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PRODUCTION OF COATED FABRICS - COATING TECHNIQUES

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TEXTILE COATING may be best described as a process to cover a base fabric on one or both sides with a layer of protective material. The combination of coating technique, coating material and base fabric selection each contribute very strongly to the ultimate properties and end-use performance of the coated fabric. This paper will endeavour to cover the more common methods of production of coated fabrics, with emphasis on fabrics for structures.

The most common and the oldest method of textile coating is the spreading of compound on to the fabric with a doctor blade or knife and there are many variations of this technique. The floating knife coater is the simplest and is predominantly used when lightweight coatings are required, minimum penetration of the compound into the substrate is desired, and coatings of medium to low viscosities are applied to close woven fabrics (Figure 1).

The fabric to be coated is supported before and after the coating knife and must be under strong tension to enable an even spread of compound to be deposited. Control of the coating weight becomes a function of type of coating blade, viscosity, tension of fabric, angle and pressure of coating knife and the porosity of the base fabric.

Dimensionally stable base fabrics should be used in this type of coating as the high web tensions required to control coating weight can lead to loss of fabric width.

The most popular method of direct coating is that of knife over roller (Figure 2). This technique has many advantages over the floating knife technique and is generally used for P.V.C. spreading and synthetic rubbers. The doctor knife is usually precision ground to a preferred profile and is fixed to a rigid knife holder to avoid flexing or bowing of the blade across the web, which would cause variations in coating weight.

The knife angle is adjustable in respect to the radius of the backing roll and also adjustable in the vertical plane. The backing roll depends on the type of base fabric generally coated and can be either rubber or steel. The engineering of the knife, holder and backing roller must be of a high standard and to fine tolerances in order that the coating weights can be accurately controlled and repeated from run to run. The fabric needs to be presented at the knife in an even, wrinkle free condition, so spreader rollers and edge guides are fitted and medium tension is applied to the web.

The factors controlling the coating compound add-on are the rheology of the coating system, the gap between knife and roller and the porosity of the base fabric. The coating knife profile has a large bearing on the coating weight of the compound and the final properties of the coated fabric. Penetration of the compound can be controlled by the selection of the correct blade for each particular application. Unfortunately for the textile coater, there is no single blade or knife to suit all coating compounds. Doctor blade or knife coating has been described as an art, not a science. If this is so then the choice of the blade is the creative part.

Figure 3 shows some of the more common blades in use today. Whilst there are no set rules as to which blade should be selected for a particular coating function, there are basic rules which aid in the selection of the blade. The finer the blade, the lower the add-on and the less penetration of compound into the fabric. The larger the radius of the blade, the greater the penetration and add-on of compound onto the fabric.

The actual dimension of the coating blade at the blade end can vary from 1 mm up to a 50 mm radius. A type (5) blade of 1 mm thickness would be used in floating blade applications where low coating weight up to 30 g.s.m. and low penetration was required, e.g. lightweight polyurethane coatings on nylon or polyester fabrics.

Type 1 and 2 doctor knives, which are approximately 3 mm thick at the knife end, are also used in floating knife applications and are used extensively for the application of priming coats and tie coats prior to the final coats of P.V.C. coated fabrics. These are a very useful, multi-purpose type of doctor knife.

The type 3 and 4 doctor knives are both used for knife over roller applications and are the most common knives used for the spreading of P.V.C. and other high solid content coating compounds. Doctor knife coating in any form is a high shear process so that the support mechanism for the knives must be rugged. The coating compound must pass through a small linear orifice between the fabric and the blade at working speeds so that the shear developed is a function of the speed of the fabric.

A variation of the knife over roller coating system is the knife over blanket system (Figure 4). A continuous rubber blanket is driven under tension by two rollers A and B. The doctor blade is placed at an angle over the blanket and the fabric is, therefore, supported before and after coating by the blanket. This method is often used in conjunction with a stentor drying oven, so the fabric does not develop too much sag across the web before entering the curing oven.

Both the knife over roller and knife over blanket coating systems are the workhorses of the coating industry and have been for many years. The major drawbacks have been from their reliance upon operator training in skills for the quality of the finished product and coating tolerances are often quoted by some manufacturers as high as - 5% of the total weight.

Whilst most manufacturers work to closer tolerances, spread coating, because of all the variables, does tend to give products which will vary in coating weight from one production run to the next. For the majority of end uses, this does not create any problems, other than cost to the producer, and it is therefore understandable why direct coating is the most popular method for production of coated fabrics.

Reverse roll coating is a system of coating which allows precision in the application of a compound on to a web. The principle of the reverse roller coater (Figure 5) is to deposit a known thickness of compound on to a transfer roller (B) and transfer this compound onto the fabric. The coating thickness can be controlled by the gap between the metering roll and the transfer roll, the speed of the transfer roll, the fabric speed and the % of solids in the compound. The rollers A, B, C, are driven separately so that a wide range of coating options are possible.

A reverse roll coater can handle compounds with a viscosity range from 2,000 to 100,000 c.p.s. and are capable of applying a wide range of coatings. These include water based, solvent based and hot melt coatings in solution, emulsion, suspension or dispersion form.

The coating weight (or thickness) can be controlled to close limits by the speed of the transfer roll and can be controlled automatically with an on-line measurement device such as a Beta gauge which measures the thickness of the coating and transmits the information back to the control device of the transfer roll. This allows the coating thickness to be continually monitored and controlled.

The reverse roll coater is an excellent coating device which is well suited for the application of tie coats, top coatings, lacquer style finishes, etc., but is not generally used for the application of heavy weight coatings to textile substrates.

