynamic and generally lighter in weight. Textile developments are contributing to the reduction of the weight of cars by the increased use of fibre composites, which replace heavier metal components. Recently approved EC legislation will require OEMs to be responsible for disposing of all scrap cars (end-of-life-cars or ELVs) by the year 2006, at no cost to the last owner. At least 85% of the material by weight of the car must be recycled with no more than 15% to go to landfill. By 2015, the figure will increase to 95 and 5% respectively. The metal components which make up about 75% of the weight of the car have always been recovered from old cars and recycled but the rest of the car is made up from many different classes of materials which, first need to be identified and then separated. These processes make disassembly time consuming and expensive, and therefore recycling of non-metallic components is generally uneconomical at present – but much is happening to change this, as will be discussed later.

Cars are now being designed from the beginning with disassembly in mind, and attempts are being made to use as few chemical types of plastic and types of fibre as possible to make recycling easier. In general, attempts are being made to apply to the motor industry the environmentalist watch words of 'reduce, reuse, recycle'. However, this frequently entails extra cost, and government action or the threat of government action has been necessary in many cases, and is likely to continue to be necessary to ensure that certain procedures are carried out. Attitudes are changing, however, and there have been some very significant voluntary actions by the industry as a whole and by certain OEMs as will be seen later in the chapter. Less than a decade ago sales personnel advised that being 'green' does not sell cars, but as time passes it is gradually being regarded as being a marketing tool. Companies now want to appear environmentally friendly and socially responsible. They are in agreement with the principle of 'sustainable development' which can be described as the objective of meeting the needs of the present without compromising the ability of future generations to meet their own needs. This term was first introduced in the Brundtland Report, '*Our Common Future*' in 1987, which was produced by a World Commission on Environment and Development. Both the EU and the UK government have published reports defining their interpretation and their strategies for achieving it.

Many industrial organizations now issue annual environmental reports and are ISO 14001-accredited or are working towards it. The general public world-wide is now aware of, and concerned about the vital environmental issues facing humanity as a whole. Evidence of this, is the existence of over 2600 environmental organizations in more than 200 countries of the world. The car is a symbol of affluence for both the developed and developing world and car ownership is steadily increasing, but rises in living standards in general produce more pollution as summarized by Meadows and his co-workers[1] in the equation; –

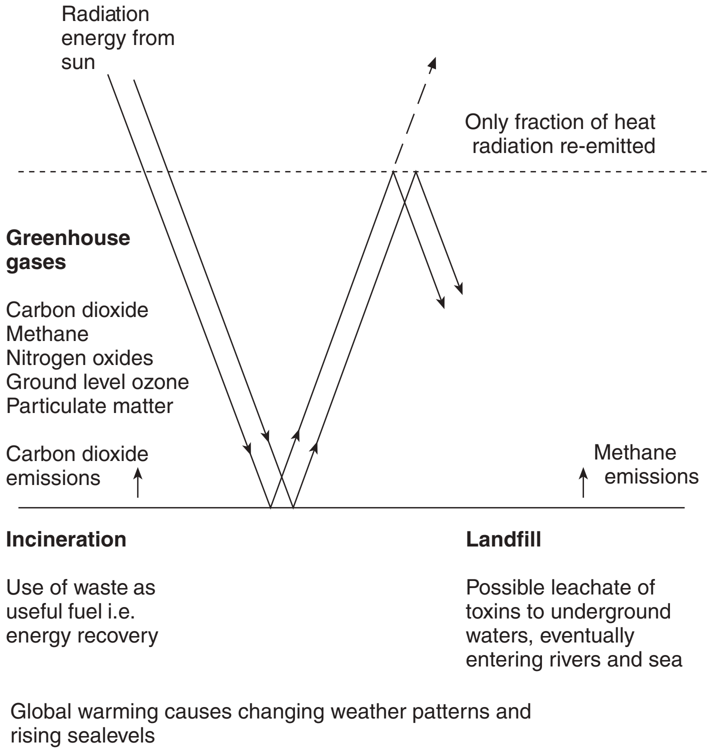
$$\text{Impact on environment} = \text{Population} \times \text{Affluence} \times \text{Technology.}$$

All three dependent factors are increasing and without drastic action an environmental disaster seems inevitable. However, much is being done by the EU, the United Nations and by governments of the world. This chapter discusses the issues and describes the various attempts which are being made to produce a more environmentally friendly car.

8.2 The greenhouse effect and global warming

Human life depends on the 'greenhouse effect', which is caused by the presence of a number of certain gases and water vapour in the atmosphere. The surface of the Earth would actually be about 30 °C lower than normal if they were absent. Small changes in their concentration cause small changes in the surface temperature of the Earth, and it is believed the whole ecology of the world could be changed by small variations. This is a very delicate balance because increases in surface temperature by only one degree C are thought likely to cause very significant changes in world climate and sea water levels.

The greenhouse effect happens because heat is retained by the Earth's atmosphere and surface, see Fig. 8.1. The atmosphere as a whole, including greenhouse gases, allows sunshine, made up of both short and longer wavelength radiation to pass through to heat the Earth's surface. The warm earth then radiates heat back, but this new radiation is at a longer wavelength, which cannot pass back outward through the greenhouse gases to outer space. Instead the greenhouse gases are heated up by this radiation energy, giving rise to global warming. The main greenhouse gases are carbon dioxide, methane, nitrous oxide, ozone and CFCs (fluorine compounds used in aerosol sprays and refrigeration). Particulate matter also contributes to global warming. Apart from CFCs which have been phased out in the developed world, all these substances are associated with use of the car, and also disposal of the car.



