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TEXTILES : SOME TECHNICAL INFORMATION AND DATA

PART VI : FUSING

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PREAMBLE

In April, 1979, SAWTRI extended its activities to include Clothing Technology. One of the first priorities, in any venture of this nature is to identify areas which have, as yet, not been researched in detail and, to use this in conjunction with the needs of industry, as a directive for future research provided, of course, it falls within the expertise available at SAWTRI. One way of collecting such information is to review work that has been published on topics related to clothing manufacture. These articles will also prove useful to industry as a source of data. One such review[1] *on sewability, sewing needles, threads and seams has already been published and it is apparent from the response from industry that there is a need for such information. This review concentrates on matters relating to* fusing *and is a compilation of data much of it being reproduced directly from the original source.*

CHAPTER I

INTRODUCTION

Traditionally interlinings have been sewn into the garment on the inside of the outer fabric. However, fusible interlinings are increasingly being used in various sections of the clothing industry and when correctly used have been found to give good results. However, complaints of problems do occur particularly with the technology of fusing becoming more sophisticated.

Fusible interlinings are coated with an adhesive which enables them to be fused under certain conditions of temperature, time and pressure onto the outer fabric by means of a fusing press.

A fusible interlining is designed to[2]:

(a) act as reinforcement in parts of a garment;

(b) provide bulk in those areas where extra thickness is required;

(c) provide stability on a wide variety of fabrics.

Typical areas where fusibles could be of benefit are given in Table I[3].

TABLE I

TYPICAL USES OF FUSIBLES[3]

GARMENTS	FUSIBLE AREA
1. All weather coats (rain wear)	Collars, cuffs, neck bands, front facings, right and left pocket welts.
2. Men's Coats, Woven and knitted fabrics.	Fully fused fronts, collars, wigams, vents, lapels, pocket stays, chest pieces and tape areas.
3. Children's play trousers	Knee reinforcement of Fabrikock or similar coatings.
4. Dress and Sports Shirts	Collars, cuffs and pockets.
5. Men's and Women's Outerwear	Fronts, waistbands, cuffs, pockets, collars.
6. Women's Suits and Dresses, Knitted and woven.	Collars, cuffs, fronts and hems.
7. Slacks	Waistbands and fly fronts, pocket welts

The advantages of fusing rather than sewing interlinings have been enumerated by various authors. The most often quoted are:

1. Simplification of production by eliminating a number of complex operations[4-14].

2. Elimination of the need for skilled operators[4-11, 13-16]. Apparently only one month is required to train an operator for fusing whereas 4 — 6 months are necessary for sewing machine operators[8].

3. Higher production rates and a reduction in manufacturing costs[4-7, 11, 16-17]. It has been stated that although there may be no saving in material costs as such, a reduction in production time and training time of operators can lead to savings[18]. A saving of up to 15 mins/garment has been reported[19-20], and elsewhere[17] a 25 min saving in time on a 220 min suit is claimed.

4. Garments have a better drape and shape retention properties[4,12-14,16,21,23].

5. More uniform appearance and better handle to the garment[6-7,9,11,15-18,23].

6. Controls shrinkage, resulting in a more stable outer fabric[9,12-14].

7. Eliminates or reduces puckered seams[4,13,15,17,24].

8. Improves other properties, increases seam strength[17], produces less distortion and wrinkling[4, 15], increases the strength of the garment at the points which have been fused[17], eliminates stretching and distortion of the fabric thereby producing a more stable garment[17], easier handling of difficult cloth[14], etc.

More specifically, the fused front process apparently has the following advantages[25]:

(a) Improves the garment by giving the foreparts a clean, new appearance which will withstand everyday wear and dry-cleaning.

(b) Controls the dimensional stability of the forepart reducing the undesirable shape changes which occurs due to environmental conditions.

(c) Gives the forepart the desired drape, handle and ability to recover from creasing and distortion.

(d) Simplifies making up the garment and affords manufacturing economy.

(e) Reduces the likelihood of manufacturing error in making up a garment.

A list of specific reasons has also been given as to why fusible interlinings should be used for mens *tailored knits* [26,27]. Fusing improves the appearance of garments made from stretch fabrics (knitted velours) and facilitates the manufacture of the fabrics[6]. They have proved especially invaluable in certain instances like yokes, collars, shaped cuffs and some front panels[6].

Surpassing tradional problems of sewing in, fused interlining avoids the cockled edges on the fronts caused by operators as well as a high residual shrinkage of edge tape[28]. The impression of bridle and lapel padding stitches showing through medium to lightweight fabrics is supplanted by smooth fusible tape. The bubble over the top button does not form as there is no canvas thickness in the front. Excess fabric in the front shoulder areas, that result from improperly basted armholes, can be avoided. The need to ease in canvas with extra fullness for subsequent shrinkage is also not necessary[28].

Apparently fused garments also retain a smoother surface when stored on hangers in damp or extremely dry conditions for a long period of time[24]. Under different climatic conditions, a fused garment also maintains a good outer appearance[24].

The following problems have, however, been encountered with fusible interlinings[30]:

(a) Bubbling caused by delamination of interlining from the outer fabric in certain parts.

(b) Staining on the outer fabric caused by strike through, i e the adhesive flows through the outer cloth onto the face of the fabric.

(c) *Curling of edges of lapels and jacket fronts.*

(d) Puckering at the border of an unfused part with a fused part.

(e) Deterioration in the handle or appearance of the fabric.

One other limitation with the use of a fusible interlining is that a fused garment cannot be undone like a sewn garment[12]. Careful handling of the fabrics during fusing to avoid any strike-back or strike through is also necessary[12]. The greatest disadvantage of a fused interlining is apparently the lack of roll on the lapel of a jacket[32].

A comparison has been made between a jacket with fused interlining and a jacket with the same interlining, but sewn in, after dry-cleaning, again after being conditioned at 35% relative humidity and finally after conditioning at 90% RH[33]. The fused interlining jacket performed the best[33].

Fusing, adhesive interlining and outer fabric variables which affect fusing performances generally are shown in Table II[34].

TABLE II

VARIABLES IN FUSING PERFORMANCE[34]

Fusing Conditions	Fusing Polymer	Interlining/Outer Shell Fabric
Temperature	Shelf Life	Construction
Dwell Time	Melt Index	Finish
Pressure	Softening Range	Relative Shrinkage
Steam Cycle (where applicable)	Adhesive Quality	Moisture and Solvent Sensitivity
	Solvent Sensitivity	
	Water Sensitivity	
	Steam Activatibility	

Wira[35] has launched a project aimed at ensuring better compatibility between outer cloths, interlinings and fusing conditions. In a recent survey[36] carried out by them, they found that finishers and weavers were largely unaware of fusing requirements of fabrics and few tested their fabrics for fusing performance at all. A fairly high percentage of clothing manufacturers had little or no control over their fusing operation and tested their fabrics less than once a day. Furthermore, confusion still existed with respect to temperature (i e glue line or surface) and pressure (press or air line) specifications and a wide range of temperatures were being employed for the same type of adhesive. Apparently the fabrics which are difficult to fuse are synthetics and tweeds, causing even more trouble than velvets and silicone-treated fabrics. Problems also arise in fabrics given a soil release or resin finish[36].

CHAPTER 2

FUSIBLE INTERLININGS

2.1 Type

A wide range of fusible interlinings are available varying in structure, i e woven, knitted, non-woven or spun-laced, but it was forecast[37] that knitted interlinings would become very popular. The recent trend in fusible interlinings is towards developing lightweight fusibles for the now popular thin fabrics (e g georgette, voile, lawn, etc). *Woven* interlining fabrics, due to their construction, are not easily distorted in wear or in cleaning and thus exert maximum control on shrinkage and shape retention, but a soft handle such as with non-wovens or knits is not possible[11]. Nevertheless, special weaves, eg broken twills or fabrics with fine warp and coarse wefts, can give a softer handle. Raised qualities also improve handle and loft[11]. Woven fusible interlinings consist to a great extent of cellulose fibres and they are not crease resistant[38]. Creases can therefore be expected when such linings are used in a laminate but the effect will be considerably less on knitted outer fabrics than on wovens[38]. However, most woven interlinings are resin finished to give good levels of crease recovery and low shrinkage after washing[11].

Warp knitted interlinings are reported to be ideal for a super soft handle but do not control shrinkage very well[11]. Lightweight warp knits which form a good flexible base are particularly suitable for very light outer fabrics. One direction is firm and stable but it has stretch in all the other directions[39]. *Weft inserted warp knits* usually have an inlaid weft yarn of viscose and when raised give a soft, lofty handle[11]. Because of their construction they have a different handle in the warp and weft direction and shrinkage control and shape retention are adequate[11]. Wider width interlining fabrics are required in the future and this is apparently where knitted fabrics have proved successful[37].

Non-wovens are produced by different manufacturing methods which affect the final properties, usually by the direction in which the fabrics are laid and agents used in the binding of the fibres. Table III gives a detailed classification of non-woven fabrics used as fusibles[40].

TABLE III

DETAILED CLASSIFICATION OF NON-WOVEN INTERLININGS[40]

Kind	Feature	Thickness Mass/unit area	Material
Soft type (General interlining)	Excellent elasticity. Front part of women's and men's suits, etc.	40 - 70 - 90 g/m² 0,3 - 0,8 - 1,3 mm	Polyester Nylon
Hard type (General interlining)	Stabilized type. Lacks elasticity. Front part of overalls, working clothes. Interlining for belt.	40 - 100 g/m² 0,3 - 0,7 mm	Polyester/rayon blend Rayon
Partial fusible interlining	Iron-bonding type. Reinforcing of hem, front, edge, pocket, cuff, etc.	30 - 60 g/m² 0,3 - 0,4 mm	Rayon
Overall fusible interlining	Pressing machine-bonding type. Front part of men's and women's suits, etc.	40 - 50 g/m² 0,6 mm	Nylon Polyester blend
Complete fusible interlining	To be inserted between cloths and fused into cloth by pressing machine. Knit, stretch cloth.		Plastic polyamide
Hard finish fusible interlining	Non-woven fabric laminated with thin polyethylene film. Neck of dress shirt, etc.	100 g/m²	Various material
Wadding type	Resistant to washing. Quilting laminate, wadding.	90 - 150 g/m² 4 - 20 mm	Polyester and others
Brassiere interlining	Higher in density than wadding type. Interlining for brassiere.	Higher in density than wadding type	Polyester and others

Non-woven interlinings can be roughly classified into two types[40]:

1. *Multi-directional* type which has a soft handle, excellent elasticity and moderate resilience and suitable for use on jersey, stretch cloth, etc.

2. *Stabilised type* suitable for rain-coats, school uniforms, overalls, working clothes[40].

Lightweight non-woven interlining fabric are normally of four different types[39]:

1. Parallel laid which have stretch in one direction — good for knitwear.
2. Cross laid which have stability in two directions but can stretch on the bias like a woven fabric.
3. Random laid with multidirectional strength but limited stretch and recovery.
4. Structured type which gives a woven effect.

More generally, non-woven interlinings have been reported to have the following features[11,40]:

1. Very light;
2. Free from ravelling at cut end;
3. Non-directional;
4. Resilient and wrinkle resistant;
5. No shrinkage after washing;
6. Keep shape and stiffness;
7. Cheap.

Increased amounts of synthetic fibres in a non-woven interlining improves crease recovery and selective embossing improves the handle and performance[11]. They can be used on certain lightweight fabrics where the weave of the fabric will show through or cause moire effects[11]. A non-woven interlining which has too few fibres in the construction, with the balance made up by additives, can have the result that these chemicals absorb and retain the dirt from wear and from washing water, which eventually shows through a white cuff or collar as a grey or yellow colour[38].

Spun-laced fabrics are produced by blowing high pressure water jets through a batch of fibres causing the fibres to move relative to each other and become entangled[95]. The interconnected entangled fibres give strength without stiffness resulting in outstanding drape and softness. Since no chemical binders are required, fibres are free to move and the handle generally softer. Air permeability and hence comfort is also greater and dye fastness to washing or dry-cleaning is not a problem. The intimate fibre interlacing also causes the strength to stiffness ratio to be greater than for other non-wovens. The resistance to pilling is also better than for non-wovens[95].

There are two basic spun-laced fabrics available, namely, the *flannel* and the *apertured* [129]. They are less expensive than cotton fusible but slightly more expensive than non-wovens[129].

Spun-laced interlinings are claimed[129] to incorporate the desirable attributes of both woven and other non-woven fabrics with additional advantages. Some of these advantages are[129]:

1. Some are free of binders and therefore repeated drycleanings and washings have little effect;

2. They have only about 1% shrinkage since they are heat set when converted into a fusible;

3. They have a tendency to move with the outer cloth;

4. The fibre interlacing properties result in excellent resistance to surface pilling or fuzzing;

5. The lack of binders results in no fugitive dye pick-up in washing which is important in lightweight sheer fabrics where a discoloured interlining will show through the shell.

The properties of a number of interlinings (without resin) have been given and some of the properties discussed[42]. Table IV gives some examples of the practical applications of some types of interlinings[11] and a table showing the specifications for different Japanese fusible interlinings has been encountered[43]. A number of articles describe the range of interlinings marketed by some interlining manufacturers as collar fusible interlinings[44-46] and for other end-uses[47-56].