The modern spread coating machine is often fitted with a Turret coating head which incorporates each of the four coating techniques mentioned. This enables the coater to select the most practical method for applying the compound to the fabric and allows for a wide range of products to be manufactured on a single coating line.

The question of curing ovens, the best method of drying - either by hot air, infra red, direct firing, electron beam, ultrasonic - is a subject in itself and no attempt is made to describe the variations in this discussion. However, it is sufficient to say that all spread coatings require some form of drying and curing and ovens up to 50 metres in length are commonplace. The total area requirement for a coating and curing machine is quite large but this balances out when the low capital cost of the spreading equipment is compared to that of a calander.

Calandring is a technique whereby thermoplastic materials, predominantly P.V.C., are applied in a molten state to a fabric substrate or used to produce a film which is later laminated to a substrate. Calander coating is a highly controllable method of coating and accurate, reproducible coating weights to reasonable tolerances can be achieved.

The coating material is initially heated in the vee between two rollers rotating in opposite directions (Figure 6) and is transferred to a third roller as a thin, reproducible film of thermoplastic material, then transferred to the fabric which is wrapped around the fourth roller. The rollers can be arranged in either the inverted L configuration or Z type arrangement (Figure 7).

The calanders operate under sophisticated process control conditions with automatic weight control to preset tolerances. This applies to both the coating type calander and the film producing calander.

There are several advantages of calander coating or calandring over spread coating methods and these are

- (a) lower raw material cost
- (b) ability to formulate to lower plasticizer levels
- (c) faster process speeds
- (d) better process control.

The disadvantages are its lack of adaptability to short production runs and its high capital cost. However, calanders do have the ability to produce high quality products at economical cost when compared to other methods. They do not require curing ovens to cure or gel the coating compound as do direct spreading methods and are not subject to the stringent pollution controls on coating ovens.

One alternative to the calander is the melt roll coater which was developed in the late 1950s and has been progressively upgraded until today it is a coating machine which can apply thermoplastic compounds to a wide range of substrates to the fine tolerances required of today's coated fabrics markets. Melt roll coaters today are similar in technology to and mechanically and electrically equivalent to the most sophisticated of calanders. The process control incorporates the latest electronic technology so that thermoplastic compounds are converted to film of defined dimensions and applied to the various substrates.

Figure 8 gives a guide to the melt roll process. Fabric is fed over a preheat roller (1) and passes in front of preheat infra red heaters (2). Preheating the fabric is necessary to achieve high adhesion factors of the compound on the fabric. Hot dry blend P.V.C. powders (or granules of other thermoplastic compounds) are delivered to the nip between the melt rolls (3) and (4). A plastic film is then formed on roll (3) - because it operates at higher speed and temperature than (4) - and is then transferred to the fabric when the rubber roller (6) presses the fabric against the film. The resultant fabric is embossed against roller (7) then cooled and re-wound. A Beta gauge is generally installed so that the actual coating weight can be adjusted automatically whilst the machine is in operation.

A wide range of thermoplastic raw materials can be processed and some of these are listed below:

Plasticized P.V.C.	High density polyethylene (H.D.P.E.)
Thermoplastic polyurethane T.P.U.	Low density polyethylene (L.D.P.E.)
Chlorinated polyethylene (C.P.E.)	Polybutene
Ethylene propylene rubber (E.P.D.M.)	Polypropylene

The ability to process the above thermoplastics gives many advantages over spread coating techniques. Dry blends only are used, no solvents or diluents are required in the compounds so solids only are processed.

The machine can be changed from one product to another with very little down time so that smaller production runs become economical.

The melt roll coater can apply coatings in a range of weights from 50 g.s.m. to 500 g.s.m. in a single pass - in some cases the melt coater can be fed with feedstock from an extruder and coating weights up to 1,000 g.s.m. in a single pass have been achieved.

The speed of operation is directly related to the coating weight so that light weight coatings operate at speeds up to 1,500 metres/hour and heavy weight coatings are as slow as 800 metres/hour. The slow rate of production makes the use of the melt roll coater far more expensive than that of a calander but with lower capital cost, small space requirements, lower energy requirements and lower staffing levels, the melt roll coater can be a viable production unit for small production runs.

Extrusion coating is a natural combination of the technology of the plastics industry added to the requirements of the textile coating industry. For many years the plastics industry has been extruding a wide range of profiles from bars to sheet and film. Extrusion coating was developed to apply polyethylene films to woven fabrics and the art has now continued to expand to include P.V.C., C.P.E. and other thermoplastic polymers.

The schematic layout of the coating portion of an extruder coater (Figure 10) shows how the film is forced from the die and falls in a vertical plane between the fabric and a chilled cooling roller. The pressure applied to the rubber roller, which is supporting the fabric, coupled with the temperature of the film, are the two major factors affecting the adhesion between base fabric and coating material. The other factors are base fabric fibre and construction, i.e. open weave or closely woven.

Extrusion coating is, like calendering, a highly sophisticated state of the coating art and is controlled to very tight tolerances. The advent of the microprocessor and mini computer have allowed advanced technology to be applied to this form of coating.

Extrusion coaters today are totally automated - from the bulk storage of raw materials being fed into high speed mixers continually feeding the blended material into the extruder and coated fabric being produced at relatively high operating speed. They are lower in cost than a calander to instal and operate and can produce similar quality goods to that from a calander.

Lamination of film to fabric offers an extremely versatile method of manufacturing coated fabrics and is a very effective way of utilizing the low cost films produced by a film calander.

The multi-ply laminator (Figure 11) is an illustration of one of many forms of laminators in use today which enables two layers of film to be combined with a fabric in a single operation.