8.1 The 'greenhouse effect'.

The amount of carbon dioxide in the atmosphere is increasing at the rate of about 0.5% every year and motor vehicles are responsible for 15% of the world's total carbon dioxide emissions. Research shows that since the middle of the last century increased amounts of greenhouse gases have raised the average global temperature by about 0.5 °C. If greenhouse gas levels continue to increase at the rate expected, a further warming of about 1.5 °C within the next 40 years could be caused[2] with serious effects on global climate. Global warming, in reality excess global warming, is therefore the concern of every nation on the Earth. This was the main subject for the meetings of world leaders from 160 countries at Rio de Janeiro in 1992. At the second meeting at Kyoto in 1997 the general target was set for developed nations to reduce their greenhouse gas emissions by 5% below 1990 levels by the years 2008–2012.[3] Within the same time frame the EU was committed to reduce emissions of six greenhouse gases by 8%, the UK agreed to reduce its emissions by 12.5%. This has special importance for the auto industry because car populations are predicted to increase substantially in the next decade. Although carbon dioxide is the chief greenhouse gas, methane, nitrous oxide and ozone in fact have a far greater effect than would be expected from their relatively low concentration.[4]

The same 'greenhouse effect' is the reason for the very hot temperatures inside cars in sunny weather. In this case the window glass acts as the 'greenhouse' increasing the temperature of the car interior.

8.3 Environmental legislation

8.3.1 Introduction

United Kingdom environmental legislation relates to air, water, land and noise pollution – although the latter does not directly concern this book. The earliest environmental laws are believed to have been passed during the thirteenth century controlling the burning of coal. However, times change and accepted standards become more demanding with the increase in the quality of life. Environmental regulations have therefore become stricter and more wide ranging to meet new circumstances. In addition to UK law there are now EU environmental laws in place. EU legislation take the form of directives and regulations. Directives are guidelines to be used by individual countries to form their own laws, whereas regulations are themselves legislative acts which apply across the EU without further action by individual countries. The EU in 1973 (then called the EEC) started the mechanism for programmes of action on the environment to reduce pollution and nuisances, to tackle environmental problems caused by depletion of natural resources, to promote awareness of environmental problems and education and also to improve the natural and urban environment. Since this date the EU has been one of the leaders in the world community in protecting the environment. The EU publish guidelines for air quality in Europe, based on World Health Organization information.

There are also United Nations environmental initiatives, through their Environmental Programme (UNEP – founded 1973), to which the UK and other EU countries have agreed. These include the Montreal Protocol in 1987 to protect the ozone layer and the decisions taken at the 'earth summits' at Rio de Janeiro and Kyoto on carbon dioxide emissions and global warming. The UN was also instrumental in the Convention in long-range transboundary air pollution adopted in Geneva during 1979 which came into force in 1983 to reduce transboundary air pollution over Europe and North America. The main concern at the time was acid rain over Scandinavia, but the Convention now also targets other pollutants including heavy metals and volatile organic compounds (VOCs).

In addition to EU and UN initiatives, there have been, since 1984, meetings of countries which border the North Sea to discuss steps to reduce the build-up of toxic chemicals and other pollutants in this area.[5] Measures agreed at the Third North Sea Conference, to cut levels of a number of specific chemicals and to treat sewage more effectively before discharge became legally binding. Switzerland, which has industries along the Rhine which flows into the North Sea, attended this conference.

8.3.2 United Kingdom laws

In recent times a succession of new laws has been implemented which update, but not always completely replace earlier ones. Thus a process may be governed by a series of laws applying to different aspects. During the 1970s and 1980s there was a sharp increase in public awareness of environmental concerns and this has been reflected in increasingly tight legislation. The 1974 Control of Pollution Act was one of the most important laws passed in this area although key aspects covering effluent discharges only came into force during 1985.

8.3.2.1 Water Act 1989; Water Acts 1991

The National Rivers Authority (NRA) was created by the 1989 Water Act to take over the regulatory duties of the individual water companies which were then privatised. This new body tightened up on existing regulations and added further restrictions and set up mechanisms to monitor and control effluent discharges into inland surface waters, estuaries, coastal waters and also underground waters. Clearly defined and absolute limits were set for pollutants together with other actions to implement their new regulations including the requirement of a named manager responsible for effluent control in each organisation.[6] Much of the 1989 Act was re-enacted by the Water Resources Act and the Water Industry Act which were passed together with three other Water Acts in 1991 with the purpose of consolidating all the previous legislation involving water. The Water Acts formalized the principle of 'the polluter pays', which, in fact, was a condition of the Treaty of Rome but was first mentioned at a UN conference on the Human Environment in Stockholm in 1972. The NRA has also implemented European laws and the decisions of the North Sea conferences which called for reductions in discharges of a large number of specified chemicals which included, cadmium, mercury, lead, chloro-organics and some textile chemicals.

8.3.2.2 Environmental Protection Act

The Environmental Protection Act (EPA) was placed on the Statute Book during November 1990. This act set up an industrial pollution control system which included 'Integrated Pollution Control' (IPC) for the 5000 most potentially polluting industrial factories. The act applied to all major solid, liquid and gaseous emissions to land, waters and air. A timetable for gradual implementation was drawn up which began on 1 April 1992 with the fuel and power industries and progressed through to November 1995 when it was extended to all other industries which included textiles. Her Majesty's Inspectorate of Pollution (HMIP) ran IPC and all existing operators had to register and were generally given between 3 to 8 years to bring their plant up to the new required standards or face closure. After January 1991 all new processes prescribed for IPC had to register immediately for authorization. This applied also to significantly modified processes.