TABLE IV

EXAMPLES OF PRACTICAL APPLICATIONS[11]

Garment	Other fabric	Requirement	Fusible chosen
Men's shirts	Woven, Polyester/ Cotton	High wash temp. Light fabric mass Medium handle Max shape retention Max shrinkage control	High density polyethylene, 30 Mesh Dot, Woven
Men's Leisure Shirts	Knitted, Polyester/ Cotton	Medium temp wash Medium fabric mass Good shape retention Soft handle Good shrinkage control Top and under collar to be fused	Polyamide, 17-25 Mesh Dot, Non-Woven
Men's Jackets	Woven, Polyester/ Wool	Dry clean only Medium-heavy fabric mass Soft full handle Directional Warp and Weft effect	Polyamide, 13-17 Mesh Dot, Weft Insert Knit
Ladies' Dresses	Woven, Polyester/ Cotton	Med temp wash Med fabric mass Med handle Good shape retention Low cost	Low density polyethylene, Scatter, Non-Woven
Ladies' Blouses	Woven, 100% Polyester	Med wash Ultra light fabric mass Super soft handle	Polyamide, 25 Mesh Dot, Warp Knit
Ladies' Blouses	Weft Knit, 100% Polyester	Med wash Med fabric mass Med handle Good shape retention	High density polyethylene, 30 Mesh Dot, Woven
Men's Raincoats	Woven, Polyester/ Cotton	Wash & dry clean Adhere to proofed fabric Med fabric mass Med handle Good shape retention	Polyvinyl chloride, 17 Mesh Dot, Woven
Ladies' suits Jackets	Woven, Polyester/ Viscose	Dry Clean only Med fabric mass Soft handle Good shape retention	Polyamide, 17 Mesh Dot, Non-Woven
Ladies' Full Length Coats	Woven	Dry clean only Heavy fabric mass Soft full handle Good shape retention and drape	Polyamide, 17 Mesh Dot, Woven Broken Twill

2.2 Fibre type and interlining properties

Interlining to be used for garments should have the following qualities[57].

1. Easy to wash and clean
   - (a) the fused fabric and interlining should be able to withstand repeated dry-cleaning and machine washing at 60° C;
   - (b) the shrinkage of outer fabric and interlining should be similar.
2. Safeguard the outer fabric, i e interlinings should be able to be fused under moderate fusing conditions.
3. Good ventilation.
4. Maintain outer fabric properties. That is, each independent dot of adhesive should be fused at the surface of both fabrics only.
5. Easy handling.

The physical properties of the interlining which are considered important are bulk, mass, resilience, drape, shrinkage and colour[18].

Both natural and synthetic fibres are today used in fusible interlinings. The type of fibre and its specific properties naturally determines the end use. High quality interlinings which can retain a good shape are made of several kinds of animal hair fibres, e g wool, camel hair, etc[57]. A number of experiments have shown[25,58] that pure wool was the most effective fibre in an interlining for shape retention and crease resistance and improved the handle and drape of the finished garment. This has led to the introduction of the Woolmark Fusible Interlining by Webbs of Worcester[58]. A small percentage of goat hair in the weft of woven interlining is said[59] to add resiliency and handle that far exceed that of other fibres. However, it does present problems during processing[59].

For a quality *knit* garment with a dry-clean only label, a *hair* canvas with a polyamide printed fusible is recommended[26]. For washable and dry-cleanable knit garments, preshrunk cotton interlining with a polyamide fusible dot should be used. A rayon/cotton sheeting using a polyamide dot will also give good results[26].

Any fusible interlinings arriving at a making-up plant should be checked for[18].

(a) defects in the basic fabric;

(b) defects in the resin application;

(c) processing changes;

(d) dirt and grease;

(e) wrinkles and creases;

(f) colour changes;

(g) bond strength with outer fabric.

To choose the correct interlining Marks and Spencer let the interlining manufacturer carry out a detailed fusing assessment (e g tests on shrinkage, washability and/or dry-cleanability) well in advance of garment manufacture ensuring that the intended end use is fully understood[60]. The final choice is then made according to the reported results and garments are then evaluated with this interlining[60].

Fusible interlinings should be stored in an atmospherically controlled area and should not be kept near fusing equipment where they may be subject to high temperatures and steam[9].

A number of articles[20, 61 –63] by various experts give some useful information about the selection of interlinings.

CHAPTER 3

FUSIBLE ADHESIVES

3.1 Types

A fusible resin (also referred to as thermoplastic synthetic resin, thermoplast, adhesive, bonding agent, etc) is not an adhesive in the cold state but, on the application of heat, physical changes and softening occur which, with pressure and time, create a bond with the outer fabric.

A good adhesive should meet a number of requirements[64 –66]:

1. It must be *thermoplastic*, i e in the heated state it must have the properties of sticking and flow but at room temperature it should be completely free of tackiness.
2. It must be resistant to ageing i e its properties must not change during storage or after fusing.
3. It must not become hard or brittle.

4. *It must be colourless and must not yellow.*
5. It must be resistant to washing and/or dry cleaning.
6. It should not affect the supple handle of the textile material but impart a stiffening effect.
7. Its melting and bonding temperature ranges should be suitable for textiles so as not to damage the fibres.
8. It must be supplied in such a form that clean processing and reliable application are possible.
9. Cost must be competitive.

The type of adhesive used depends on three characteristics[10].

1. fusing or melting temperature;
2. viscosity of resin at that temperature;
3. durability of the resin on dry cleaning or laundering.

A number of adhesives are available on the market each with different properties and different fusing requirements[64-69]. These are discussed below.

3.1.1 Polyethylene

Polyethylene (PE) is an important adhesive and above all is a *cheap* bonding medium for fusibles[65,66]. However, differences between polyethylene produced by the low pressure (high density) and high pressure (low density) processes exist[65-66]. Generally, they can be divided into three classes according to their relative density (specific gravity)[64]:

(a) low density; 0,910-0,926 relative density;

(b) medium density: 0,926-0,940 relative density;

(c) high density: 0,940-0,965 relative density.

In the low pressure (Zeigler) process, linear molecules are produced almost without side chains and therefore the molecules can be packed more closely together and this yields a relatively stiff resin[65-66]. It is difficult for a solvent to penetrate into the interstices between their molecular chains and loosen the crystalline structure in order to swell the resin or even to dissolve it. A relatively large amount of energy is also needed to melt the crystalline structure owing to the strong cohesion of the molecules. Consequently, the fusing point (or glue line temperature) of high density polyethylene is relatively high (128° C)[65-66].

In contrast to high density polyethylene, low density polyethylene has a great number of short and long side chains resulting in a more coiled structure of the molecules; the distance between the chains is greater and the density of packing is lower[65-66]. The greater distance between the molecules enables a solvent to penetrate more easily into the spaces, to loosen the structure of the resin and to swell or even to dissolve it. The fusing temperature, too, is lower (about 100° C for a density of 0,912 and about 118° C for a density of 0,934). The stiffness of low density polyethylene is also lower than that of high density polyethylene[65-66].

Another important factor is the melt flow index (MFI)[64]. The melt index describes the flow behaviour of a specified quantity of a polyethylene resin pressed at a specified temperature through a narrow orifice under a specified load. The higher the melt index, the lower the melt viscosity and vice versa and for polyethylene the melt index ranges from 2 — 200. For practical use, it can be anticipated that a polyethylene powder with a high melt index is not only rather easily fixed but also penetrates rapidly into the fabric and quickly fuses on heat sealing. On the other hand, the low melt viscosity may cause the well-known and feared strike-through and strike-back. The greater the MFI, the less resistant to dry-cleaning solvents the resin is likely to be. On the other hand, thermoplastic powders with a low melt index are difficult to fix as they hardly penetrate into the fabric. Additional adhesion is achieved by calendering with cooled rollers after sintering. Even in fusing later on, adhesives with a low melt index require a higher pressure and prolonged fusing time in order to achieve a good bond strength. There is then little chance of strike-through and strike-back occurring. According to the range of these figures, one can expect results which range from insufficient to excellent regarding their resistance to solvents, and laundering. They are generally insoluble in any solvents below 50° C but the higher the density the greater the resistance to dry-cleaning solvents[64].

Low density polyethylene is the cheapest adhesive and is sinter coated, fuses easily (even on steam press) and has excellent washability but only moderate dry cleanability[67]. They are good for small areas which have a retaining stitch. High density polyethylene, on the other hand, has excellent wash and dry-cleaning properties but is more difficult to fuse (requires temperatures up to 170° C and pressures up to 69 kPa). It is always dot coated and is especially good for critical end uses such as shirt collars where laundering conditions are severe and penetration of the outer fabric by the adhesive might easily occur[67].

3.1.2 Polyamides

These are generally terpolymers and are made by mixing the basic ingredients of nylon 6, 6.6 and 11 or 12[64,67]. By varying the constituents a wide range of properties can be obtained. Plasticisers are sometimes added to increase the melting range and lower the melting temperature[64,67]. Copolyamides of this kind have a relative density of about 1,2 and, according to the ratio of monomers used, a melting range of 105° to 140° C and according to the molecular weight a melt flow index between 15 and 200[65,66]. Two classes are generally used[64].

High melting range — dry cleanable and washable up to 60° C.

Lower melting range — dry cleanable only.

By virtue of its molecular structure, a much stronger adhesion can be obtained with polyamide than with the pure hydrocarbon chain of polyethylene[65-66]. Consequently, by using the same quantity of bonding agent, a stronger adhesion is achieved, or a lower quantity is applied resulting in the same adhesion. This, of course, is combined with a softer handle of the interlining. A further reason for the current significance of polyamide is the outstanding resistance to solvents in dry-cleaning. In addition, polyamide has a relatively low fusing point and can be fixed by steam presses. This can be attributed to the fact that the water imbibition of the copolyamide used for fusibles and based on nylon 6, 6.6 and 12 is about twice as high as that of polyamide based on nylon 6 or 6.6. Due to the swelling, the fusing point is remarkably reduced. It can, of course, also be a disadvantage in that the bonding strength, too, is considerably reduced by the increased swelling in steam and water, and the resistance, to washing is accordingly poorer compared with other adhesives. The ratio of blending polyamide 6, 6.6 and 12 can, of course, be altered in order to reduce the swelling, thus increasing the resistance to washing. At the same time, however, the fusing temperature is also increased, so that these polyamides are no longer fusible on steam presses but have to be fused on electrically heated presses[65,66].

Polyamide resin, it is claimed[70], is very easy to fuse and the fusing conditions need not be strictly controlled. The polyamide is thermoplastic and the process of fusing can be repeated if necessary. It contains no solvent soluble plasticisers and therefore the original handle and stiffness remain almost unaffected throughout the normal life of a garment. Interlining with polyamide adhesive should also apparently not be seriously affected by environmental circumstances such as relative humidity and will withstand temperatures of up to 60° C in dry and steam ironing. Comparatively little polyamide adhesive is required to give a good bond and, therefore, other properties of the laminate are not adversely affected[70]. The biggest disadvantage is the relatively high temperature required at fusing which makes it unsuitable for fusing onto leather, fur or water repellent fabrics[67]. It has limitations as far as washability is concerned particularly in the lower temperature melting range and is therefore widely used as a dry cleanable resin. Initial high adhesion levels at low coating weights make the resin suitable where the natural handle of the substrate is to be retained, e g hair cloths, lightweight twills, or weft inserted knits for menswear interlinings[67].

It also has to be pointed out that the polyamides are the most expensive bonding agents for fusibles at present. Copolyamides and most of the other adhesives mentioned above are applied either by the spraying, powder point or paste point method[65-66].

3.1.3 Copolymers based on vinyl chloride and vinyl acetate

Of great importance is polyvinyl chloride (PVC), especially in the form of an externally plasticised copolymer with vinyl acetate[65-66]. On this chemical basis, it is possible to produce either freely flowing powders or printable pastes, so-called plastisols. Material of this kind enabled the producers for the first time to manufacture dot-coated fusibles on a commercial scale[65,66].

Plasticised polyvinyl chloride/acetate copolymers have a relative density of about 1,3 and a melting range between 120° and 150° C[65,66]. An exact fusing point, as demonstrated by polyethylene or polyamide, cannot be given because a plastisol is chemically not a uniform substance, but a blend. A determination of melt-index according to the method described previously is not possible either as the thermal behaviour and the melt viscosity are severely influenced by the so-called gellification process. It can, however, be taken for granted that the gelling viscosity depends on the plasticiser or combination of various plasticisers[65,66].

Coatings of PVC are marked by a supple hand and a very good resistance to laundering and drycleaning[65,66]. It gives an excellent smooth appearance on thin sheer fabrics and a good bond to heavily finished or siliconised fabrics[67]. As a result of the abovementioned gelling process, PVC coatings can in practice be fused only once compared with the other thermoplasts which are fusible several times[65,66]. This fact can either be an advantage or disadvantage to the manufacturer[65,66].

It is often said that interlinings coated with plasticised PVC have a distinctly harsher handle after dry-cleaning because part of the plasticiser is extracted by the solvent[65,66]. This statement is correct as far as the behaviour of simple monomer plasticisers is concerned. However, if the vinyl resin is plasticised with polymeric plasticisers, the handle of the fused textile will remain the same as in the original state even after several dry-cleaning processes. It has also been stated that the harshness resulting from the extraction of the plasticiser is observed only when fused apparel has been washed or dry-cleaned *immediately* after fusing without being subjected to any mechanical use. But it is well-known that garments very rapidly loose their "body" and shape by wearing, laundering or dry-cleaning but become somewhat stiffer by the partial extraction of plasticiser in dry-cleaning. The "floppiness" of the apparel caused by wearing is thus equalised, and the garment has the same handle and body as in its original state[65,66]. PVC is generally printed and is both dry-cleanable and washable. It is normally used as a body fusible and in some cases for shirt collars[64].

3.1.4 Polyvinyl Acetate

This adhesive is only of limited importance. For fusible purposes, it is supplied with a relative density of 1,1, relatively high melt index and a melting range between 75° and 90° C[65,66]. One of the few advantages of polyvinyl acetate is its good resistance to white spirit. Owing to the low fusing point, a fastness to boiling water cannot be expected. Even the resistance to water is rather poor because of the hydrophilic acetate group. Therefore, polyvinyl acetate is only used in those cases where a low fusing temperature without special fastness is required, for example in the fusing of leather and fur and is also used in millinery[64-66].