The films can be combined, in the case of open mesh scrim base, by applying adhesive to one face only and the temperature of the heated drum preheating the film, combined with the pressure of the embossing unit giving the final adhesion. However, best results are obtained when the film receives an application of adhesive on applicators at (B) and (D) and then forced onto the substrate prior to travelling around the heated cylinder. The base fabric, if closely woven, can be pretreated with a bonding agent or tie coat that is re-activated when the heat is applied to it so that optimum bond is achieved.

The films to be laminated can be of varying thickness or preprinted and a wide range of thermoplastic films can be combined to fabrics using this method. Providing high quality films are used, high quality laminates can be produced.

Other methods of coating which are in common use in the textile industry are:

cast coating; transfer coating; dip coating; curtain coating; spray coating; foam coating; rotary screen coating.

The selection of the correct coating method is really dependant on the end product required and the decision of how to make is not always simple. However, the industrial fabric industry predominantly requires coated man-made fibre fabrics coated with thermoplastic resins which can be high frequency or hot air welded as well as being suitable for sewing.

The coating industry today has reached the stage where the engineering of coated fabrics for a specific end use is now possible. There are now specialist coaters who have placed their technology and skills into certain directions and produce specification fabrics for the membrane structure industry together with their other products into such fields as tarpaulins, pond or pool liners, inflatables, construction covers, etc.

The specification of a coated fabric for structures starts with the calculations of the strength requirements for the base fabric - the tensile strength of coated vs. uncoated does not differ substantially. Having calculated the strength requirements, the type of structure and its use must be considered. The number of factors which must be considered include:

- location and surrounding environment
- chemical pollution
- flame retardant requirements
- flex resistance
- permanence - years of expected life
- temporary - how often is it to be erected?
- wind loadings
- abrasion resistance
- elongation under stress
- method of fabrication.

These factors then allow the selection of the correct base fabric and, in turn, set the parameters for the selection of the best possible coating polymer or compound.

Selection of the correct base fabric and fibre type has been the subject of many discussion papers over the years. The most common fibres in use today for coated structures are:

- filament polyester yarns
- fibre glass
- polyamide (nylon 66)

with polyester and fibre glass being the most popular.

Polyester fabrics have a higher modulus under load than nylon and this helps to minimise the elongation under stress. Polyester fabrics have better dimensional stability under temperature change, are less hygroscopic than nylon and are suitable for coating with a wide range of polymers. This does not mean that nylon should be discarded as a base fabric for structures as applications such as inflatables require relatively high extension properties. Both nylon and polyester exhibit very good flexing properties and are relatively simple to coat, depending on base fabric construction.

Glass fibre for textiles became available commercially some 40 years ago and has been extensively used for many coating applications. The fibre has superior resistance to flame, smoke and toxic fume emission to other fibres, low moisture regain and a high specific gravity. Glass fibre fabrics can be coated with P.V.C., E.P.D.M., silicone, neoprene, Teflon^(R), and other polymers for various end uses. Glass fibres are available in multifilament form from 25 denier to 2480 denier.

Coated glass fibre fabrics have been the basis of some of the most spectacular membrane structures and tension structures so far manufactured and will continue to be used for many years to come.

Aramid fibres are a recent development and the fibres exhibit some highly desirable features which will be of interest in the future to textile coaters. The fibre is flame resistant and has good thermal stability, possesses high tensile strength and modulus of elasticity and low elongation. Fabrics woven from aramid can be coated with P.V.C. or rubber and whilst in limited use today, will certainly grow in applications over the course of the years.

When a fibre type has been selected, a fabric can then be woven to give the required end performance specifications. The most commonly used constructions are shown in the photographs in Figure 12 (1 - 4). The type of construction then sets the coating method to be employed.

The open scrim fabric cannot be direct spread coated and can be coated only by calander or melt roll coating or film can be laminated to the scrim.

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Open knitted fabrics must be processed in the same manner as scrims and care in handling these fabrics is required as they are tension sensitive during the coating process. Because the scrim and knits are open in construction, adhesion of the film to the film on the opposite face is achieved mechanically and by the thermoplastic nature of the film itself.

The most common construction of a base fabric for coating is the plain weave fabric (Figure 12 (3)) and can vary in weight from 60 g.s.m. to 1,000 g.s.m. depending on yarn denier and count. The fabric pictured here is the very basic 1,000 denier polyester and weighing 200 g.s.m.

The panama weave (Figure 12 (4)) comprises 2 - 1000 denier polyester yarns woven in parallel and weighs approximately 300 g.s.m.

Most man-made fibre fabrics resist adhesion of coating polymers to their surface and as adhesion levels are critical to end fabric performance, tie coats must then be applied.

Thus, the method of coating a close woven fabric has now been determined. An effective tie coat (or bonding coat) can best be achieved by spread coating techniques - either doctor blade, reverse roll, etc. Occasionally, impregnation is used instead of doctor blade but is carried out on the traditional coating/curing oven.

All tie coats (or bond coats) must be correctly cured prior to the final coating process so that the finishing coats adhere to the prime coat and there is no interface delamination.

The final coats can be applied by any of the coating methods described, e.g. calander coating, melt roll coating, lamination, spread coating. The selection depends not only on the available equipment in the coating plant but also in the polymer system, or coating compound required for the end product.

For industrial fabrics and membrane structures in particular, the weathering performance of the coating material would be the most critical factor. The life of a structure, where the major surface is now textile based rather than traditional building materials, has now moved from temporary to near permanent.

P.V.C. is the most widely used coating compound for industrial fabrics. It is cost effective, can be flame retarded, is flexible, easy to apply to a wide range of fabrics, and can be produced on a wide range of coating machinery. P.V.C. can be formulated to meet specific needs and is resistant to a wide range of oils, solvents, acids and alkalis when correctly formulated. It is a very versatile resin but for long term exposure - over 5 years - has not been very successful.