Air Pollution Control (APC) also became law within the 1990 EPA act to control smaller scale polluters which were to be regulated by local authorities. Industries such as textile finishing, coating and lamination and solvent-joining operations generally came under this category. Thus the EPA was implemented by two mechanisms; IPC controlled by HMIP for large scale polluters which had national implications (so-called Part A), and APC for smaller polluters regulated by local authorities so any relevant local factors could be taken into consideration (so-called Part B). Both systems applied the same regulations and used the same guidance notes.

8.3.2.3 BATNEEC

Applicants for authorization for a process had to be able to show that attempts had been made to prevent or minimize emissions or to render them harmless using the 'best available techniques which do not entail excessive cost' (BATNEEC). These regulations applied to both Part A and

Part B processes and to all aspects of the operation including design, staff training and qualifications, operating procedures and emission levels. The interpretation of BATNEEC however needs careful consideration.[7] Each word is open to qualification and definition depending on individual circumstances and merits. If the cost of the best available technique is considered to outweigh the environmental benefit this will be taken into account. HMIP has drawn up technical notes for the Part A processes and the Department of the Environment and Local Authority concerned drew up the notes for the Part B processes. These notes include abatement technologies, monitoring techniques, storage, handling aspects and emission controls.

8.3.2.4 The environmental agencies

The 1995 Environmental Act established the Environmental Agency in England and Wales (EA) and the Scottish Environmental Protection Agency in Scotland (SEPA). From April 1996 the new agencies were made responsible for waste regulation and control of water pollution by combining the activities of Her Majesty's Inspectorate of Pollution, the National Rivers Authority, some agencies of the Department of the Environment and the local authorities' waste regulation authorities (WRAs) which were responsible for regulating the handling and disposal of waste. The objective of this reorganization into a single agency was to simplify matters for industry and to produce more effective control. The new Environmental Agency is responsible for air and water monitoring and advises the government on environmental standards and the means necessary to ensure that they are met. However some responsibility for air pollution control remains with local authorities. Under the Air Quality Regulations of 1997, they have a duty to manage air quality in their own areas which includes monitoring, modelling and establishment of emissions data bases.[8]

8.3.3 European legislation

The EU since the early 1970s when it first adopted a formal environmental policy has passed well over 200 laws and further impetus was applied by the 1987 Single European Act. This demands that full account of the environment and of the principle of sustainable growth is taken into account when proposals in all areas of Community policy are put forward for legislation. A European environmental Agency has been set up in Copenhagen to provide independent, reliable, objective and comparative information on the state of Europe's environment. This unit will publish periodic reports on the state of the environment and is examining a range of issues including air quality and nature conservation. The agency is unusual for an EU institution because it includes some non-member countries such as Norway and Switzerland.

8.3.3.1 European IPPC

The European Integrated Pollution Prevention and Control Directive (IPPC), based on Part 1 of the UK Environmental Protection Act 1990, concerns major industrial operators who are to be licensed in an integrated way to control emissions to the air and water and to manage waste to protect the environment as a whole. In addition IPPC is also concerned with the use and nature of raw materials including water, energy efficiency, prevention of accidents, low waste technology, noise and also restoration of a factory site to a satisfactory condition when production ceases. The overall concept is to make industry aware of the process as a whole and to adopt clean technology throughout. This EC Directive of 1996 will apply to all new installations within the European Union by October 1999 and to all existing installations by October 2007. It is broader in scope than IPC, and in the UK by the year 2007, there are expected to be 5000 major sites which will be affected – some of which fell outside the scope of the EPA.[9] The conditions of licensing will ensure that there will be no breach of EU environmental quality standards or laws and that high standards of environmental protection will be applied to protect the environment as a whole using the best available techniques. The monitoring will need to be done by an independent test laboratory to CEN Standard 45001.

8.3.3.2 Air quality

Deteriorating urban air quality is one of Europe's two major environmental problems (the other is agriculture) and further Directives from Brussels are expected. One expected to be in place by the year 2000 seeks to cut emissions of petrol-engined vehicles by up to 40% and halve the emissions of diesel engines.[10] There are also plans to reduce sulphur content of fuels and other measures aimed at control of car exhaust emissions.

The European parliament is also processing a directive by which member states will be required to have national reduction plans for volatile organic compounds (VOC). The objective is to reduce VOC emissions by 66.6% when compared with 1990 levels. This measure is likely to affect those factories which use solvent-based adhesives on a large scale. There have however been very significant contributions to clean air by voluntary actions, which have also produced cost savings. An example is the reduction of VOCs from paint spraying by careful management and use of new technology at Vauxhall's Ellesmere Port factory, which has also cut their electricity bill by 6%. Another example is Fords at Halewood who have reduced VOC emission by 40% and saved £60 000 on chemicals and waste disposal in the process.[11]

In the UK, air quality in the general public environment is monitored for the main pollutant gases, lead and particulate matter, PM 10 at various urban sites. This is co-ordinated by the National Environmental Technology Centre under EU regulations and reports are available on Freephone 0800 556677 (in the UK), on levels of nitrogen dioxide, sulphur dioxide, ozone, benzene, 1.3 butadiene, carbon monoxide and also particulate matter. Under the Environmental Act 1995, air quality standards were set in the National Air Quality Strategy and local authorities will be responsible for ensuring that the levels set are not exceeded in their area after the year 2005.