3.1.5 Ethylene vinyl acetate (EVA) polymers

According to the ratio of ethylene to vinyl acetate these copolymers have a relative density of 0,93 to 0,96[65,66]. Their melt-index ranges from 4 to 50, and their softening temperature from 60° to 95°C. EVA copolymers are rarely utilised for fusibles because of their limited resistance to solvents, but they have an excellent adhesion especially to metal and an outstanding fastness at low temperatures. They are the most suitable material for the backcoating of moulded carpets used in the automobile industry[65,66].

A thermoplast having surprising properties is obtained when an EVA copolymer is partially or completely hydrolised, and the vinyl acetate group is converted into vinyl alcohol. There is, for example, one product of this kind on the market which has a relative density of 0,95 and a melt-index of 90 at a fusing temperature of 180°C. This material is not only marked by an excellent resistance to perchloroethylene, but also by a surprisingly high fastness to laundering which surpasses that of polyamide without exception in spite of the water-soluble vinyl alcohol group. Although the material has a fairly high melt index, it does not strike through because the amorphous part of polyvinyl alcohol in the molecule acts as a retarder. Owing to the possibility of certain chemical reactions of the hydroxyl group, it is quite imaginable that this thermoplast can be further modified by crosslinking and converted into a semi-duroplast by suitable components. Although modified EVA copolymers have not been widely used until now, they nevertheless seem to be the most interesting thermoplasts of recent years[65,66].

3.1.6 Other adhesives

Mention is made of two further adhesives. These are blends of novolac and polyvinyl acetate, and plasticised cellulose acetate[65,66]. According to tests carried out, the former has a good resistance to washing and dry-cleaning but the bonding strength is lower than that of other thermoplastic powders. A considerable disadvantage seems to be the yellow colour of the powder, limiting its application to those interlinings which are to be fused to dark or close woven apparel[65,66].

Cellulose di- and triacetate have a very high melting range and can only be used for fusibles in a highly plasticised state[65,66]. A ratio of 50 to 100% of plasticiser by mass of resin is quite common. But the freely flowing powder is possibly affected and agglomerates. In sintering, part of the plasticiser can be removed by evaporation, resulting, however, in a reduction of fusability. A great number of plasticisers suitable for cellulose acetate are extractable either by hot water or dry-cleaning solvents. The outlet of cellulose acetate as bonding agents for fusibles is thus considerably restricted[65,66]. Cellulose acetate has a fusing temperature range of 120 - 165°C and is both washable and dry-cleanable. It is used for a wide variety of body fusibles[64].

Thermoplastic polyurethane and polyester are also a possibility for the future[64-66].

Table V summarises some typical properties of the adhesives just discussed[65,66]. Other articles[69-70] also list some of the properties of the different types of adhesives.

TABLE V

PROPERTIES OF FUSIBLE MATERIALS[65-66]

Chemical Composition	Melting Range (°C)	Melt Viscosity	Fusing Temp. (°C)	Repeatable Fusing	Fastness to Dry-cleaning	Fastness to Washing
Polyvinyl acetate	80-95	low	120-150	yes	only white spirit	mild wash
HD Polyethylene	100-120	low-high	130-160	yes	satisfactory	mod wash
LD Polyethylene	125-136	high	170-190	yes	very good	very good
FVA Copolymers	75-90	low-medium	100-120	yes	moderate	mild wash
Modified EVA	105-115	medium-high	steam or 110-160	yes	very good	good
Plasticised PVC	100-120	medium-high	130-150	possibly	good	good
Polyamide	90-120	medium-low	steam or 150-170	yes	very good	good

3.1.7 Identification of adhesives[65-66]

The most reliable method of identifying an adhesive is selective extraction followed by infrared analysis. Besides this method, there are some other simple reactions. The so-called Beilstein test using a copper wire will often meet the requirements of determining PVC. In the presence of PVC, the copper wire shows a green flame colouration. Polyethylene is mostly identified by the kerosene-like odour on heating or burning. The good extractability of polyamide in low alcohols is frequently used as a determination. Blends of different thermoplasts, for example, polyamide, polyethylene and modified EVA copolymers — preferably used in the textile industry — are separated by extraction in different specific solvents. Polyamide is removed by hot methanol, modified EVA copolymers dissolves in hot butyl alcohol, and possible residues of polyethylene, as it is resistant to alcohol, are extracted in hot toluene.

Another very simple but not quite reliable method of determination is by means of selected dyestuffs, which give a more or less characteristic colouration.

3.1.8 General

Table VI shows some recommendations for the use of different types of resins[64] while Table VII gives the end-use and after care treatment of various resins[64]

PVC, polyamide and polyethylene are the adhesives most commonly used in the clothing trade today[71]. However, polyamide has been developed the most, since they can now be fused under numerous conditions and tolerable press variations, giving good adhesion to a wide range of fabrics. Dry-cleaning does not change the handle or bond strength, moisture does not affect the bond, no heat or light discolouration as occurs with PVC or polyethylene, less adhesive is required and handle is improved. Polyethylene is still extensively used in shirts, blouses, pyjamas etc where high washing temperatures are involved. The trend for softer handle and therefore adhesives which give the same bond strength at lower coating weight are favoured. Until recently only PVC adhesives could produce adequate bond strength and resistance to washing and dry-cleaning but now polyamide based adhesives with a high affinity for siliconised rainwear give the advantages of a wide range of fusing, handle and handle retention during dry-cleaning[71]. Fusible interlinings using a polyamide dot resin system will not stiffen in subsequent dry-cleanings[26].

The main difficulty found with PVC adhesives is that the softening temperature range is so critical that a few degrees above or below ruins the fusing[72]. The pressure which had to be exerted during the fusing process increased this hazard and the fusing was spoiled by moisture. Polyamide resins, on the other hand, were generally not as washable as PVC but were easier to fuse. Polyethylene adhesives form the bulk of the highly washable shirt interlinings.

TABLE VI

RECOMMENDATIONS FOR USE OF ADHESIVES[64]

	COATING RESIN TYPE	Steam Press	Electric Flat Bed Press	Continuous Fusing Press	Washability	Dry cleanability	Cost
	Polyethylene						
A	Low density	x	xxx	xx	xx	x	Low
B	Med/High density	o	xxx	xx	xxx	xxx	Med
	Polyamides						
C	(Copolymer) (Terpolymer)	xx	xxx	xxx	x	xxx	High
D	P.V.C.	o	xxx	xxx	xx	xxx	Med
E	CA	x	xxx	xxx	xx	xx	Med
F	PR	x	xxx	xxx	x	xx	Med
G	(Polyester) (Polyurethane)	Insufficient Experience in Use					Med
H	PVA	xx	xxx	xxx	o	x	Med

Key to Table

xxx Very Suitable	xx Suitable
x Limitations	o Not Recommended

Notes

1. This is only a general guide, fuller and more precise information is available from individual manufacturers.
2. The handle of a fused laminate is influenced by the fusible base fabric as well as the resin.
3. Hand irons are only suitable for tapes and small areas.
4. When steam presses are used care must be taken to ensure adequate steam pressure.

The use of dot coatings, whether PVC or polyamide, is almost universal[72].

It is felt[37] that there is still only one reliable fusible interlining for highly siliconised rainwear and that is PVC. Some adhesives, notably PVC plastisols, which are used for several brands of dotted coatings, require accurate fusing temperatures (± 5°C) but other adhesives, eg. polyamides, a variation of 10-20°C will not affect the bonding[73]. Bonding of most PVC compounds would be ruined with *steam* whereas when fusing a polyamide resin, steam has a definite advantage.

TABLE VII

WHERE & WHY — A RESIN GUIDE[64]

END USE				*AFTER CARE TREATMENT		
	Chest-Piece	Front	Small Parts	Dry Clean	Wash	Steam Press
1. Men's						
Jackets	CDEF	BCD	CDEF	•	•	•
Overcoats	CDEF	CD	CDEF	•	—	•
Trousers	—	—	CDEF	•	•	•
Knitwear	—	CD	CDEF	•	•	•
Shirts	—	ABD	ABD	—	•	—
Pyjamas	—	—	ACDE	—	•	—
2. Ladies'						
Suits	CDEF	CD	CDEF	•	•	•
Dresses	—	—	CDEF	•	•	—
Blouses	—	—	ABCD	—	•	—
Overcoats	CDEF	CD	CDEF	•	—	•
Knitwear	—	—	CDEF	•	•	•
Slacks	—	—	CDEF	•	•	•
Pyjamas	—	—	ACDEF	—	•	—
3. Children's						
Jackets	CDEF	CDEF	CDEF	•	•	•
Coats	CDEF	CDEF	CDEF	•	•	•
Trousers	—	—	CDEF	•	•	•
Dresses	—	—	CDEF	•	•	—
Blouses	—	—	ABCD	—	•	—
Shirts	—	—	ABD	—	•	—
Pyjamas	—	—	ACDE	—	•	—
4. Rainwear	—	CD	CD	•	•	—
5. Leather and Fur	—	CH	CH	•	•	—

Coating Resin Type:

A Low Density Polyethylene
B Medium/High Density Polyethylene
C Polyamides
D P.V.C.

E Cellulose Acetate
F Phenolics

G Polyesters and Polyurethanes
H Poly Vinyl Acetate

• Suitable for Dry Clean, Wash, Steam/Press

— Not applicable

Polyethylene and some other fusibles have an indefinite prefusing *storage* time. PVC, however, will begin to deteriorate in a relatively short time[27]. Average plant conditions apparently will not harm fusibles but if temperatures exceed 38°C, the fusing properties will gradually deteriorate. Excessive *humidity*, on the other hand, will not harm the fusibles immediately, but if the base fabric has a high moisture content, the resultant fused laminate bond will suffer[27].

3.2 Adhesive Application

Adhesive is applied to various base fabrics in quantities ranging from 3 g/m^2 to 60 g/m^2 [74]. Less than 15 g/m^2 is used for temporary bonding and quantities more than 15 g/m^2 are suitable for permanent bonding. Most fusible interlinings will average between 50 g/m^2 - 65 g/m^2 [74]. Some important properties of fusible polymers and fabrics for two types of applications are shown in Table VIII[34].

TABLE VIII

IMPORTANT PROPERTIES OF FUSIBLE POLYMERS AND FABRICS[34]

	Random Powder Spray-Sinter	**Gravure Powder Dot Printing**
Fusible Polymer		
Particle Size Distribution	x	x
Presence of Fines	x	x
Dry Powder Flow	x	x
Bulk Density		x
Moisture Content/Static Propensity	x	x
Melt Index/Softening Range	x	x
Fabric		
Variation in Thickness (Especially Selvage)		x
Bow and Skew	x	x
Sensitivity to Temperature/Tension	x	x
Width Variation		x
Moisture Content	x	x

A number of different methods are available for applying adhesives and these have been discussed in a number of articles[22, 29, 2, 67, 34, 64, 74, 31, 41]. The most popular of these methods will be discussed briefly.

3.2.1 Sprinkle or scatter or sinter coating

Sifted powder or granulated hot seal adhesives with grain diameters ranging from a minimum of 100 μm to a maximum of 500 μm, are sprinkled as evenly as possible onto the woven or non-woven interlining fabric and are then slightly melted by infra-red heating[31]. Ideally, the particles are distributed over the interlining surface on a random basis but some concentration in small areas cannot always be avoided. For copolyamides, the mass of the coating varies from 20 - 30 g/m², for polyethylene from about 20-50 g/m². The melting range of both adhesives may vary from 95° C to 125° C[31].

Two methods are used to distribute the resin[74]. The *air doctor method* is when the base fabric, which is under tension, is guided over two rollers which are connected by a conveyor belt. A doctor device distributes the resin accross the surface of the fabric, which is then subsequently melted by a heating process. This method is only used on dense fabrics which are not sensitive to high tension and abrasion[74]. With the *powder sprinkling method*, the resin powder passes through a funnel shaped container onto a cylinder with a surface much like a emery cloth. The powder is removed from the cylinder by brushes, so that it falls down on the fabric which is carried by an oscillating screen. This method is considerably faster and more precise than the air doctor method[18, 74].

The *use of sprinkle coated interlinings is limited to small parts, iron-on* tapes, collars, hat bands and interlinings that are not to be dry-cleaned[31]. The dry-cleaning fastness is generally lower than for dots that are distributed in set screen-meshes, the handle mostly hard and less textile-like, the inclination to strike-through higher, and the surface appearance after fusing irregular. Of the two aforementioned adhesives, copolyamides achieve comparatively better dry-cleaning fastness than high-pressure polyethylenes. Consequently, sprinkled coatings do not meet fully today's demands for dry-cleaning safe front fusing[31]. This is still the cheapest method but the end result is not so uniform and flexible[12, 64].

3.2.2 Dot Coating

Adhesive may be applied to the base cloth in the form of a pattern of dots by various methods[18]. These include[18]:

1. Rotary screen printing of paste

2. Rotary screen printing of powder

3. Needle penetration method
4. Application of a split film net
5. Engraved roller printing of paste
6. Engraved roller printing of powder.

The most popular of these is powder point printing with engraved rollers and paste screen printing.

Powder point (dry dot coating)

For this type of coating, powder adhesives of a grain diameter ranging from approx 60 μm to maximum 200 μm are printed onto woven, warp knitted or weft knitted interlinings, with mostly copolyamides and low pressure polyethylene powder[31]. Depending on the desired end-use, copolyamides with different melting points are used. For instance, leather and furs call for a melting point ranging between 60° C to 90° C, while 100° C to 125° C is usual for men's and women's wear. As yet, low-pressure polyethylenes printed in screen mesh form with a melting point of 130° C are used only for shirt cuffs and collars[31].