The P.V.C. film, on exposure, suffers from loss of plasticizer after a period of time, thus causing embrittlement and eventual total breakdown. The exposure life of a P.V.C. coated fabric is basically related to the coating thickness, with the choice of correct U.V. stabilizers and plasticizers being of primary importance.

Most P.V.C. coated fabrics suffer from dirt collection problems so top coating with an acrylate or similar clear lacquer has become popular in order to

- (a) slow down plasticizer loss
- (b) reduce the resultant tackiness
- (c) act as an additional U.V. barrier.

However, even with a top coat, the life of a P.V.C. coated fabric will not achieve the 10 to 20 year expectancy of the textile structures market requirement and does not allow it to compete with the virtually indestructible Teflon^(R) coated fibreglass.

However, the exposure life of P.V.C. coated fabrics can be extended dramatically with the lamination to the P.V.C. of a thin pigmented polyvinyl fluoride film. P.V.F. is chemically inert and is resistant to staining, soiling, abrasion and flexing. P.V.F. does not discolour and it would appear that a P.V.C. coated fabric with a protective P.V.F. lamination would be an alternative to Teflon^(R) coated fibreglass.

Chlorinated polyethylene (C.P.E.) is another thermoplastic resin gaining in popularity in the textile coating field and is being extensively used as a roofing membrane in the U.S.A. C.P.E. has several properties which give the product some outstanding performance characteristics. C.P.E. has excellent weathering properties and because it contains no plasticizers, there is no resultant tackiness and dirt collection. C.P.E. coated fabrics are essentially inert to attack from algae, bacteria, etc., and can be flame retarded to meet the major requirements of the industry.

The resistance of coated fabrics to chemical attack is important when selecting fabric for a specified end use. The location and possibility of pollution from the atmosphere, which can affect the coated fabrics, require some consideration. A chart of the chemical resistance of typical coating materials is attached as a guide (Figure 13).

To summarise the discussion, it could be said that textile coaters today have the opportunity to structure coated fabrics for specific end uses. The advances that have been made in coating technology over the last 20 years, coupled with advances in fibre and resin technology, have allowed the textile coater to advance from what was an art to really a science.

As the development of light weight structures has grown, so have the skills of the textile coater and we look forward to a bright future.

Teflon^(R) is a registered trademark of E. I. duPont de Nemours and Co., Inc.