8.3.3.3 Landfill

In the UK at present about 25% by weight of the car goes to landfill with about 75%, mainly metal being recycled. Proposed European Directive DGX1 (Environment) will require by 2005, no more than 15% to go to landfill. This will decrease to 5% by the year 2015, with at least 85% being recycled. It is proposed that 10% may be incinerated with energy recovery. A European Landfill Directive, close to becoming law will prohibit disposal of whole tyres by landfill in 2002 and shredded tyres in 2005.[12] Every year some 350 000 to 400 000 tonnes of scrap tyres must be disposed of. Landfill is generally recognized as the least attractive option for a number of reasons. There are the risks of toxic chemicals entering watercourses and the formation of methane, a greenhouse gas with the added possibilities of explosions and uncontrollable fires. EU 1998 landfill directives will reduce the amount of waste disposed of in this way. In the UK, using 1995 levels as the baseline, biodegradable waste must be reduced to 75% by 2010, to 50% by 2013 and to 35% by 2020.[13] Landfill charges are increasing in many countries of the EU. In the UK at present, waste classed as 'inactive', e.g. bricks, concrete or glass is charged at £2 per tonne, while all other waste that decays is charged at £7 per tonne. All landfill operators in the UK must now be licensed by the Customs and Excise.

8.3.4 United States legislation

The situation in the USA has followed a generally similar pattern to the UK with much environmental legislative activity and public concern from about the 1970s onward.[14,15] Major acts and amendments have included, environmental protection acts of 1970, 1980 and 1995, the Clean Air Acts of 1977 and 1990, Pollution Prevention Act of 1990 and Clean Water Act of

1987. There has also been special emphasis on control of insecticides, fungicides and rodenticides with an act passed in 1988. Public concern has also been influenced by international scale disasters such as Bhopal, Chernobyl and the Exxon Valdez oil spillage.

8.4 The effects of pollutants

8.4.1 Air pollution (exhaust fumes)

Air pollution is caused by harmful gases or vapours and solid particulate matter. There are many air polluting gases which are harmful to human, animal and plant life but the main ones are; oxides of sulphur, carbon monoxide, hydrocarbons and oxides of nitrogen.[16–18] The last three are present in significant concentrations in car exhaust fumes. Sulphur additives along with lead additives are being phased out of petrol and diesel in the UK and in other developed nations of the world. Particulate matter is also present in car exhaust fumes, especially those with diesel engines. Since the beginning of 1993 all new cars within the EU have had to comply with strict regulations on emissions. The catalytic converter has reduced pollution but is not yet a standard item on every single car. Oxides of sulphur, produced mainly from industrial burning of fossil fuels gives rise to acid rain which is harmful to human health and also damaging to agricultural crops, vegetation and materials including buildings. Oxides of nitrogen contribute to acid rain and produce adverse physiological conditions including eye and throat irritation if present in high concentration. Carbon monoxide is toxic to human and animal life because it combines with haemoglobin in the blood resulting in less oxygen being carried to body organs, heart patients being especially vulnerable. Hydrocarbons and oxides of nitrogen are the main constituents of traffic smog and under the action of sunlight they produce ozone, which is an eye and throat irritant. Their ability to create ozone is measured by their photochemical ozone creation potential (POCD). This ozone should not be confused with the UV filtering ozone layer, which is several miles above the earth's surface. One of the hydrocarbons present in exhaust car gases is benzene, which is a carcinogen and is believed to contribute to anaemia. In addition all combustion processes involving organic compounds produce carbon dioxide, the chief greenhouse gas.

8.4.2 Particulate matter

Particulate matter comprises many different substances, although it is mainly soot (carbon). It is present in a wide range of particle size but the most harmful to human health are the particles, smaller than 10 microns in diameter.[19,20] These particles do not settle rapidly on the ground as dust but are present for long periods in the air and are therefore more available for breathing into the human body. The American Environmental Protection Agency classified these particles as PM10s (particle matter less than 10 microns), and PM10 pollution is the total weight in microgrammes of all particle matter of 10 microns in diameter or less contained in one cubic metre of air. In the USA the legal limit is 50 µg of PM10 per cubic metre of air as an average in a year.[19] Many cities of the world have peak PM10 values of 100 to 200. Particle size is important because particles larger than 10 microns usually get no further than the nose or throat. Particles smaller than 5 microns can enter the bronchial tubes at the top of the lungs but the smallest, 2.5 microns and less can penetrate into the deepest, (alveolar) lung tissue where gas exchange occurs between the air and blood. If soluble the particle matter enters the blood stream, if not particles can remain in place for months or years. Particle matter is believed to be the cause of bronchitis, asthma, other chest and breathing conditions and contributing to lung cancer. In the UK motor vehicles are responsible for 26% of PM10 particulate matter.[21]

8.4.3 Land and water

Pollution of waters by the textile automotive industry is mainly caused by manufacturing processes such as dyeing and finishing. Toxic liquors will harm marine life and could be harmful to humans on beaches. Pollutants are broken down chemically and biologically in the water, but both mechanisms require action by the dissolved oxygen in the water. This reduces the amount of dissolved oxygen in the water available for survival of fish and other marine life. Measures of these effects are the oxygen demand indices, BOD – biological oxygen demand and COD – carbon oxygen demand.

Disposal of industrial waste by landfill is one of the least attractive options because of the potential problems, not to mention the appearance of such sites. Decay of organic substances can result in the formation of methane gas which not only carries the risk of explosion, but also contributes to global warming. In addition toxic materials and heavy metals may at some time in the future pollute underground waters which may in turn contaminate rivers and even drinking waters. Heavy metals such as lead and mercury accumulate in the body until present in sufficient quantity to act as poisons. Lead is believed to cause damage to the brain and to the central nervous system, mercury also affects the central nervous system, whilst cadmium is believed to produce bone conditions.[22,23]