Resin powder from a carefully selected particle range is doctored onto an engraved roller filling the engraved holes[75]. The interlining base cloth passes over a heated roller and then against the engraved roller. Heat transferred through the cloth from the infra-red heated roller partially, and in some cases fully, melts the resin which then adheres to the cloth. Oven heating is often provided after the printing operation to ensure that the resin is fully fluxed and has adhered to the base cloth satisfactorily. Engravings are generally 35 to 120 dots/10 cm depending on the application required and heat and pressure of two rollers is carefully controlled for every resin type used. Finer fabrics generally require interlinings with smaller dots in high concentrations whereas heavier fabrics need larger dots to give a satisfactory bond[64].

The applied quantities for copolyamides vary from 10 to 25 g/m^2 and for low-pressure polyethylene from 22 to 30 g/m^2 [31].

Powder dot is apparently the most popular coating and creates a soft, textile handle after fusing, achieves a fully dry-cleaning proof bond and can be applied in almost all sectors of the garment industries[31]. The often somewhat difficult assembly of the cut interlinings and the cut parts of outer fabrics, and the fact that strike-through can sometimes also occur, are the disadvantages. Occasionally, edge welding may occur when cutting the interlinings. Also, the bond may weaken noticeably during the first 48 hours after fusing or dry-cleaning. This, however, can be remedied by additional fusing[31]. The main advantage of this method is that no compounding is necessary[64].

Paste dotting (screen printing)

Fine resin powder fractions (0-80 μm) are mixed with water and various wetting and suspending agents to form a smooth paste. The paste is then screen printed in dot form onto woven, non-woven, warp knit and weft knit fabrics[31]. The mesh used is mostly regular. The aqueous copolyamide paste, or PVC-plastisol that also contains a softener, is forced through the mesh of the screen onto the interlining. Under the influence of hot air and infra-red heat, the printed dots dry and sinter onto the interlining surface[31, 64]. About 53 dots/cm² is normal[74]. For this process, the adhesives can easily be modified with appropriate additives[31, 64]. This method gives precisely shaped dots and is used particularly to produce finer print dots used in shirt collar top fusibles[31, 64].

The melting point for copolyamide-based adhesives can range from 65° to 120°C, depending on the intended end-use[31]. Interlinings of this type are available for all applications, whereas PVC-plastisol coated articles with melting points of about 100°C are mainly limited to rainwear. The applied quantities vary between 12 and 28 g/m² for copolyamides based adhesives and are considerably higher, at 50 g/m², for PVC-plastisol[31].

The paste dot coating necessitates particularly careful printing preparations of the interlining surface and is now used less often than powder dot coatings[31]. The handle after fusing is slightly harder than with powder dot coating. Special advantages are: the cut interlinings can easily and rapidly be placed onto the outer fabric pieces, the tendency to strike-through is reduced, and the bond does not weaken after fusing or dry-cleaning. Another advantage is that the adhesive pastes can be adapted easily to any desired fusing condition. Consequently, paste dot coatings on copolyamide basis offer safe results that reduce to a minimum the formation of bubbles and the weakening of the bond[31].

The use of screen printing with PVC-plastisol is decreasing steadily[31]. Although the interlinings, mainly used for rainwear, initially show a soft, textile handle after fusing, several disadvantages are involved: during fusing, the evaporation of the softening agents produces an unpleasant odour; due to the large amount of adhesive paste needed, strike-through occurs frequently and only moderate bonding is achieved; the most serious deficiencies appear only after dry-cleaning; although the bond is strengthened, the handle becomes considerably stiffer, the garments are highly prone to creasing, and it is not possible to re-fuse after dry-cleaning; the adhesive cannot be re-activated[31].

3.2.3 Other methods

Other methods include preformed systems, extrusion laminating, hot melt coating, emulsion coating, spray coating and double coating.

Double coating first became known under Kufner's brand name 'Double-spot'[31]. For this latest type of coating, every single dot consists of two superimposed layers of adhesives with different properties. During fusing, the dot shaped base layer operates as a barrier and prevents strike-back through the interlining. It forces the top layer of the individual dot to form a strong bond with the outer fabric. The base layer flows a little, if at all, while the top layer melts easily to facilitate fusing. With this sort of coating (double coating) not only can strike-through be avoided, but fusing conditions can be expanded to cover a wide range without effecting hand and bond fastness significantly. Even for fabrics that are difficult to fuse, such as heavily silicone treated poplin for rainwear, almost the same bond fastness is achieved as for other fabrics. The production techniques are naturally more complex than for other coatings. In general, a second layer is applied onto the base screen-printed dot before or after it has dried, either by the powder sprinkling method or as a liquid film by roller. With the sprinkled powder method, superfluous powder is released later from the intermediate space. When a roller is used, only the peaks of the base dots are dipped into liquid adhesive film. The coating is suitable for any kind of interlining fabric, including non-wovens. Again, the adhesives are mainly based on copolyamide, but lately special polymers have been used that are resistant to water and steam and only begin melting at 130° C. That means that they are not re-activated in subsequent ironing/pressing operations, nor do they show any tendency to re-fuse on the reverse side of the interlining, or suffer a change in handle. The quantities of adhesives vary between 15 and 28 g/m². The range of applications covers all types of textile garments, but double coatings have been specially successful in the particularly difficult field of water repellent silicone treated rainwear fabrics. Lapels are also particularly favoured for coating multi-range interlinings for men's and women's wear since they equalize differences in temperature caused by the variation of thickness between coat-tail and shoulder areas[31].

Hot melt is similar to paste printing except that molten resin is printed onto the backing fabric. The system requires resins that are viscous at low temperature having good thermal stability[41].

Preformed fusible net is a web of resin dots with thin interconnecting filaments[41]. The web is fixed to the fabric backing by heat and pressure. This results in shrinkage or contraction of the interconnecting filaments into the resin dot[41].

Spray coating is a random coating method resulting in a cob web like deposit resin on base cloth[41,74]. This can be done with molten adhesive or from solvent systems[41].

Net film coating is used primarily for fusibles on shirt collars and cuffs[74]. A thermoplastic foil is applied to the base fabric in a continuous motion as it is formed. The foil is then welded to the fabric as it passes through hot roller and cooling zones. The interlining results in a hard and stiff handle with a laminate of low permeability.

3.3 Other Aspects

3.3.1 Heating[74]

Powdered resins are normally fixed by fusion in infra-red heated channels with stationary air. If the melting point of the resin is between 160° C and 180° C, a heating zone length of about 30% to 50% of the working speed in m/min is the most satisfactory. Usually 20 to 30 s are available for fixing the powder.

In the case of spraying, it is usual to evaporate the solvent and this is performed in air or infrared heated drying channels.

3.3.2 Particle size

For scatter coating, powders with a particle size between 200 and 350 μm or 300 and 500 μm, depending on the structure and weight of textile material, are used[65, 66]. Powders of this kind are usually produced by grinding on special mills, sometimes by using liquid nitrogen as cooling agent. A broad range of particulars is obtained subsequently and has to be divided into the required particle sizes by passing through sieves. As a ground powder rarely has a shape like a globe but is more or less anisotropic, a certain proportion of larger or smaller particles are always obtained, too[65, 66]. Very fine powders for paste coating are often produced by precipitation from solvents[64]. This process tends to give more spherical and uniformly sized particles but the process is more expensive than grinding[64].

For the powder point process, a particle size between 80 and 200 μm is most suitable because the stencils of the rotary screen printing machine have a thickness of 200 to 300 μm and the engraved printing rolls have an average engraved depth of 300 μm[65, 66]. Powder with a particle size of less than 80 μm would dust off and easily escape out of the agglomerate of the printed but not yet fixed powder point. A coarser powder on the other hand would fill the cavities of the printing roll only randomly thus resulting in an irregular add-on[65, 66].

For the preparation of printing pastes, special minute and globular powders are necessary[65, 66]. The optimum particle size lies in the range between 15 and 30 μm, a small proportion may have a diameter up to 60 μm. Coarser particles yield pastes with bad running behaviour[65, 66]. Therefore, particle size fractions of the various polymers used have to be carefully selected[64].

For *powder* or *sinter* coating, the particle size of the resin powder is an important factor — too large particles leads to an enlarged bonded area and stiffness in isolated areas whereas too small a particle results in an accumulation of resin within the fabric structure and also leads to stiffening[41].

3.3.3 General

Table IX gives some details of certain methods of coating interlinings[31]. Fine fabrics (eg silks, cottons and cotton mixtures) are likely to have a better appearance when fused with a *dot* than with a *sintered* coated interlining[76]. The reason for this is that the resin is regularly deposited forming a more uniform bond whereas the *sintered coated* interlining may well have slightly heavier coating mass in different places. However, *sintered* interlinings are much cheaper[76]. *Continuous coated* fusibles give a high bond strength, but result in stiffening and are used mainly in shirt collars and cuffs and belts which can take advantage of the stiffness properties[41]. *Dot* coating can be developed to have little or no effect on the base fabric, so handle, aesthetics and crease recovery are unaffected and as a result it is the most important method of coating today[71]. For shirt interlinings, low pressure polyethylene *dot* coating is almost the only safe way to guarantee fastness to washing and boiling, air permeability and a textile handle[31].

Although non-woven *scatter coated* fusibles are cheaper, they apparently do not provide the optimum in such desirable properties as handle, drape and performance[25]. *Scatter coated* fusibles have been claimed to be more tolerant of process variations than *printed* fusibles but very little difference in bond strength consistency, handle and wear performance have been encountered[25].

CHAPTER 4

FUSING PROCESS

4.1 Methods

The positioning of the interlining and face fabric influences the fusing conditions and hence the press setting required to give the recommended glue line temperature[77]. The different methods are[77]:

1. *Single fusing* which is with the interlining on top of the face fabric.

2. *Reverse fusing,* the converse of single fusing.

3. *Sandwich fusing.* Two laminates are fused in one operation, commonly with the outer fabrics on the outside and the fusible interlining in the middle. The heat capacity increases and therefore the fusing conditions need to be adjusted.

4. *Double fusing.* Two fusible interlinings are fused to a face fabric in one operation eg chest piece areas of jacket. In this case there is also a need to adjust the fusing conditions.

Reverse fusing advantages include[18]:

1. An adequate bond is produced at lower pressure because the adhesive is drawn into the outer fabric.
2. Less chance of "strike-back".

Conventional (single) fusing advantages[18] are:

1. Less chance of "strike-through".
2. Less likely to produce dye fading in the outer fabric.
3. Since the heat transfer properties of the interlining are known, it is possible to specify the fusing conditions.
4. The interlining is usually thinner than the outer fabric. Therefore the fusing time will be less.

Progress in fusing methods have been reported[121] to be in the direction of *multizonal* interlinings (eg the chest area of a one piece interlining is made heavier than the lower parts to give additional support in that area instead of a separate chest piece) and *double laminate* fusing in the chest area (eg fusing of a chest piece directly on top of the main body interlining). Care must be taken in the latter case that suitable interlining materials are used, eg knitted or specially designed non-woven fusibles. The disadvantage is that the chest tends to be a bit flatter[121]. *Multilayer* fusing is not popular with fusible interlining manufacturers because of temperature variations which can exist (and as a result affect bond strength) as the heat penetrates the various layers[121]. With *sandwich* fusing, although two parts can be fused at the same time, laying up of the parts is difficult and strike-through can cause parts to stick together[121]. It has been suggested[122] that the possibility of combining the lining and interlining into one sandwich fused component should be investigated.

4.2 Fusing conditions

4.2.1 Fusing Press

A very wide selection of fusing presses are available on the market, either of the *tray* press *(flat bed)* type or of the *continuous* type, each with their advantages and disadvantages and specific end-uses. Table X lists some of the general advantages and disadvantages of each[108]. A number of articles[78, 123-128] describe some of the different fusing presses and compare their different features.

TABLE IX

DETAILS OF CERTAIN METHODS OF COATING INTERLINING[31]

Coating Types	Interlining Construction	Adhesives Type	Form	Amount (g/m²)	Melting Range (°C)	Mesh	Range of applications
Sprinkle coating	Woven Non-woven	Copolyamide	Granulate	20-30	95-125	—	Small parts, tapes, collars
		Polyethylene		25-50	95-125		
Powder dot coating (Gravure printing)	Woven, warp knitted weft knitted	Copolyamide	Powder	10-25	60-125	Dot screen 9-25 mesh	Front fusing of textile outerwear, fur, leather, small parts
		Polyethylene		25-30	125-135		
						25-30 mesh	Shirts
Paste dot coating (Screen printing)	Woven, warp knitted non-wovens weft/warp knitted	Copolyamide	aqueous paste	12-28	65-120	Dot screen 9-25 mesh	Front fusing of textile outerwear, fur, leather
		PVC + softener	Plastisole	approx. 50	approx. 100	approx. 17 mesh	Front fusing for rainwear
Double coatings	Woven, warp knitted, non-woven	Copolyamide	aqueous pastes or powders	15-28	Base: 120-135 Top: 100-115	9-25 mesh	Frontfusing for textile outerwear
a) screen-printing, rollcoated b) Screen printing, sprinkle coating	weft knitted	Special polymer			base + top approx. 130		lapels rainwear

TABLE X

THE ADVANTAGES AND DISADVANTAGES OF BOTH TRAY AND CONTINUOUS FUSING MACHINES[90]

Tray Fusing Presses

Advantages	Disadvantages
1. Low maintenance costs	1. Fixed size
2. Applied Temperature very nearly equals resin melt temperature	2. Can affect heat sensitive fibres
3. Easily calculable fusing times	3. Enforced machine waiting times
4. Specific pressure simply adjusted	
5. Simple quality checks	
6. Flexibility in loading and unloading devices	
7. Cooling devices simple to fit	
8. Flexibility of positioning	

Continuous Machines

Advantages	Disadvantages
1. No enforced machine waiting time	1. High maintenance costs
2. Kinder to heat sensitive fibres	2. Applied temperatures must be much higher than resin melt temperature
3. Infinite length	3. Difficult engineering of cooling devices
	4. Stacking devices required complicative engineering
	5. Quality checks difficult
	6. Calculation of specific pressure difficult
	7. Impose rigid work flow

In selecting a fusing press, the important points to consider are[78]:

(a) Built-in safeguards to prevent loss of heat

(b) Ability to maintain constant and equal heat over the whole fusing area

(c) Ability to ensure even pressure at every part.