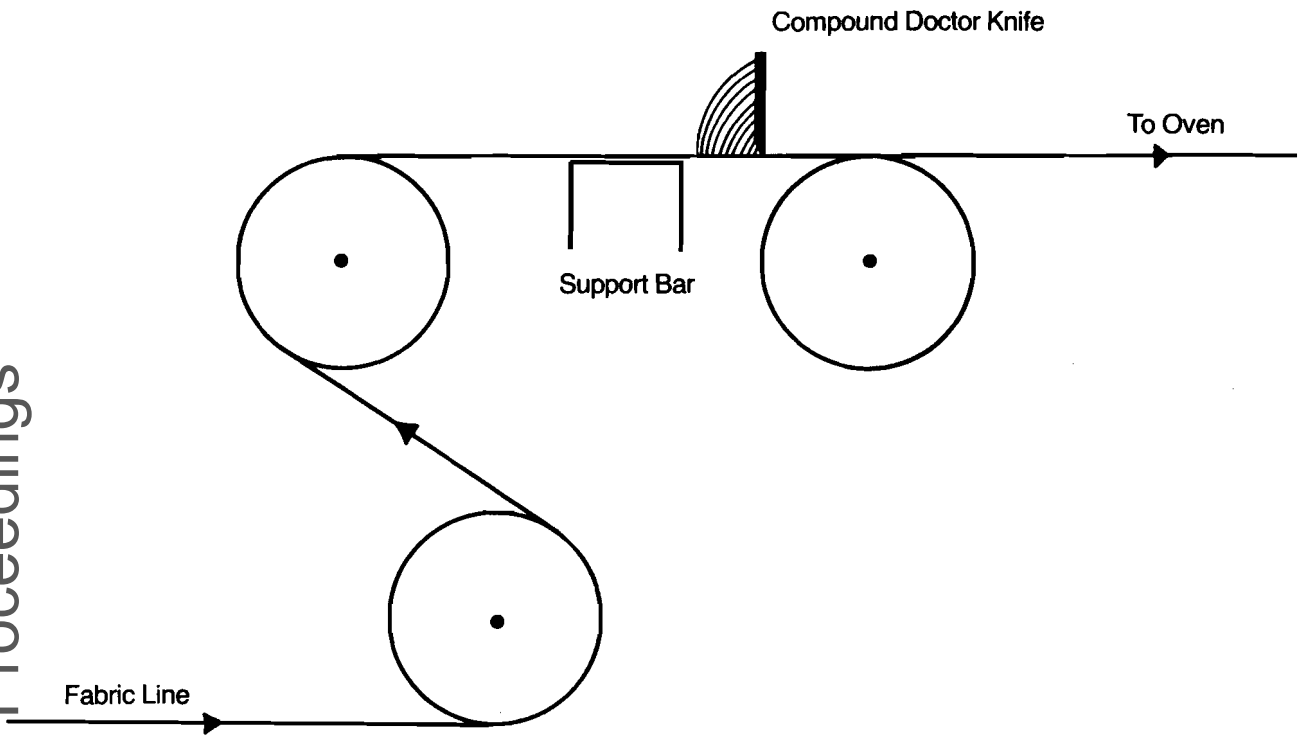


Fig. 1 FLOATING KNIFE COATER

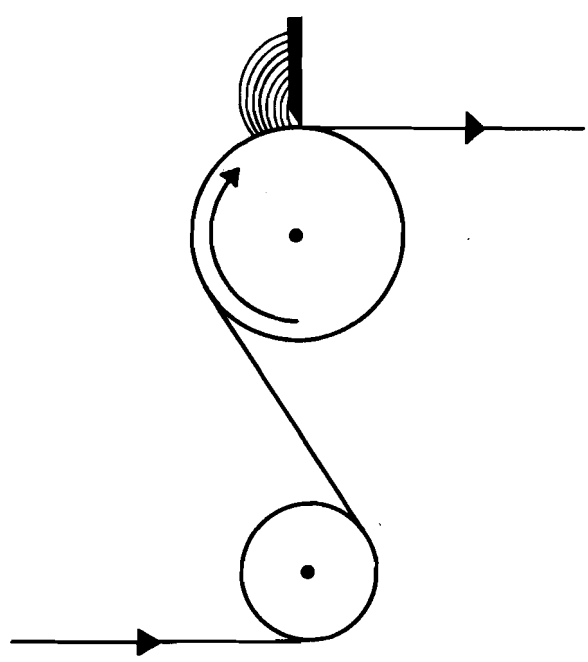
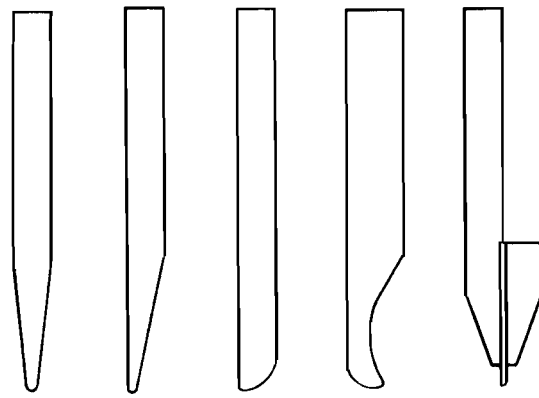