8.5 Manufacturing concerns

In common with most major industries, automotive and textile producers take environmental and health and safety issues very seriously. Environmental policies and environmental management systems have been established by all major manufacturers. BS 7750 issued in 1992 was designed to enable industry to establish effective environmental management systems for sound environmental performance, for participation in environmental auditing procedures and for management reviews. This standard had links with the quality management standard systems BS 5750 and was also consistent with the then draft EC regulation to set up voluntary schemes for environmental management, which became known as the Environmental Management Audit Scheme (EMAS). Four years later the first of the ISO 14000 series were published by the Swiss based International Organization for Standardization, which draws from 111 countries. ISO 14000 is a group of voluntary international standards, which have the objective of providing consistent and effective environmental management system for all operational procedures. ISO 4001 is the first of some 20 separate standards, which cover all issues from environmental auditing to the assessment of life cycles of products. ISO 4001 requires identification of environmental aspects, policy and objectives and a commitment to comply with all relevant legislation and regulations.[24,25]

8.5.1 Wet processing

Textile processes attempt to use the minimum amount of water for economic as well as for environmental considerations. The textile manufacturing industry is potentially environmentally polluting in two ways; discharge of effluent from wet processing and air emissions from stentering, finishing, fabric coating and lamination. Both are now very carefully controlled by the environmental pollution laws which have become progressively stricter in recent years; informative articles have appeared in trade journals.[6,26–29] Manufacturers may not discharge trade effluent into a public sewer without authorization from the local water authority. The application form for permission should include details of the effluent, chemicals, suspended solid matter, biological content etc. and information on the amount to be discharged in a day including the peak rate of discharge. In April 1989 a list of 23 chemicals which were to be subject to stricter control was announced by the government, the so called 'red list'. These chemicals were already on the EC 'black list' and are now subject to control under BATNEEC to minimize inputs into the environment. The 'red' list includes mercury and its compounds and cadmium and its compounds. Discharge levels are also subject to agreements reached in North Sea Conferences, especially the

Third in 1990 and the Fourth in 1995 at which there were further commitments to reductions.

The environmental effects of textile chemicals have come under scrutiny and certain chemical types have had to be replaced with more environmentally friendly ones. Certain anionic sulphonates with branched molecular chains which are not biodegradable are being replaced by straight chain types which can be broken down by bacteria in the effluent plant. Also certain phosphate chemicals which support algae growth in rivers and waters are being phased out. The algae 'blooms' are harmful to both plant and marine life by blocking out sunlight and reducing the oxygen content of the water. The chemical manufacturers have been very active and can supply much useful information. Discharge of coloured dyeliquors to sewers was once one of the most common infringements but now this seldom happens. There are a whole variety of ways of removing colour from effluent including use of membranes, activated carbon, inorganic adsorbers, ozone, coagulation/flocculation and the latest biological methods.[30–35] All work reasonably well, the main limiting factors being the speed of colour removal and capital cost, but some of the colour-removal processes themselves present disposal problems, i.e. membranes. Any damage to the environment caused by harmful discharges must be made good and the bill sent to the offender under the 'polluter pays' principle.

There are also restrictions on pH and temperature of effluent discharges which mean that provision must be made for alkali-dyeing techniques and dropping the high-temperature dyebaths to minimize oligomer in polyester dyeing. The rate of discharge and peak disposal rates must be notified to the local authority. The discharge of prescribed substances such as mercury and its compounds, cadmium and its compounds, and certain organic compounds is very severely restricted. Consent levels are agreed with the local water company under conditions set by the Environment Agency who also set monitoring levels procedures. Process Guidance notes (PG series) are available from the DETR through HMSO.

Lubricant content of loomstate or unfinished fabrics can sometimes be up to 2% by weight and much of this 'oil' is removed during scouring and stentering. Most fabric however is now scoured and spent liquors should be treated before discharge to drains, with pH, temperature and solid content being the usual factors requiring attention. All stenter fumes should be abated before discharge to atmosphere and the emissions should be monitored regularly in accordance with standards arranged with the Environmental Agency. Coatings applied to automotive fabrics are now invariably water-based and the material driven off during processing is mainly water but there may be organic chemicals, which have to be removed before the emissions are released to atmosphere. Guidance Notes relating to air quality (AQ series) have been prepared by the DETR and are available from HMSO.

8.5.2 Lamination and joining

Joining methods using solvent-based adhesive spray application methods and flame lamination are potentially highly polluting but are now very carefully controlled.[36,37] Many solvent-based adhesives have been replaced and continue to be replaced with hot-melt, high solids content and water-based varieties. However joining with solvent-based adhesives is still widespread. In the fabric-coating industry, water-based resins are used whenever possible but in some cases it is proving difficult at present to obtain the high standards of performance and durability normally achieved with solvent-based types. However, as stated above, solvent use is to be subject to closer restrictions, and targets have been set by the EC to reduce VOC emissions by 66% compared to 1990 levels with a compliance date of 2007.

Flame lamination fumes are monitored and must be treated by very effective methods, if necessary by the carbon adsorption techniques. Under the Environment Protection Act 1990 and the Environment Protection (Prescribed Processes and Substances) Regulations 1991 Di-isocyanate Processes, operators of potentially polluting industrial plant must be registered with the Environmental Agency before beginning production and must regularly monitor levels of potentially harmful substances. Guidance notes for operators are available from government book-shops, the relevant pamphlet for flame laminators is IPR6/5, entitled 'Toluene di-isocyanate use and flame bonding of polyurethanes'.

8.5.3 Health and safety aspects

8.5.3.1 Control of hazardous substances

In addition of course, all chemicals and materials used in the textile and automotive industries are subject to the Control of Substances Hazardous to Health regulations (COSHH) of 1994 (which replaced the original 1988 regulations) and March 1999, which cover, all aspects of purchase, handling, transportation, storage, use and disposal. The most important issue is that an employer cannot carry out any activity, which exposes employees to any hazardous substance unless a 'suitable and sufficient' assessment has first been made. The assessment must be reviewed regularly and whenever any significant modification to the process has been made. Hazardous material may include gases, vapours, liquids, fumes, dusts, solids or micro-organisms and when stored or transported are also subject to the Classification, Packaging and Labelling of Dangerous Substances Regulations of 1984. Guidance notes on safe handling, maximum exposure limits, occupational exposure limits and monitoring strategies, are regularly updated and are available from the Health and Safety Executive.