To eliminate possible fusing problems, it is advisable to purchase a good fusing press, especially for large area fusing[78]. However, there are comparatively simple and inexpensive presses which would be adequate for small part fusing of garments with short wear-life[78].

The variables involved in the fusing machine are:

1. Temperature of heaters in the machine.
2. Time of fusing.
3. Pressure on the fabric.

4.2.2 Temperature

The bonding process can be illustrated with the aid of the bond strength vs glue line temperature curve in Fig 1[12]. No bonding occurs until the resin

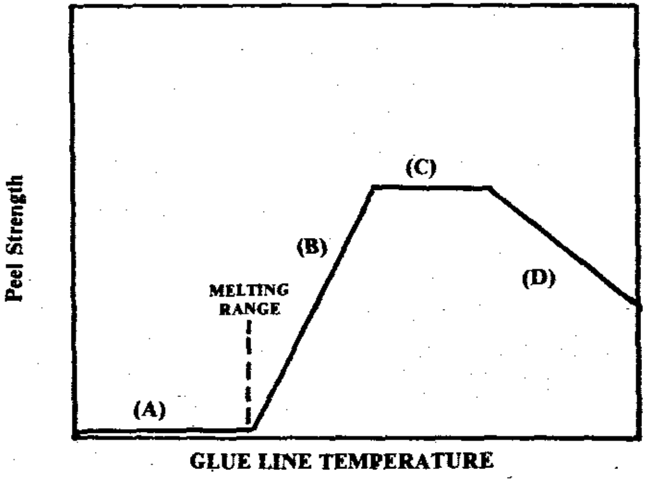


Fig. 1 – Glue-line temperature vs peel strength (schematic)

attains a temperature near its melting range (section A). As melting occurs, the resin viscosity decreases, and it begins to flow into the fabric so that bonding can occur. As the glue line temperature continues to increase, resin viscosity continues to decrease, resin flow subsequently increases, leading to a stronger bond (section B) until a maximum bond strength is achieved (Section C). Further temperature rises lead to further movement of the resin which can lead to objectionable resin strike-back and strike-through which reduces the bond strength (Section D). The shape of the curve will naturally vary with different resin and fusing conditions[12].

The strength of the bond between the interlining and the outer fabric depend on the temperature attained by the *adhesive* i e the temperature at the interface between the interlining and the outer fabric termed the *glue line temperature*[19]. If the temperature is too low there would be inadequate spreading of adhesive at the interface and if the temperature is too high there would be excessive flow of the adhesive away from the interface, both causing lower bond strengths[19, 27]. There is, therefore, an optimum glue line temperature for maximum bond strength[19, 27]. Results show that a wide range of glue line temperatures exist when fusing cloths of different mass/unit area and between fusing through the outer fabric and through the interlining. In one particular case, an optimum glue line temperature of 140° C was found for a particular interlining (Staflex S24 PVC adhesive) producing maximum bond strengths[19]. The time to reach the glue line temperature and the air line pressure were of secondary importance and the effects depended on the nature of the outer fabric and the interlining used[19].

The temperature of the press determines the glue line temperature and it is important that this is within specified limits, depending on the adhesive, in order to produce a laminate with adequate bond strength and optimum stiffness[18].

The bond apparently becomes more permanent (generally) as the temperature is increased but high temperatures may result in dye sublimation or even yellowing[24]. For a press that heats from one side only, press bucks should be heated to temperatures of 20 to 30° C higher than that required for bonding since the passage of heat through outer fabric or interlining can lead to temperature losses of 15 to 20° C (see Fig 2)[24].

Elsewhere it has been stated that it is usual to set the press about 10° C higher than the required final glue line temperature so that the time to reach the final glue line is not excessive (e g a final glue line temperature of 140° C would be obtained by setting the press at 150° C for a fusing time of 15 s)[18].

The usual temperature range for fusing (press temperature) will be between 150 to 160° C and this is considered a safe upper limit for most fabrics[67]. Synthetic fibre fabrics will, however, sometimes shrink excessively at this temperature[67].

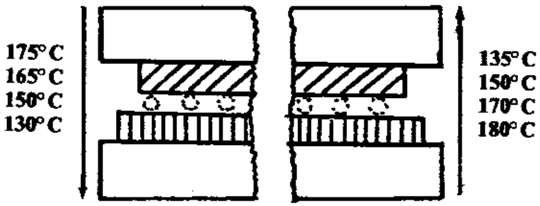


Fig. 2 – The drop in temperature during fusing according to whether the heat is transferred from the top or bottom platen.

Glue line temperature is subject to a number of variables[14]:

1. Type of resin system.
2. Type of equipment being employed for fusing.
3. The individual substrate characteristics of the chosen interfusing.
4. The fabrics being fused.

Some manufacturers are convinced that greater production results if shorter fusing cycles with higher temperatures are employed. However, production rate depends upon the operator's speed and efficiency[14,73], and often the extreme temperature which fabrics can be subjected to can have injurious effects (e g excess shrinkage, discolouration, strike-through etc)[14]. Work study of the loading is suggested[73]. The pressure applied must be sufficient to adequately drive the resin into the outer fabric but must not cause strike-through or a change in handle[14].

Wagner[79] discussed the importance of temperature and pressure in fusing (tray press). When fusing takes place, the heat is transferred from the heated plate through the layers of the unit and consequently there is a descending temperature curve depending on the conductivity of the different layers (see Fig 3). Wagner recommends that the bottom plate be heated by steam and that the plate covers should be as thin as possible but must remain even. Better heat transfer is apparently obtained by heating the bottom rather than the top plate but this increases the risk of strike-through. Wagner has recommended certain temperature and pressure control systems[79].

All fibres contain moisture, natural fibres considerably more than synthetics, and during fusing some retained moisture will be released affecting the temperature[80]. Atmospheric conditions prevailing in the factory and

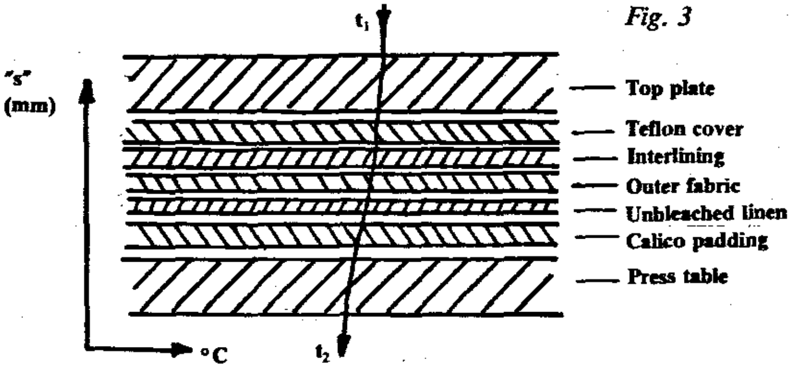


Fig. 3

therefore storage conditions of top fabrics and interlining are important. Each fabric has a different thermal capacity and this depends on fibre type, fabric thickness, fabric construction and surface characteristics[80].

Studies on a flat bed press with the upper head electrically heated proved that a certain period is required for heat to penetrate the interlining with the glue line temperature approaching the head temperature asymptotically, although it never actually attains the head temperature[12]. In addition, the use of various pressure and types of backing fabrics has a marked effect upon heat transmission. The following equation has been derived for relating the temperature of the glue line (T_G), the buck (T_B) and the head (T_H) to the fabric and the time cycle (t):

The rate of heat transfer is given by $\frac{d \Delta t}{dt} = - kt$

and by substitution and integration:

$$2{,}3 \log\left(\frac{T_G - T_B}{T_H - T_B}\right) = kt$$

where k is a constant proportional to the insulation value of the interlining[12].

The type of heating elements and their position in the press are important[81]. The actual temperature must be close to the thermostat setting and the thermostat must control the setting within a limited range. The position of the elements must be such to minimise heat loss[81]. The heat capacity of materials used on the presses (Teflon sheeting on flat-bed presses or belts on continuous presses) must be taken into consideration when setting temperature. Methods of measuring the temperature are with a pyrometer or thermopapers, the latter being the only effective way on continuous presses[81]. Thermopapers, however, only indicate the maximum temperature and do not show possible variations in temperature[77, 81].

Precision heat controls and uniform heat are of the utmost importance and in some instances steam should be introduced to speed the action and to cause a cross-linking between the two materials[76].

In principle, the best working conditions to attain the same adhesive temperature, irrespective of cloth type, are those where the head and buck working surfaces are at the same temperature and the fusing time is sufficiently long for the adhesive to reach this temperature[25]. In practice, however, it is preferable to have the platen adjacent to the cloth at a lower temperature (5 to 10° C lower than the other) thus eliminating any risk of thermal damage[25].

Maintaining the required pressure and temperature *evenly* throughout the press is apparently the most difficult problem in fusing[73]. Presses can loose heat in a number of ways:

(a) As the press is opened.

(b) Evaporation of moisture in outer cloth.

(c) Moisture accumulation in damp pressing pads.

(d) Cooler bucks, trays or conveyors moving into the heated area.

(e) Damp or cold cloth which is being fused.

Excessive temperature should be avoided since excessive drying tends to give a harsh handle[73]. Excess heat also causes the resin to deteriorate and reduces its mechanical strength[82]. A relatively steep rise of temperature on the interlining and outer fabric will cause a "shock" heating up which can lead to a considerable increase in shrinkage of the laminate and strike-back on very light interlinings[83-84]. It can also result in variations in bonding when sandwich fusing. To eliminate these disadvantages, Meyer has produced the RPS continuous fusing press which have two heating zones. After the first heating zone, pre-fusing is effected by means of intermediate press rollers. Final fusing then takes place in the second heating area followed by the main fusing rollers. By means of the longer heating zone, slower and more careful warming up is obtained, avoiding the "shock" of rapid increases in temperature. The shrinkage results found for this system equal those of a tray fusing press. Furthermore, they have introduced a Variotherm programme system on which the heating curve can be pre-set (Fig 4). A slowly rising temperature at the early stage with a little steeper at a later stage prevents the danger of penetration of certain types of interlining.

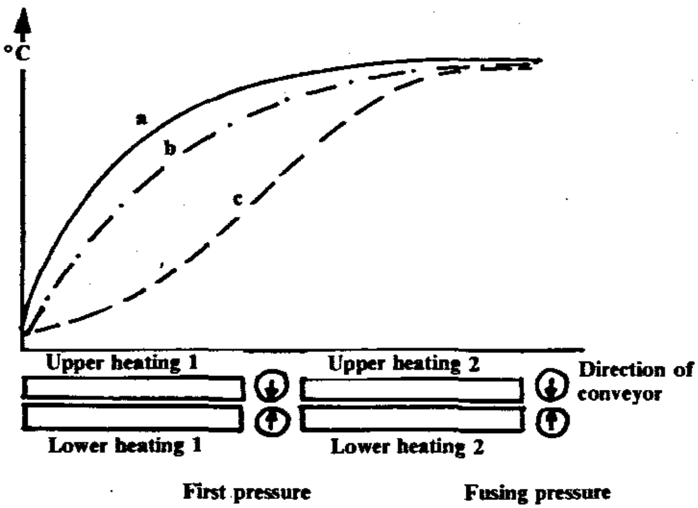


Fig. 4 – Heat-up curves on the RPS unit, variotherm system

Fabrics which are difficult to warm-up, and consequently difficult to fuse, would require a steep rise in temperature at an early stage. Sandwich fusing of different heights of garments at uniform fusing settings require a fairly steep rise of temperature at the beginning and then a more moderate curve[83-84]. Elsewhere[24] it has been stated that preheating before the fusing stage results in shorter application of heat for a required glue-line temperature.

Electrical heating is virtually the only kind used in fusing presses because of easy regulation[24]. Radio frequency heating has also been used for welding fusible systems[41]. Ultrasonics is another method which has received some attention[41].

The need for thermostats on all presses to be correctly set by manufacturers is emphasized by Dorkin and Chamberlain[85]. For a given dial setting, it was found that the actual temperature reached by the sample depended on the time that the press was closed and only after periods of 60 s or more does it approximate that shown on the dial. In all the presses examined, they found variation in temperature from point to point over the buck area to lie within what may be considered normal commercial limits[85].

To avoid delamination in subsequent finish pressing or pressing after dry-cleaning or laundering, the initial fusing should occur at temperatures higher than the garment will be subjected to in steam pressing at any subsequent time[3].

4.2.3 Pressure

Pressure is applied to the parts being fused to ensure[81]:

1. intimate contact between fusible interlining and outer fabric
2. adequate heat transfer
3. controlled even penetration of the resin into the outer fabric.

To test the pressure, the bond strength of a number of samples fused in different positions over the whole area of the press, should be tested[81]. The range of pressure recommended for most fusible interlinings is in the order of 14-28 kPa at the buck[67].