Fig. 2 KNIFE OVER ROLL



1. Taper. 2. Bevel. 3. Bullnose.
4. Spread. 5. Floating Knife

Fig. 3 DOCTOR KNIFE PROFILES

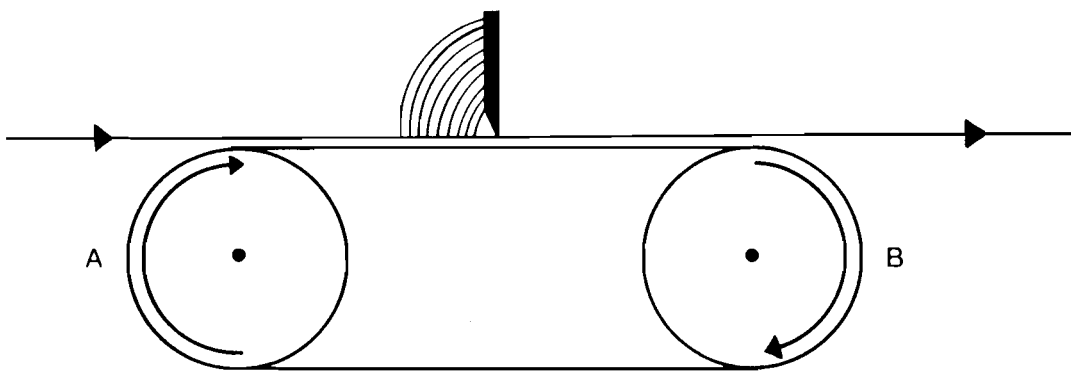


Fig. 4 KNIFE OVER BLANKET

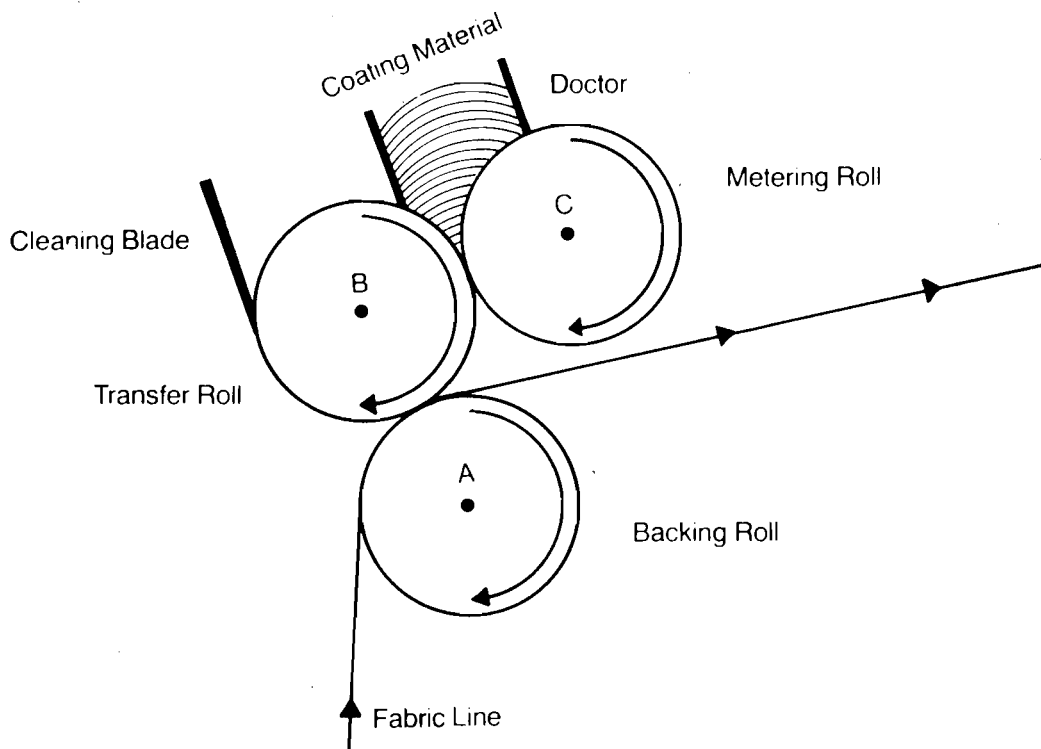


Fig. 5 NIP-FED REVERSE ROLLER COATER

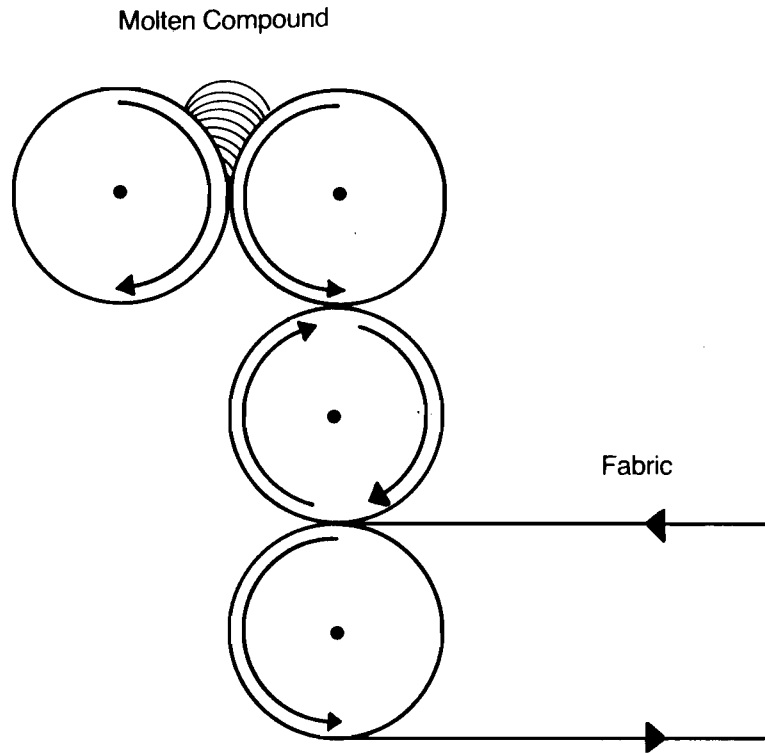


Fig. 6 INVERTED "L" CALANDER

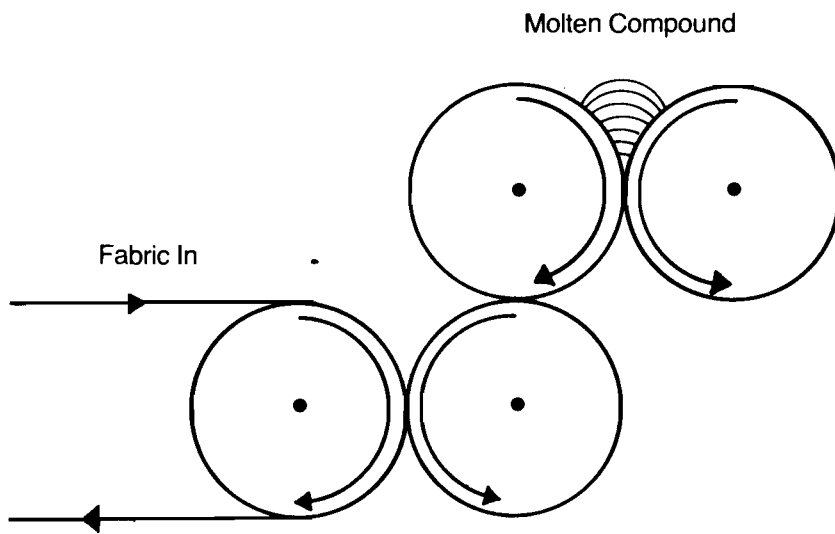