Manufacturers and suppliers must supply documented information on chemicals, adhesives and other raw materials in material safety data sheets. These documents contain information on chemical composition, physical and chemical properties, toxicological and ecological aspects, potential hazards with first aid measures, storage and transport, protective clothing and other controls necessary for safe handling and disposal. They should conform in format and content to EC Directive 91/155/EEC. EU regulations have generally tightened control of potentially harmful chemicals.[38]

8.5.3.2 Hazardous material content

Some customers are now concerned with the presence of potentially toxic chemicals in car interior trim components and an increasing number now require information on this. Hazardous material assessment forms are issued which list chemicals such as lead, nickel, cadmium, mercury, certain organic chemicals including bromine, etc. and the usage in the manufacturing process or concentration, in parts per million in the finished article must be declared. There are halogen and phosphorus flame-retardant chemicals in some flame-retardant qualities of both fabric and polyurethane foam. Although the risk to health from this source is likely to be quite low compared with similar chemicals in some apparel or even domestic furniture, consumer concern must be taken seriously. Considerable effort has been made by the chemical industry to replace these materials but so far with limited success. Higher concentrations of alternative chemicals are required to produce the same performance. However, the situation is not yet clearly resolved especially because bromine compounds have been found in the marine environment and in mammals.[39,40] Some researchers however believe that the benefits of flame retardants outweigh the risks to human health and the environment.[41–43]

8.5.3.3 PVC

The use of PVC has been questioned by some environmentalists and pressure groups, especially because of the possible formation of dioxin chemicals during its manufacture and eventual disposal.[44] Certain OEMs, notably BMW are reducing or have discontinued the use of PVC in cars, although others still use significant amounts. Amendments to draft proposals to an ELV EU Directive which would have reduced or phased out the use of PVC in EU-built cars were defeated in the European Parliament.[45]

8.5.3.4 Eco-labelling

In a strict interpretation of the term, ecolabels are applied to consumer goods as an indication that the product has been manufactured under environmentally friendly conditions, from environmentally friendly materials and will not pose any threat to human health or to the environment during its useful life nor at disposal. This process is a life-cycle analysis, also called a 'cradle to grave' approach but in practice is almost open-ended for many products and at best is extremely costly and time consuming to carry out. However this has been the basis of the EU ecolabel, which started with only a limited number of products including T-shirts and bedlinen. There have been recommendations for simpler procedures, which concentrate on the more important characteristics of products. There are several ecolabels in Europe such as the 'Blue Angel' in Germany and 'White Swan' in Scandinavian countries and in the USA there is the 'Green Seal'. Some of these labels are based on environmental audits of the manufacturing process alone such as energy efficiency. Others are based on assessments of the content of hazardous material.[46–48] Such a label is the Oko (or Oeko)-Tex Label run by the International Association for Research and Testing in the Field of Textile Ecology, which includes the Hohenstein Institute in Germany and BTTG in England.[49] To obtain an Oko-label, textile products are analysed for content of a range of potentially hazardous chemicals such as cadmium and mercury and a label given if they are absent or below defined levels. Another example is the Toxproof mark offered by TUV Rheinland, Cologne, which is issued to textile goods only after they have been tested to TUV criteria which includes heavy metals, chlorinated phenols etc. Eco-labelling is believed to encourage competition for environmental innovation but as yet there seem to have been few efforts to apply them to the automotive industry. It has been suggested that they be applied to public transport!

8.6 Sustainable development

8.6.1 Recycling of interior trim

Throughout Europe there are about 12 million ELVs disposed of every year and this is increasing at the rate of about 3% per year. The metal parts are recycled but the remainder, about 25% by weight of tyres, glass and an assortment of plastics, textiles and other materials loosely termed 'shredder waste' from automobile shredder waste, ASR (sometimes called 'crusher' waste – ACR), mostly goes to landfill at present. Car seats and other interior items are included in this ASR posing serious challenges for the industry which will become more pressing as the deadlines for reduced landfill approach. OEMs are supporting schemes to identify and sort scrap material. Most of the major OEMs are also making efforts to increase the recycled material content of their cars and certain OEMs are making recycling a key design consideration, specifying that parts supplied must be made from a certain percentage of post-consumer recycled material.[50–52] From press reports, Fords appear to be especially energetic in this exercise and are putting pressure on their suppliers. Eventually Fords want to attain 90% vehicle recyclability (by weight), whereas others such as Daimler Chrysler want to do even better – 95% by the year 2005.[53] The EU legislation mentioned earlier, will require a system of collection – at no cost to the last owner, and disassembly to be created for re-use, recovery and recycling at the end of the vehicle's life. An amendment stated 'producers must meet all, or a significant part of the costs'. OEMs hope that this leaves some room for negotiation as to actually who, in the industry will pay. A previous draft stated that the responsibility will rest with the automotive sector's 'economic operators', which was interpreted as every commercial organization involved with vehicles and not only the OEM. The cost of course, will ultimately be passed on to the consumer. Needless to say, the European car industry considers these measures unreasonable because the car is already 75% recycled by weight and actual waste from cars, the industry claims, represents only 0.2% of all European industrial waste.[54] In addition since 1997 there have been voluntary agreements within the industry to improve the car's environmental impact (see below). However, the EU considers ELVs a priority and these measures are very likely to affect the textile industry eventually because fabric and fabric laminates are major interior components of motor vehicles. The passing of the directive which will have serious financial implications for OEMs was by pressure from the automotive industry, especially in Germany.[55–57] Automotive industry spokesmen have claimed that the new law is 'too heavy a burden' and that in practice, it encourages the production of heavy cars using more metal – if the ELV directive had already been passed, the 3 litre car could not have been developed. The 3 litre car uses three litres of petrol to cover 100 kilometres i.e. 92 m.p.g. and contains a high proportion of weight saving plastic material. Recycling analyses of automotive plastic and textiles have been carried out.[58–60]