Dorkin and Chamberlain[85] carried out extensive studies on the temperature and pressure variables on a number of flat bed presses. They concluded that the pressure exerted on a sample in a flat bed fusing press is a variable quantity depending on the *sample* (area, thickness and compressibility) and the fusing *press* (compressibility cladding, flatness of the head and buck surfaces and its variation with temperature). Pressure applied to normal size samples (700-800 ins^2 or two jacket fronts) was found to rarely exceed 17kPa (2,5 lbs/ins^2) but on smaller samples (those used for test purposes) may be three times as great[85].

Fusing pressures used are usually less than 28 kPa (4 lbs/ins^2) although higher pressure may be desirable for fusible shirt linings. For solid platen presses the approximate actual pressure on the fabric is given by[18]:

$$\text{Actual pressure} = \text{Nominal pressure} + mt\,(1\text{-}R)$$

where Nominal pressure = Force applied to press ÷ area of platen and
m = compressive modulus of press clothing

t = thickness of fabric to be fused

R = ratio of area of fabrics to area of platen.

Experiments showed that for typical values, the *actual* pressure is likely to be about 50% higher than the *nominal* pressure[18]. The pressure of head on to the buck is the vital factor and not the air line pressure in the case of a tray type press[73]. The former can be calculated from the air line pressure:

$$\text{Fusing pressure} = \frac{\text{air line pressure x area of ram cylinder}}{\text{fusing area}}$$

There is a certain relationship between pressure and the flow properties of adhesives as well as the nature of the cloth surface, since adhesion is dependent on the penetration of the adhesive into the interstices of fabric and yarn[73, 86]. If the adhesive flows freely at the fusing temperature, pressure need not be high. Similarly, if the material has an open surface or is absorbent, pressure can also be fairly low. The position is, however, reversed if the flow point of the adhesive is high and the surface of the material is smooth. If the fabric has a hairy of fibrous surface adhesion will be difficult since the fibres tend to hold the resin away from the base cloth[73, 86]. However, it is always preferable to avoid excessive pressure since it drives all the moisture from the cloth and hardens the handle. *Time* is related to pressure and temperature to the extent that if fusing time is lengthened pressure may be lightened and this is usually required for more delicate fabrics and those with a pile[86].

When fusing, heat can reach the adhesive through the interlining (conventional) or through the outer fabric (reverse)[73]. For reverse fusing, lower mechanical pressure is said to be required and adhesion formed by the flowing of the adhesive gives a stronger bond. The low pressure is also claimed to minimise the flattening of yarn, reduce shine and avoid strike-back. The disadvantages are considered to be that there is more chance of strike-through and each cloth would require a different time and pressure for fusing according to its mass and porosity. Pressure and time can apparently be standardised better by passing heat through the interlining first[73, 87].

Excessive pressure will increase the stiffness of the laminate[18] and thins the glue line causing "strike back" resulting in a weak bond and unpleasant feel[82]. Uneven pressure and temperature causes a patchy bond[82].

Pressure is apparently not as important for good bond strength as temperature and time, but has a considerable influence on evenness of adhesion[24]. Parts varying in size experience different pressures because pressure decreases as the area of contact increases[24].

The pressure is influenced by the cladding, hard cladding requiring lower pressures than soft cladding[73]. Silicone rubber has been found to be a good compromise. With increased fusing time, pressure can decrease and this is usually required for more delicate fabrics and those with a pile[73].

Pressure does provide better bonding but there appears to be two responses depending on the fabric[12]. With compressible fabrics, increasing the pressure may result in moderate increases in original bond strength; as high pressures are approached, however, this effect may disappear. With relatively uncompressible fabrics, the effect of pressure at the lower levels is even less significant and actually may reverse at higher pressures. This is probably the result of the resin being squeezed from the interface and possible modification of capillary movement of the molten resin within the fabric by the elevated temperature[12]. Excessive pressure can also have a marked effect on resin strike-back and strike-through and on fabric stiffness[12].

The simplest and most practical way to measure uniformity is to fuse an interlining to a face fabric of sufficient size as to *cover* the *whole* fusing area of the press[60]. The adhesive strength between the fabric plies is then measured on a number of strips cut from this piece so that a picture can be built up of adhesive levels attained over the whole fusing area[60].

The problems which can arise on flat bed presses are insufficient air from compressor, scissor type press not closing properly, warped metal bucks, worn padded bucks etc[81]. On continuous presses, debris often becomes trapped between the belts and the rollers causing uneven pressure and roller wear can also result in uneven pressure. The actual pressure applied in continuous fusing presses by the roller system is not only a function of air pressure applied to the cylinders but also the diameter of the rollers and the shore hardness and thickness of the rubber covering used[81].

4.2.4 **Time**

The time cycle used for fusing depends on the type of interlining and resin used, the type of application, the nature of the outer fabric and the type of fusing equipment being used[81].

The recommended fusing time for most fusibles is between 7 — 12 s, 10 s being the most common[67]. High temperatures with shorter times are likely to have an adverse effect on fabrics and uncontrolled fast flow resin with possible strike-through. Slower fusing times allow temperature variations to even out[67].

Although limited temperatures are achieved, fusing by steam press, apparently requires less time to achieve the maximum glue line temperature (2 - 3 s) and is little affected by fabric mass, thickness or thermal insulation provided the fabric is sufficiently porous[22]. However, plasticisation of some resins by the moisture present in steam is a problem[22].

The fabric density factor (mass/unit area of fabric x fabric thickness) was found to influence the time for maximum peel strength when fusing through the fabric. The greater the density factor, the longer the time required[88].

4.2.5 **Cooling**

Two methods of cooling exist — parts are laid out on conveyor belt or frame sufficiently long to cool down or passed over a vacuum table to effect the cooling[89]. Before a fused laminate is removed from the press, it must be cooled to a temperature below the softening point of the adhesive[89]. If handled too soon, deformation (fingerprints) can occur and remain permanently shaped into the laminate especially when using lightweight fabrics[17, 12,27,41,89]. Some resins which undergo a crystallisation process may require several hours at room temperature in order to develop their maximum bond strength and durability[12]. Thorough cooling of the parts after fusing can, therefore, be very important for evenness of bond strength. Parts which are subjected to irregular movements while hot have been found to have a third of the usual bond strength at these points[24].

A fusing press should contain a cooling device which must be capable of reducing the temperature of the fused assemblies to approximately 27°C without affecting the productivity of the fusing machine[90]. Little change in productivity is however likely to occur at this temperature[90].

4.3 Strike-through and strike-back

Strike-through is the accidental forcing or flow of adhesive through the outer cloth particularly on lightweights[73]. Excess pressure is usually the cause. *Strike-back* is the accidental forcing or flow of the adhesive to the back of the interlining[73]. When this occurs the adhesive will be transferred to the head of the press and contamination results when fusing conventionally[73, 87].

Heat may be passed to the glue line either through the interlining (conventional) or through the outer fabric (reverse) or from both sides. There is controversy about which is the best of the former methods, the argument being based on the theory that the adhesive will tend to flow towards or away from the hot side.

Fusing with heat through the cloth (i e reverse fusing) is claimed[88] to make use of the natural properties of an adhesive causing it to flow into the back of the cloth (i e it initially softens slowly, then melts and wicks by capillary action towards the heat source). Low pressure conditions are needed which minimises the flattening of yarn and so reduces shine. The laminate is said to have a substantial loft. When heat is applied through the interlining (i e conventional fusing), the spot of resin becomes heated first and any wicking action will occur back into the interlining. It is therefore necessary to go to the point where the adhesive becomes sufficiently soft to allow it to be squeezed into the cloth under high load. Low loading also allows steam (driving out of moisture in fibre) to escape more easily and the collecting of water in hollow parts or in the cladding is avoided and the rate of temperature is not affected[88].

Fusing with the heat through the cloth is said[24,25] to be unrealistic since the outer fabric is in contact with the hottest platen and this increases the risk of inducing deleterious thermal effects e g colour change, surface distortion, etc. It is felt that the adhesion between fusibles and outer cloth is almost entirely brought about by physical entanglement of the melted adhesive and the yarns and fibres of the cloth, under the influence of pressure and temperature[25]. If heating is taking place *through* the interlining, there is a probability that the outer fabric (which is now at the bottom) will not be heated sufficiently for the adhesive to flow into it[24]. Therefore, the adhesive might flow back into the interlining and cause strike-back. It is suggested that heating from both sides is the best solution[24].

On a tray fusing press, heating from the "head" of the fusing press, strike-back rather than strike-through is likely to occur because the adhesive will flow towards the hotter side[91]. With this type of fusing the heat is next to the interlining and, therefore, there is less chance of damaging the outer fabric. If, however, the heating is done from below, i e through the outer fabric, apparently a better bond is achieved because the adhesive will tend to flow into the outer fabrics as this is the hotter side, reducing the likelihood of strike-back[91].

Lighter fabrics used by the dress and blouse trade are in greater danger of adhesive strike-through than heavier fabrics and are often quite delicate and easily damaged by high temperatures especially synthetics[38]. Knitted outer fabrics require fusibles which move with the knitted structure yet holding it firm where needed e g front edges[38].

A method of testing the strike-back which might occur during fusing has been proposed[67]. It is recommended that a piece of the laminate be folded over on to itself and pressed on a steam press at maximum pressure. A quantitive measure of the strike back can then be obtained by peeling the two layers apart as in a bond strength test. The test is said to be very severe but can be useful as a guide[67].

4.4 General Comments

A very comprehensive guide to the quality control of fusing has been published by BIMA[92]. A trouble shooting guide is presented in a number of articles[93-96]. An information sheet by the Clothing Institute gives some of the main causes of difficulties during fusing and indicates ways in which these can be detected and overcome[100].

A Canadian firm maintains[98] that a Quality Check Chart on fusing conditions should be filled in regularly and this must include:

1. Bond peel strength several times a day.

2. Check temperature of fusing press at least twice a day.

3. Dry-cleaning test on sample to check bond after dry-cleaning at least once a day.

4. Check evenness of pressure at least once a week.

5. Cleaning of the buck and head covers to remove excess fusing agents once daily.

Advice on what conditions and properties to check before fusing have been discussed in another article[99]. A number of fusing quality and production procedures have also been listed by Union Special[3].

When fusing onto knitted fabrics, it is important to consider the following characteristics of the knit fabrics[40].

1. Elasticity.
2. Tendency to cause laddering and material yarn breakage.
3. Tendency to change in appearance during fusing process.
4. Directionality.
5. Crease recovery.
6. Washability.

Due to its structure, poplin is difficult to fuse particularly when highly siliconised for water repellent properties, and adequate results cannot be obtained with normal fusible interlinings[101]. Moygashel, harsh worsteds, polyester and worsted mixtures are also apparently difficult to fuse[76].

To eliminate soiling of the press it has been suggested[89] that interlinings are cut 5 mm smaller than the part to be fused. The recommended fusing conditions for a number of lightweight fusible interlinings of different manufacturers are given in a Table[38]. Figs 5 - 7 show temperature vs time curves for the fusing of three Staflex grades of fusible interlinings[102]. Illustrated are the safety zones for good fusing[102]. Methods for calibrating a flat bed press and a continuous press have been given[18]. Two other articles[90,104] deal with the whole fusing process in general.

In conclusion therefore, failures in fusing can be divided into several main headings[103].

(a) Incorrect selection of interlining quality.

(b) Incorrect choice of outer fabric.

(c) Incorrect operation of the fusing press.