Fig. 7 "Z" TYPE CALANDER ARRANGEMENT

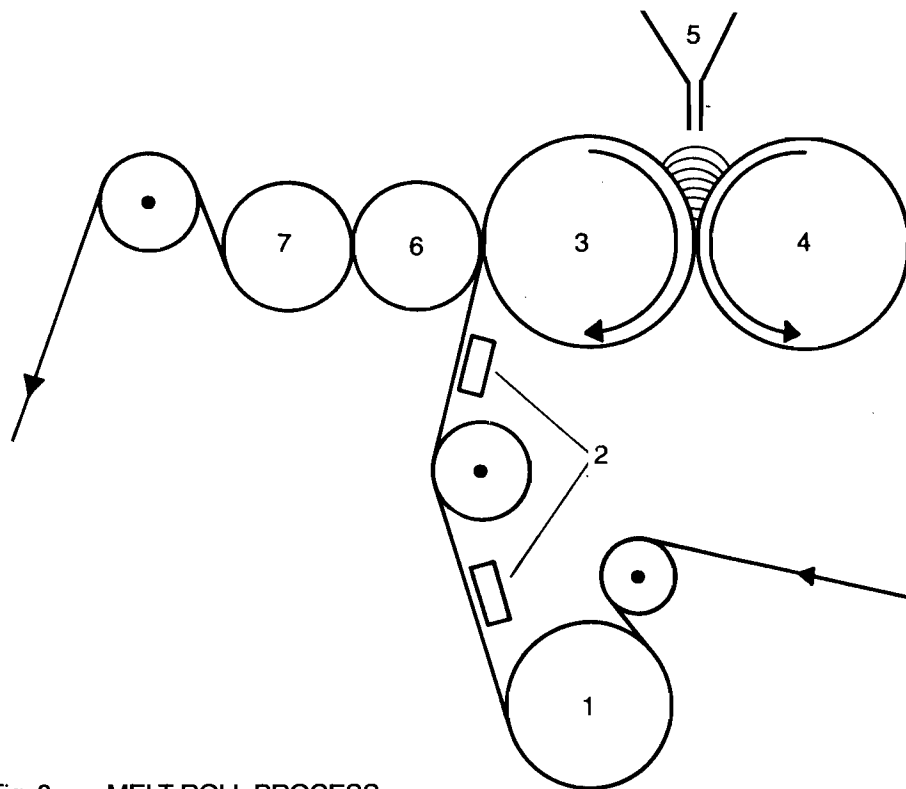


Fig. 8 MELT ROLL PROCESS

Fig. 9 Thermoplastics suitable for
Melt Roll Coating for Industrial Fabrics.

Plasticized P.V.C.
Thermoplastic Polyurethane
Chlorinated Polyethylene (CPE)
Ethylene Propylene Rubber (EPDM)

High Density Polyethylene (HDPE)
Low Density Polyethylene (LDPE)
Polybutene
Polypropylene