8.6.2 Fabric recycling

The car seat laminate is generally made up from polyester face fabric, polyurethane foam and a scrim fabric which is either nylon or polyester. These chemically dissimilar materials are not easily separated and therefore cannot be easily recycled. The use of polyester scrim reduces the number of chemical types to two but even this presents a problem. Chemical hydrolysis can be used to break down the three polymers into simpler chemicals which can be used as fresh raw materials, but at present this is not commercially feasible,[59] although much work has been carried out and reported,[61–70] several different types of non-woven and knitted fabric have been evaluated as substitutes for laminate polyurethane foam including the 'spacer fabric', Kunit, Multinit and wool/polyester blended fleece made from recycled garment waste. Some are being used commercially in German-made cars. These foam substitutes do not need a scrim backing and those in polyester together with a polyester face fabric produce a seat cover laminate all in one polymer type.

Some polyester fibre manufacturers, Hoechst and EMS have demonstrated the possibility of running recycled polyester face fabric into non-woven material. Shredded face fabric is mixed with 30% of virgin polyester polymer, melted and re-extruded into a non-woven fibre which although discoloured can be used as the foam substitute in a new seat cover. When this seat cover comes to the end of its life it can be shredded, melted and extruded again but this time with a higher proportion of virgin polymer to compensate for the used polyester being recycled a second time. Alternatively it can be used in a less demanding end-use. Thus the same polymer is reused but each time in a progressively lower specification application. Non-woven polyester spun from recycled polyester bottles by Wellman is currently being used in some production models. Bottle manufacturers continue to develop and improve polyester bottles for many other end-uses and there could soon be a surplus of polyester bottles available for recycling. However 'closed loop' recycling is generally recognised as the most satisfactory recycling procedure. This is when the recycled material, in the present context, automotive interior trim fabric is recycled back into the original end-use, i.e. back into an automotive textile.

8.6.3 Recycling of polyurethane foam

The manufacturers of polyurethane throughout the world have responded to the challenges of the environment and pointed out the ways in which waste polyurethane foam can be reused and recycled or disposed of with minimum effect on the environment.[72–74] The methods involve shredding into crumbs and smaller particles and reprocessing them by compression moulding, adhesive rebonding or thermoplastic rebonding into useful articles including backings for carpets, rugs and other items, making use of the acoustic and shock-absorbing properties. Polyurethane foams have been ground into powder and added into new compound mixes as filler. Studies have been carried out on the feasibility of chemolysis, breaking the material down chemically into the original raw materials for use in existing or new products. Composting and incineration as a useful fuel to recover the energy have also been considered. The Polyurethanes Recycle and Recovery Council (PURRC) of the (American) Society of the Plastics Industry, made up from 14 major manufacturers was set up as early as 1990 and have worked to tackle the problem of both process and post-consumer waste. In the USA there is a market for foam for recycling into new products such as carpet backing. The European Isocyanate Producers' Association (ISOPA) provides a focus for the environmental responsibilities of the polyurethane industry and has issued a series of comprehensive technical information sheets on recycling possibilities for polyurethane foam.[75]

Seat makers have carried out work to explore using ground-up foam from car seats as filler for virgin foam in new car seats. Physical properties are reduced in quality but may be satisfactory in use. However, the problem of interior trim foam being joined to other materials and the high cost of dismantling and handling remain. Foam processing waste in fabric lamination plants, however, are taken back by certain manufacturers for reprocessing or reuse.

8.6.4 Logistics of automobile recycling

The first step in the recycling process is collection of the ELV. A single scrap car has little value to its last user and occasionally abandoned cars are seen littering the landscape. These are not only an eyesore but also constitute a health and safety hazard. About 8 million ELVs are scrapped each year in the EU. With a certain amount of pressure from governments, voluntary accords have been set up since the early 1990s in different countries, amongst them were the Automotive Consortium on Recycling and Disposal (ACORD) in the UK, PRAVDA in Germany, and the Environmental Car Recycling in Scandinavia (ECRIS).[76–78] They were set up to provide national frameworks for economic break-even for recovery systems, to reduce waste disposal from ELVs and to ensure that all are properly collected.

The Association des Constructeurs Europeens d'Automobiles (ACEA), in Brussels promotes research to improve the design of vehicles for ease of disassembly and also selection of materials to aid recycling and to minimize material which cannot be recycled. The Consortium for Recycling (CARE) was established in the UK in 1996.[79] CARE is made up from ten OEMs and a number of car dismantlers and works with government bodies and other organisations to produce specific results from practical work by helping individual companies. Recytex, previously a subsidiary of Viktor Achter, the car upholstery manufacturer has processed textile waste from its parent company and others since 1993. Recently Recytex has been co-operating with Mercedes-Benz and others on the use of recycled non-wovens for sound insulation.[80,81] Car manufacturers are co-operating with each other in various ways, for example Volvo will scrap Mercedes cars in Sweden and

Mercedes will scrap Volvo cars in Germany. Toyota are very active in recycling activities especially in Japan and they are co-operating with VW in Europe and also General Motors.