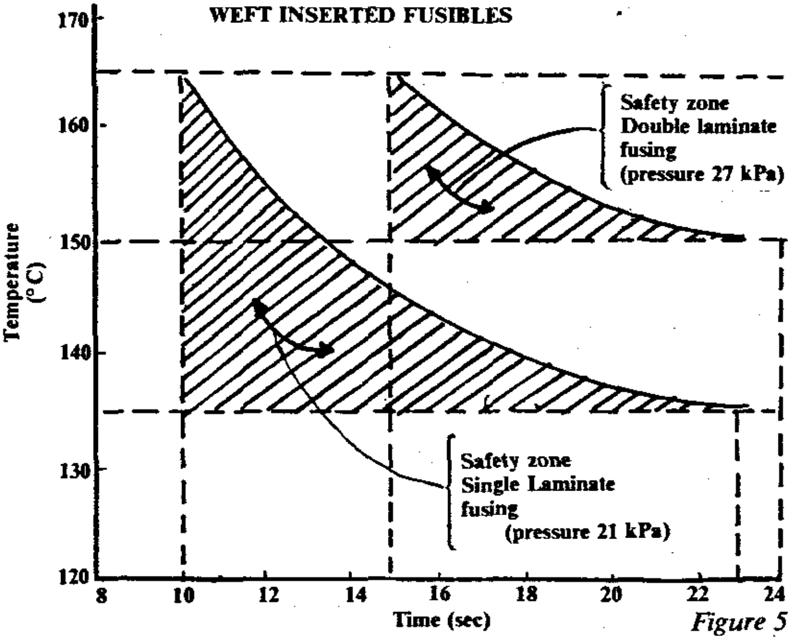


Figure 5

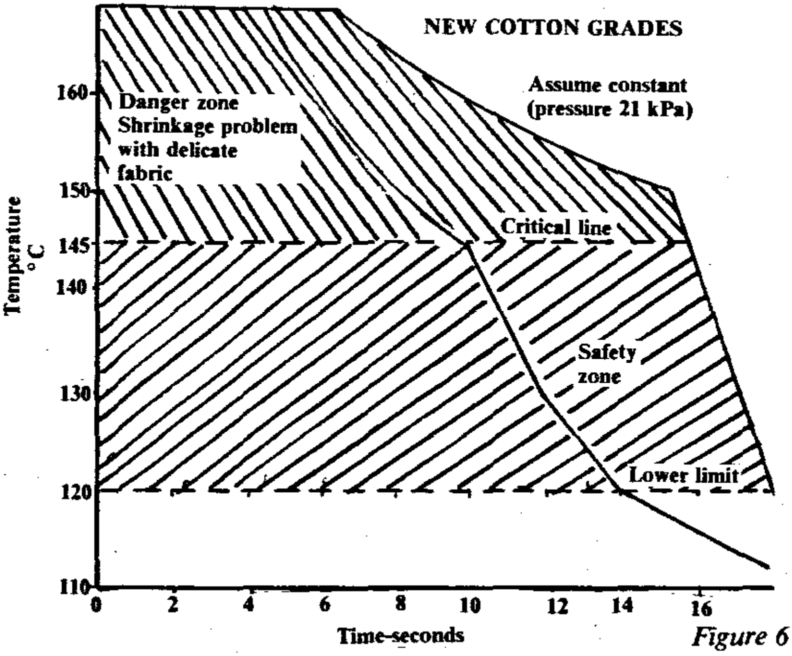


Figure 6

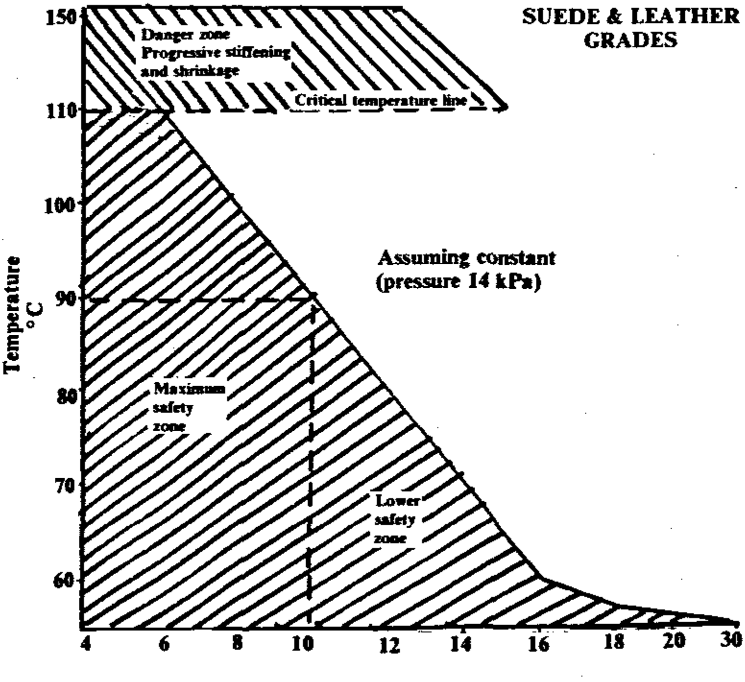


Figure 7

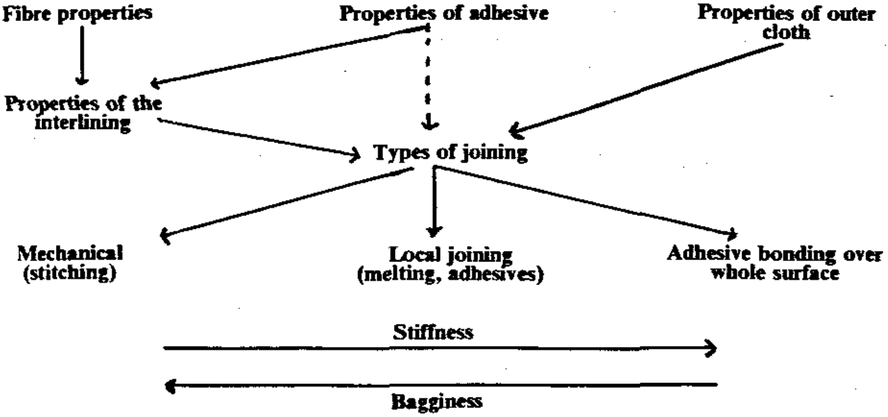
CHAPTER 5

LAMINATE PROPERTIES

5.1 Physical Properties

The properties of the laminate will naturally depend on the properties of the outer fabric and the interlining, the type and application of adhesive and the fusing conditions.

The properties of interlinings should only be evaluated after they have been fused[42]. However, testing the properties of the actual lining will serve as a guideline for the selection of suitable types of interlining for various garments. The composition of the outer fabric should serve as a guide for the choice of interlining as well, e g fibre type, special finishes, structure. The most important properties of interlining fabrics have been listed together with some test methods and specifications[42]. The properties, or more specifically the stiffness and bagginess of the resultant laminate, are affected by properties of the different components as follows[42].



The influence of face fabric and interlining properties on the laminate properties have been studied by Shishoo *et al* [105]. *Extension stiffness* of the laminate was found to be nearly equal to the sum of the extension stiffness of the components at the same level of extension. Highly correlated linear relationships were obtained between experimental and calculated extension properties, these apparently being independent of adhesive type, adhesive distribution and the nature of the base cloth. The *shear stiffness* depended on the type of adhesive deposition. The *bending stiffness* of the laminate was four to ten times greater than the sum of the bending stiffness of its components. The relative orientation of the face and interlining fabric was an important contributing factor in the stiffness measurements. The wrinkling measurements, although limited in their range, proved that the wrinkling behaviour of the laminate was determined by the wrinkling propensity of the interlining[105].

Shiloh[106] tested the wrinkling and bending of laminates where different interlinings was fused to wool and cotton outer fabrics. She found that in the dry state, cotton fabric wrinkled slightly more than cotton-wool fabrics but in the wet state this order was reversed. Fusing inhibited recovery from deformation probably owing to the larger frictional restraint after fusing. The order was slightly reversed in the buckling test. Generally, the bending and wrinkling performance of the composite fabrics was found to be affected more strongly by the properties of the lining fabric than by the properties of the face fabrics[106].

Elsewhere it was found[21, 68] that the bending stiffness and the crease recovery angle of a laminate increased with the mass of the fusible interlining but other factors (eg type of adhesive, quantity of adhesive, fusing conditions) could have made a contribution. Repeated dry cleaning of the laminate with non-woven fusible, reduced the drape (became soft and limp). A laminate with a wool fusible (lightweight worsted outer fabric) although significantly softer than a corresponding one with cotton fusible, had better crease recovery for both sharp creasing and light random creasing[21]. The laminates were found to be stiffer in the warp direction than in the weft direction. With a particular interlining, the bending stiffness of the laminate was found to increase with time, reaching a maximum at about 20 s. The crease recovery, on the other hand, decreased with an increase in fusing time[21].

The four factors affecting the laminate handle are[3, 17]:

1. Fusible material

2. Pressure

3. Temperature

4. Time

The *type of adhesive* can play an important role in the fabric properties eg softer handle are obtained with adhesive of high specific adhesion — 15 g/m^2 of polyamide gives the same adhesion as 25 g/m^2 of high pressure polyethylene or 40 g/m^2 of PVC[11]. Differences in coating mass can naturally affect the handle and drape, particularly on fine fabrics[11].

The choice of coating method can also have a significant effect on the handle, adhesion and possible show through on certain fabrics[11]. Scatter coating produces a medium handle, making it suitable for a range of both inter- and outerwear applications but not for demanding applications. Paste prints tend to be a little firmer than the equivalent powder coating. Dot coating gives a laminate which is much softer than any previously available. In fact, dot coating can be manipulated to have little or no effect on the properties built into the base fabrics in terms of handle, aesthetics and crease recovery[11].

The size and spacing of the printed or scattered dots also affect the finish of the fabrics e g fine dots more widely spaced produce a softer finish than large dots closely spaced[39].

Raising the back of the fusible has been found to produce a softer laminate, leave the crease recovery (heavy creasing) unaffected and improve the wrinkle recovery significantly[21]. The *face fabric* can also produce problems during fusing (e g thermal shrinkage in the case of synthetics, pile crushing in the case of velvets and corduroy, handle change for leather and suede, etc[11].)

It has also been found that an interlining which produces desirable properties when fused to one type of fabric need not necessarily be compatable with another[21].

5.2 Bond strength

The fusing conditions are chosen to produce an adequate bond strength and at the same time to produce a laminate of desirable stiffness[91]. However, faults due to incorrect fusing eg. strike-through, strike-back, dye sublimation etc., must be avoided[91]. A good bond has been formed when a fusible interlining is peeled away from the outer fabric and an equal amount of resin adheres to the interlining and the outer fabric[17].

The causes of a poor performance of a bond can be a result of a number of factors[29]:

1. Improper curing.
2. Insufficient adhesive.
3. Variation in adhesive distribution.
4. Excessive penetration of adhesive into the shell fabric.
5. Poor combining of component fabrics.
6. Differential shrinkage during drying.
7. Slippage of outer fabric over tricot.

In addition, the strength of the bond depends not only on the dry-cleaning or washing medium but also on the fusing methods and type of fibre and fabric[18]. A stronger bond can apparently result from "reverse" fusing[22].

It was proved by Rose and Zeligman[107] that adhesion (bond strength) increases with temperature up to a point and then falls steadily. The temperature at which this maximum occurs depends on the *resin* and the *fabrics* comprising the laminate. Increase in adhesion by increasing time was found to be true only over a small range of temperatures[107].

Disher reported[73] that bond strength increases with time at a constant temperature of 170°C but an optimum is reached whereafter it drops dramatically. An increase in time, at a lower temperature (130°C) on the other hand, will increase the bond strength progressively although it will be lower[73].

Cusick and Cook[91] reported that optimum bond strengths were found for shorter fusing times with higher press temperature (PVC dot coated cotton fusible interlining onto a worsted suiting of 237 g/m²). Furthermore optimum peel strengths occurred at a glue line temperature of 155° C (PVC adhesive) but the relationship depended on the type of adhesive used. An increase in pressure on a tray fusing press had little effect with a PVC adhesive, but an increase in pressure from 14 to 28 kPa increased the bond strength of the laminate by 25% when using a polyamide adhesive[91]. Pressure changes had no effect on the drape coefficient or stiffness of either type of adhesive[91].

Crow[108] also found that bond strength increased with time and/or temperature until it reached a maximum. In addition, the majority of interlinings gave a higher bond strength when samples were fused with the suiting next to the heat source. However, the latter depended on the nature of the interlining and the outer fabric, especially the mass of the fabric[108].

Research at Isaac Braithwaite[82] also found, after a series of tests, that bond strength shows a maximum with an increase in time (temperature and pressure kept constant). An increase in pressure also showed a maximum bond strength (the other variables kept constant)[82].

Microscopic studies on fused laminates produced some interesting observations[108]:

1. Under the same conditions of time and temperature, some adhesives became more fluid than others and so accepted the fibres of the outer fabric more readily, thus forming a stronger bond.

2. Rough surfaced fabrics (e g those comprising textured yarn or wool) were much easier to fuse as they keyed into the adhesive more readily, giving a good bond under less severe conditions than was necessary for smooth surface fabric.

3. At very short fusing times, the adhesives penetrated the outer fabric more readily if the fusible interlining was nearer the source of heat. At longer times, there appeared to be no difference.

4. Strike-through appeared to occur only when the interlining was fused to an outer fabric which had inter-yarn spaces sufficiently large for the adhesive to pass through and also when the interlining did not match the outer fabric.

It has been suggested[67] that an initial bond strength of about 560 cN (20 ounces) is considered adequate for satisfactory performance. However, some resins decrease in bond strength during dry cleaning, some remain virtually unchanged and some actually increase. The relative wet shrinkage of the two components, coupled with the flexibility of the outer fabric will also affect the performance of the bond subsequently[67]. Elsewhere 1100 cN/5 cm is generally considered to be an adequate bond strength[91].

The bond strength laid down by Jantzen[86] to be commercially acceptable is between 440 and 560 cN measured with a 2,54 cm width of fabric. This does not mean a good performance of washing and dry-cleaning and therefore standards have been set for values after cleaning. These are:

Printed interlinings > 440 cN/2,54 cm width of fabric for 100% tested samples.
Sintered interlinings > 440 cN/2,54 cm width of fabric for 75% tested samples.

Dorkin[75] concluded after a number of experiments on a range of fabrics and interlinings that the interlinings which gave laminates with high initial bond strength and good resistance to dry-cleaning and flexural fatigue did not give good draping properties.

Werner[57] recommends testing bond peel strength on 2 or 4 cm width of fabric at a peeling speed of 200 mm/min. To guarantee the durable use of a garment, he suggested a bond strength of at least 490 cN (measured on 2 cm width of fabric).

Apparently tests have shown that bond strength may decrease by 25% if parts are moved uncooled[86]. There is a tendency to assume that the *best* or most desirable bond strength is the strongest but this need not be the case. A very high bond strength may be obtained at the expense of other desirable properties such as loss in handle, low crease retention etc[86].

It is suggested that peel strength be carried out *dry* and *wet* after dry cleaning or washing. The dry peel strength is a good measure of an adhesive bond but few fabrics will ever delaminate in the dry state. The results of many tests proved that samples with good durability to home laundering and dry cleaning have a range of peel strength values as follows[29]:

	Peel strength (cN)/ 2,54 cm strip
Dry	334-445
Wet after laundering	112-167
Wet after dry cleaning	112-167

Since there are a number of ways of interpreting the stripping force of a laminate, Dorkin and Chamberlain[109] have suggested the use of *bond energy* (i e energy required to separate the two components) as a measure of bond strength. In addition, the "spread" should be calculated from the standard deviation and the mean value to give a direct measure of the irregularity of the bond energy. This spread will give an indication of the weaker parts in the bond, which naturally will be the first to delaminate[109].

A test for determining the resistance of a bond to dry cleaning has also been suggested by Dorkin and Chamberlain[109]. This involves shaking 30 x 5 cm conditioned samples in bottles of an end-over-end bottle shaker. Dry solvent is used and a temperature of 30° C is maintained throughout the shaking which is run for 20 min (1 000 revolutions) at about 50 revs/min. This is followed by tumble drying for 1 hour at 60° C. After conditioning, the samples are tested for bond energy. They have found that a change in bond energy, if any, is found after the first or at the most after the second dry cleaning treatment. Irregularity in bond energy can also be determined[109].