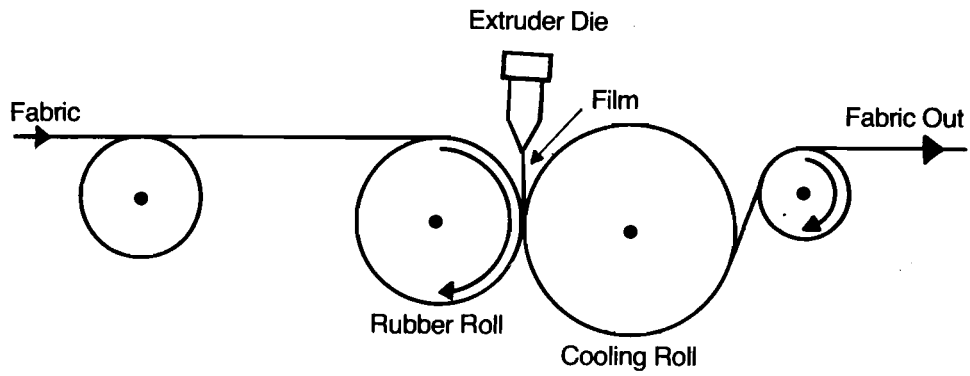


Fig. 10 EXTRUSION COATER

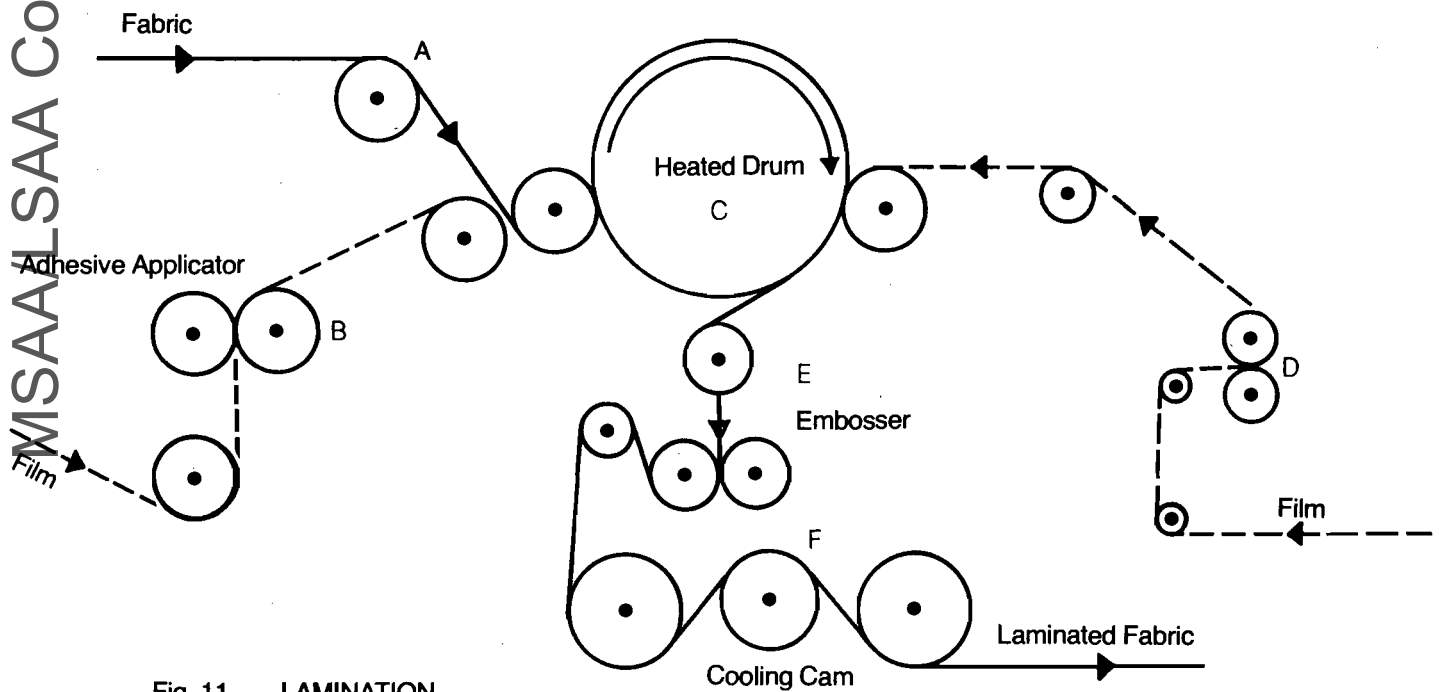


Fig. 11 LAMINATION

MULTI-PLY LAMINATOR

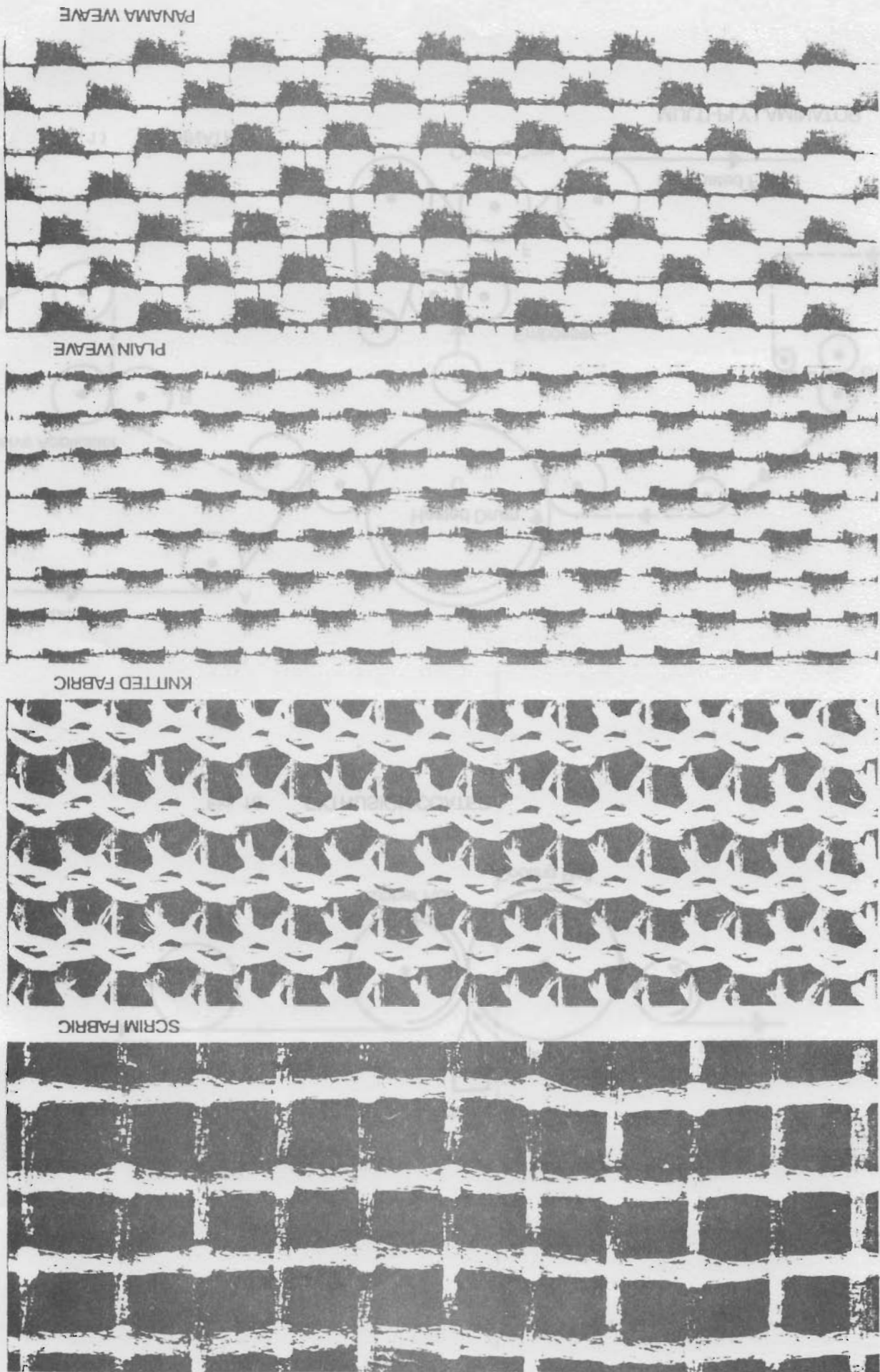


Fig. 12

Chemical	C.P.E.	HYPALON	P.V.C.	EPDM
Glacial Acetic Acid	A	C	C	C
Ammonium Hydroxide	A	A	A	A
Chromic Acid	A	C	A	C
Citric Acid	A	A	A	C
Copper Sulfate	A	A	A	C
Cotton Seed Oil	A	A	C	C
ASTM – Fuel A	A	C	C	C
– Fuel B	A	C	C	C
– Fuel C	A	C	C	C
Hexane	A	B	C	C
Hydrochloric Acid	A	A	C	C
Kerosene	A	C	C	C
Linseed Oil	A	A	C	C
Lubricating Oils	A	C	C	C
ASTM Oil # 1	A	A	C	C
Oleic Acid	A	C	A	C
Phosphoric Acid	A	A	C	A
Sodium Hydroxide	A	A	C	A
Sulfuric Acid	A	A	A	A
Nitric Acid	B	C	C	C
ASTM Oil # 3	B	C	C	C
Benzene	B	C	C	C
Carbon Tetrachloride	B	C	A	C
Cyclohexanone	B	C	C	C
Gasoline	C	C	C	C
Heptane	C	B	C	C
Naphtha	C	C	C	C

A – No Effect
 B – Minor to Moderate Effect
 C – Severe Effect

Fig. 13