The second step in the recycling process is disassembly, which must be accomplished quickly to be economic. Plastics must be identified and sorted and different types must be separated from each other, which is not easy, and it may not always be possible to do this economically. The actual impetus for recycling only arose within the last 10 years or so and many of the cars currently being scrapped were not actually designed with recycling and disassembly in mind. In addition some components made maybe 10–15 years ago contain substances which are now considered toxic and therefore prohibited from being used in a new car. After many years' use certain materials such as the seat covers are likely to be heavily soiled, which means there will be high levels of contaminants with which to contend. This may add to the case for better cleanability of seat fabric.

The non-metallic parts of the car make up about 25% of the weight and comprise glass, rubber, plastics and textiles. These materials, about 300 kg in an average vehicle represent the biggest challenge with adhesives, paints, coatings and fasteners further complicating matters. At present the cost of dismantling, sorting and transporting components is not generally commercially viable but the pressure is on to change this or find alternative solutions. Vehicles being built at the present time benefit from these lessons and future ELVs should gradually become more and more easily dismantled. Cars being built now will not become ELVs until the year 2010 onwards and it has been suggested that when a polymer type is chosen for a car part, a second future use for it, at the end of the car's life, is decided in advance. To assist dismantling, the EU have requested OEMs to code car parts before the year 2000 and to produce dismantling manuals. One notable exception to the trend of easier disassembly is the move towards directly joining car seat covers to the foam cushion and squab in seat making.

Analysis of impact on the environment shows that the least expensive and least adverse effect on the environment is when a component can be recycled into its original product, i.e. so called 'closed-loop' recycling. The second best is when it can be used in another article which usually requires less demanding properties, for example face car seat fabric being recycled into backing material. The third option is to incinerate the material to generate useful heat but this generates the inevitable carbon dioxide and other gases, which may have to be treated before release to atmosphere. Plastics in fact, generally have high calorific values and are efficient fuel. The fourth and least satisfactory disposal method is landfill, which may, as has already been mentioned, produce environmental problems of its own. Some components consume so much energy and other resources to recycle them that it is judged more overall environmentally friendly to use the two latter options. Each case has to be assessed on its own merits and in some countries of the world with a shortage of fossil fuels, such as Japan, incineration is a preferred option.

Car carpets are generally one polymer but with high levels of binders and a coating of bitumen or other material to assist vibration and sound absorption. They can also contain very large amounts of dirt – one report records up to 1 kg of dirt per square metre of carpet.

8.6.5 Use of natural fibres

In recent years there has been a revival of the use of natural materials in the automotive industry. The reasoning being that use of raw materials from renewable sources is more environmentally responsible than the use of synthetic fibres and plastics, which generally originate from limited oil reserves. In addition natural materials are more biodegradable than most synthetic ones but there are also technical advantages, such as adhesion to plastics and physical properties. Flax, sisal and hemp are being explored as replacements for the more expensive glass as long fibre reinforcement in polyurethane injection mouldings for door panels and in other applications. Some products are already on the market and are being used notably by German OEMs.[82]

The Crea Tech Process developed by Alpha Plastics and Haas Kunstoff has explored the use of natural thermoplastic material extracted from certain plants, which is filled with derivatives from wheat, oats and soya. The resultant compound resembles and has similar properties as ABS but will biodegrade under high humidity after 10 years. The same company has developed machinery and software for insert moulding using leather or Alcantara as the decorative material, which is bonded to a melt-injected plastic, such as polypropylene or ABS. The novel feature is that the bond between the covering decorative material and the rigid part is controlled to be adequate for the purpose but allows the materials to be separated at the end of the life of the car to facilitate recycling.[83,84]

8.6.6 Reduced emissions by reduced weight

Much development work has been carried out to reduce pollution by making the car lighter in weight. Some OEMs, have requested efforts be made to reduce car seat cover fabric weight by 30%. Generally this is not possible without compromising the fabric performance, especially abrasion resistance. The use of polypropylene, which is 30% lighter in weight than polyester, has already been discussed and it is generally unsuitable for car seat covers. It is suitable, however, for many other areas of the car, including parts of the interior trim covering material, as backing fabric for carpets and also in woven velvet upholstery.

The car industry is responsible for 12% of all carbon dioxide emissions in Europe. Because of this the EU council of ministers of the environment have requested a contribution from the car industry so that the EU can comply with its commitment made at the Kyoto summit on the environment to reduce carbon dioxide emissions in Europe to combat global warming. In response the European Automobile Manufacturers Association (ACEA), have proposed very significant reductions by improvement of fuel consumption in new cars made in Europe.[85] The first step is to introduce to the EU market, no later than the year 2000, models emitting carbon dioxide corresponding to an average fuel consumption of 4.9 litres per kilometre (equivalent to 48.2 miles per gallon). Further improvements up to the year 2008 will result in car fuel consumption at levels 25% less than 1995 levels. The target quoted by the German chemical industry is the '3 litre car', i.e. a production car which will cover 100 km using just 3 litres of fuel. This is equivalent to 94 m.p.g. in the UK and 78 m.p.g. in the USA.[86] This will require substantial savings in weight and will need contributions from all material suppliers. It has been reported that this target will not be met in high volume production cars until much of the glass in cars is replaced by lighter plastic substitutes. However, since that report, several small cars have been produced which can meet this target.

Textile fibre in the form of composites should contribute substantially to reduced traffic fumes by allowing considerable weight savings in the form of composites. However there are technical problems to be overcome before large metal replacement composites can be made commercially in the quantities required by the high volume automotive industry. Also, as previously described, advanced tyre cords and textile fibres–rubber combinations are already contributing to reducing rolling resistance in tyres leading to economies in fuel consumption and prolonged tyre life. The replacement of polyurethane foam and fibreglass by polyester or better still, polypropylene non-wovens could also reduce the weight of the car by useful amounts. Polyester however has certain processing advantages over polypropylene.

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