Another test which these authors[109] consider necessary is the *resistance of the bond to wetting* and *drying*. This just means soaking tests strips in water containing a little wetting agent for 5 mins at 30° C without agitation. The samples can then be examined for bubbling and the bond strength tested wet. Polyamide adhesive interlining will normally show reduction in bond strength. Two apparatus and test methods for the determination of the *resistance of the bond to flexural fatigue* have also been discussed. Standard test methods for measuring the *drape and crease resistance of a laminate are proposed*[109].

A number of different methods used by manufacturers to test the bond have been given[73]:

1. Bond peel strength test but the test is apparently only effective for comparing different fusings of the same cloth and interlining since a higher or lower force on another laminate does not mean any better or worse a bond. This test is only effective on woven interlinings.

2. Subjecting fused fabric to dry-cleaning.

3. Flexing test which involves a concave rolling of the fused test piece.

4. UV light cabinet can detect duller, darker or brighter shades denoting overfusing, underpressure and overpressure respectively (a fluorescent must be included in the resin).

5. Other tests include exposure to all weather conditions (sunshine, cold, heat high humidity etc), flexing tests, shrinkage tests[73].

Crow[108] has reported on the simple methods of determining the bond strength of fusible interlinings. A spring balance is unsatisfactory since the hook distorts the fabric, a constant rate of stripping is impossible, fluctuations occur in the readings and many spring balances are not accurately calibrated. The quadrant type of tensile tester is too expensive and it is difficult to define exactly what it measures. In addition, no correlation was found between the transfer ratio (amount of adhesive transferred from interlining to the outer fabric) and the bond energy[108]. Finally Crow[108] proposed a simple method of determining the bond strength which produced results found to correlate, within limits, with bond energy results determined on the Instron. The test method is quite simple. On a suitable gallows frame, a screw clamp is attached from which one component of the laminate to be stripped is attached to the other component and increasing weights are hung from it until the laminate strips rapidly and decisively. This is then designated as the stripping force of the sample[108].

Kaltsoyannis and Crow[85] have suggested a level of bond strength (based on a series of tests and the opinion of industry) below which a laminate bond should not fall. This is 18 oz/inch (980 cN/2" strip, bond energy = 392 cN.cm/cm². The average coefficient of variation as a measure of the variability of the bond, should be 12% with an upper limit of 20% but this only gives an indication of the possibility of bubbling in a particular case and has its limitation. It was also concluded that a laminate which has an original bond energy of less than 196 cN.cm/cm² may cause trouble on subsequent dry cleaning and flexing to an extent which depends on how much below 196 cN.cm/cm² the original bond energy falls and the irregularity of the bond energy.

A method of evaluating the adhesion of interlining to an outer fabric using the Elmatester has also been reported[111].

5.3 Shrinkage and colour change

A recent survey carried out by WIRA revealed that critical problems encountered by clothing manufacturers, besides shrinkage during fusing, were steam shrinkage and lack of dye fastness at high temperatures[36].

Major complaints received elsewhere about the poor performance of certain laminates have been two-fold[29]:

1. Shrinkage caused by combing dimensionally unstable fabrics.

2. Delamination due to either the use of poor adhesives or to the improper application and/or lack of curing of good adhesives[29].

Two particular problems are reported by Marks and Spencer[60] to disrupt fusing production:

1. Fabric shrinkage

2. Fabric finish

They suggest that a standard "fusing test" should be developed and included as a quality control test[60].

However, one reason for fusing has been stated[6-7] to be to help control shrinkage in the fabric. It controls the fronts, making them perfectly straight, getting rid of some of the puckers and wrinkles that are created by fabrics shrinking differently. It also keeps the fabric stable and prevents it from puckering after cleaning[6-7].

Dimensional changes in the fabric during fusing can present a number of problems during the making-up or subsequent wear of a garment. These are[112]:

(a) Differential shrinkage between the outer fabric and the interlining resulting in the breaking of adhesive bonds during subsequent cleaning or wear[21,112]. It is apparently caused by the incorrect selection of fusible interlining[38]. A 2% limit has been suggested as being reasonably safe[21].

(b) Overall shrinkage of fused parts resulting in mismatching with parts not fused[112].

(c) Greater hygral expansion, in the case of natural fibres, of unfused parts relative to parts fused with interlining when moisture changes occur[112].

Although it is generally accepted that there is minimal shrinkage in synthetic fabrics, apparently two reactions take place which cause the fabric to shrink[27]. These are:

(a) *Relaxation* of the tensions which have been introduced into the fabric during processing.

(b) Shrinkage due to the *contraction* of the yarns when they come into contact with heat[27].

Shrinkage has been observed frequently in the rainwear field where fabrics have a high synthetic content[27].

The basic cause of shrinkage of textiles is the relaxation of strains impose in yarn or fabric manufacture[113]. A number of methods have been introduced to control shrinkage, namely:

1. Mechanical shrinkage eg sanforizing of cotton fabrics.

2. Resin stabilisation.

3. Heat setting of synthetic fibres.

The latter apparently is likely to be troublesome in some cases especially when fusing temperature exceed the effective heat setting temperature[113].

It is felt by Staflex that it is important that the combination of interlining and outer fabric should be tested and not the components[113]. Practical experience suggests that low adhesion vastly outranks differential shrinkage as the prime cause of fusible failure. Furthermore, high adhesion can neutralise or minimise the effects of differential shrinkage[113].

Heating of a polyethylene coated fusible interlining during fusing leads to changes in polymer which may result in dimensional change according to the dimensional stability of the permanent interlining[114]. This can be reduced by cutting the fusible interlining in the width direction or on the bias[114].

If one fuses at temperatures approaching the setting temperature, there are great dangers of changes in colour of the fabric and of unacceptable shrinkage particularly where polyester knit garments are concerned[115]. It is therefore important to fuse at the lowest temperatures possible, compatible with the performance of the interlining[115].

Textured synthetic fibre double knits are generally easy to fuse but the major problem is heat shrinkage[116]. The normal temperature for fusing knits is between 138° C and 160° C but the lower limit is recommended if heat shrinkage is to be avoided[116].

Very lightweight woven and knitted 100% polyester outer fabrics present problems mainly because polyester tends to extend with heat treatment then retract when cold[39]. Others extend and do not return whilst some are completely stable throughout fusing. *Acrylics* have a lower softening temperature and tend to *glaze* with heat. Dyestuffs which are suitable for acrylics can change shade permanently with the application of excessive heat, therefore adhesives with lower fusing temperatures are essential for acrylics[39]. On washable garments, it has been suggested that the laundering shrinkage of the interlining and outer fabric should be within 1-2% of each other[41]. Values greater than this are likely to cause the laminate to pucker, curl or show other deficiencies. Synthetic fibres have greatly increased this problem[41]. The shrinkage will also depend upon the way in which they are aligned (e g warp to warp, warp to weft) and the end use of the garment and the nature of the cleaning process[41].

According to Shaw[112], the amount of shrinkage occurring during fusing is, however, dependent to a large extent on the type of fusing equipment utilised. On continuous fusing presses, the fabric is either passed between a pair of belts or around a drum and the mechanical pressure on the fabrics is relatively low. As a result of this, shrinkage occurs more frequently on these types of presses compared with the discontinuous or tray press where pressure is continuously applied to the fabric and interlining[112].

Maximum dimensional change on laundering and dry cleaning have been specified by some leading companies and, depending on the fabric, these vary from 2 to 4% in each direction[29]. Some simple shrinkage tests for interlining compatability have been given by BIMA recently[22].

The high temperatures applied during fusing can often result in a colour change in the cloth, particularly in blended fabrics. This sometimes only becomes apparent after the garment has been made up and then only when viewed from certain angles[117]. Colour or shade change may also result from the removal of moisture during fusing[118] but the original shade will return when the moisture returns to normal. It has also been reported that damp fabric creates steam during fusing causing shrinkage and an uneven bond[82].

5.4 Dry cleaning

There are four important factors that play a role during dry cleaning and which could cause reactions in fused fabrics, namely solvent, mechanical action, moisture[119] and temperature[66]. If the adhesive is affected by a solvent (e g swelling or dissolving of the plasticising agent) the bond is weakened and in extreme cases delamination occurs. When using sensitive fabrics (e g finely woven or knitted fabrics) laminated parts are usually more resistant to mechanical action during dry-cleaning and as a result differences in appearance between fused and unfused parts occur. Migration of hairs from the interlining through the outer fabric can also occur during dry-cleaning[119].

Normally small amounts of water are added to the cleaning solvent during dry-cleaning action[119]. The amount of water to be added is calculated according to the sensitivity of the goods. Two methods are used:

1. % of mass of goods to be cleaned.

2. Permissable moisture content of cleaning solution on completion of the cleaning cycle[119].

Table XI gives volumes of water which are considered average[119].

Often however, the moisture content calculated does not include the interlining and problems can arise[119]. For example, if the weft of the interlining contains *wool and/or animal hair* mixed with spun rayon, and the volume of moisture calculated for the face fabric is too high for the animal fibre, these will shrink after a number of dry-cleanings and wavy folds will appear on the fabric. In many cases it has been found that this waviness even occurred after a single dry-cleaning and the 20% water content, usually used for jackets and coats, caused the waviness. How the water makes contact is apparently not important while the amount of water is important. Only slight differences in waviness occurred when spray and dipping techniques were compared. Textiles manufactured from cellulose and synthetic fabrics are far less sensitive to water added to the cleaning solution than wool textiles, although differences in

TABLE XI

WATER USED IN DRY CLEANING

Kind of goods	% water based upon mass of goods	% relative humidity measured in the steam chamber
Knitwear of wool, sensitive woven fabric, silk	0,1 — 0,5	below 70
Light-weight ladies attire, sensitive woollen goods.	0,5 - 1,0	70 - 73
Jackets, coats, suits, dresses	1,5 - 2,0	75 - 78
Trousers	2,5 - 3,0	80 - 82
Cotton, mixed fabric, cotton/ synthetics, etc.	4,0 - 5,0	87 - 90

residual shrinkage between interlining and outer fabric can cause waviness[119].

Stain removal generally causes very little trouble but care should be taken with stain removers that dissolve enamel or oil paint[119]. A guide for testing laminated fabrics for dry cleaning resistance has been described[119]. Table XII shows the influence of temperature of washing and dry-cleaning on the bond strength of a range of fusible materials[66].

Some interesting observations have been made elsewhere[110]. Dry-cleaning in perchloroethylene resulted in an increase in bond strength of a number of laminates and the increase was generally complete after the first dry cleaning. Three different variations of dry cleaning gave approximately the same results and Hoffman pressing after machine dry cleaning did not affect the bond strength. It was also found that in some cases bond strength increased upon wetting (probably due to swelling of the wool fibre) but a couple of samples lost more than half their strength. In one case, the latter result was explained by the type of interlining coating (random type). The article is concluded with a proposed combined testing procedure[110].

5.5 Effect of moisture

The presence of moisture is unavoidable during fusing since the two fabrics, the outer fabric and fusible interlining, each contain an amount of moisture depending on the type and proportion of fibres present in the two fabrics as well as the relative humidity of the atmospheres surrounding

TABLE XII

INFLUENCE OF THE TEMPERATURE OF WASHING AND DRY-CLEANING

Product	Mass Applied (g/m²)	*Initial Bond Strength	Bond strength after one dry-clean in perchlorethylene			Bond strength after one dry-clean in trichlorethylene			Bond strength after one wash		
			20°C	35°C	50°C	20°C	35°C	50°C	40°C	60°C	95°C
HD Polyethylene	30	26,2	20,6	18,1	delam.	14,7	13,5	delam.	22,1	16,2	10,7
LDD Polyethylene	30	21,6	20,9	16,5	16,4	19,7	17,4	16,4	16,5	16,8	17,4
LD Polyethylene	30	22,5	22,5	21,6	20,9	22,8	18,9	19,4	18,8	18,4	18,8
EVA Copolymer	30	36,9	delam.	delam.	delam.	delam.	delam.	delam.	32,7	31,7	delam.
Modified EVA	30	27,9	20,7	24,2	25,0	24,7	22,8	22,5	24,9	22,3	20,3
Polyamide	20	25,0	22,8	22,8	21,1	23,6	20,1	20,1	21,3	27,9	—
Plasticised Cellulose acetate	30	14,6	14,8	13,6	12,9	14,0	14,9	13,5	14,5	12,8	—
Plasticised PVA	45	17,6	19,8	16,4	13,6	21,1	14,9	delam.	20,2	18,9	13,4
Plasticised PVC/PVA	45	12,5	15,0	16,2	12,6	14,0	14,7	delam.	12,4	11,5	10,4

* Bond Strengths are in N/5cm width

them[27 120]. During fusing, the moisture present is evaporated by the heat of the press. This is in the form of steam and escapes around the edges of the press or passes into the cladding. As the moisture content builds up, so the effect on the parts being fused becomes more serious and eventually the fusing temperature of the resin is not reached and poor fusing results[27, 120]. Dorkin[120] found that satisfactory fusing could be carried out on fabrics with high moisture content provided that the steam produced was able to escape. However, if the moisture was forced to remain in close proximity to the fabrics being fused (e g press with closely fitting head and base and cladding which contained a high concentration of moisture) poor bond strength would result[120].

Conditioning samples of interlining and outer cloth at different relative humidity atmospheres and then bonded under standard fusing conditions revealed that an increase in the moisture content resulted in a poorer bond strength[68].

The specific moisture content of the outer fabric can have a measurable effect on temperature development which leads to various fusing conditions when fusing pure wool and synthetics[24].

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