Tape John Johnston

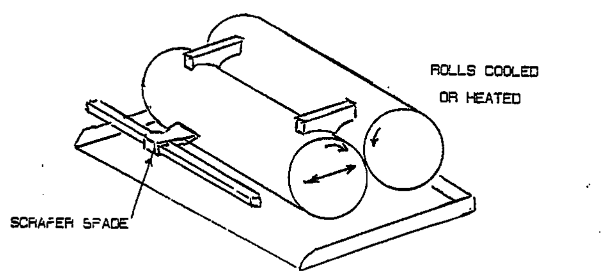
MANUFACTURING METHODS

John Johnston

RUBBER MILLING

Virtually all rubber/resin adhesive system manufacture begins by milling the rubber. The two basic reasons to do this are to reduce and spread the molecular weight, and to incorporate fillers. Addition of filler at the solvent mix stage would result in poor dispersion, and the filler would rapidly separate and precipitate.

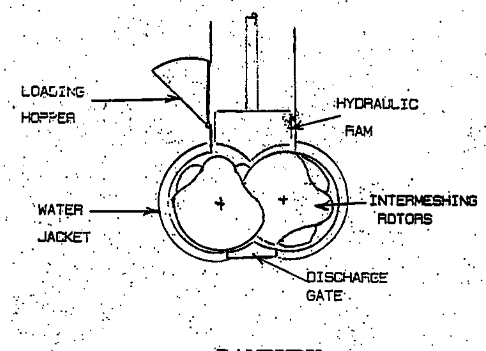
The oldest and time-honored method of achieving both of these needs is by use of a two roll mill. One roll travels faster than the other allowing a shear action at the nip. The rolls can be heated or cooled, and the gap between the rolls can be adjusted by opening and closing the rolls, and so control the degree of shear. The work done in shearing the rubber generates considerable heat, hence the need to cool the rolls. The cooler the rolls, the greater the break-down. The anti-oxidant should be added at this stage.



TWO ROLL MILL

Once the rubber is sufficiently plasticized, the filler(s) can be slowly incorporated by addition to the rubber on the mill. By alternating the filler addition with addition of any necessary tackifying resin(s), a complete 100% solids adhesive can be made this way, suitable for the calender coating process, to be discussed later. This mixing stage is usually done with warm rolls, giving a final boost of temperature on completion, to bring the adhesive up to the calender running temperature, and to finalize the mixing process. If the material is needed for a solvent based adhesive, and only a rubber/filler mix is needed, as much tackifying resin as the rubber/filler blend will accept while still producing a dry blend, will provide faster solution into the solvent.

While the two-roll mill method is very effective for rubber break-down and rubber/filler blends, it has been largely replaced for these tasks by the banbury. Here, the rubber is processed between two powerful rotors, held there by a hydraulic ram. The mixing chamber is cooled, and most machines are multiple speed. It is much more efficient and controllable, requiring less operator manual input. The finished batch is dropped though a door in the base of the machine, usually directly into a two roll mill for

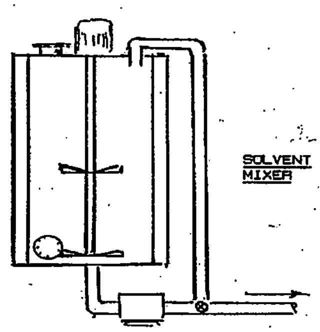


BANBURY

sheeting, and possible later chopping, to speed up the mixing process. Again, some resin can be added to the banbury mix to help solubility.

MIXING

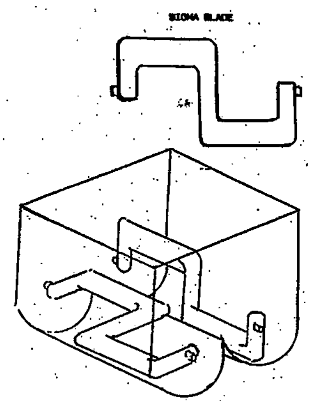
Latex mixing requires nothing more than a propeller stirrer, ensuring that the mixer speed neither generates foam nor be so high as to cause localized heating and resultant coagulation. Latexes can also coagulate due to too high a mechanical shear. Addition of components as called for in a specific formula can be done by volume, with compensation, if necessary, for the effect of temperature, but an easier way is to set up the mixing tank as a weighing machine, using strain gauges at each of the supporting legs.



GEL STRIPPER/PUMP

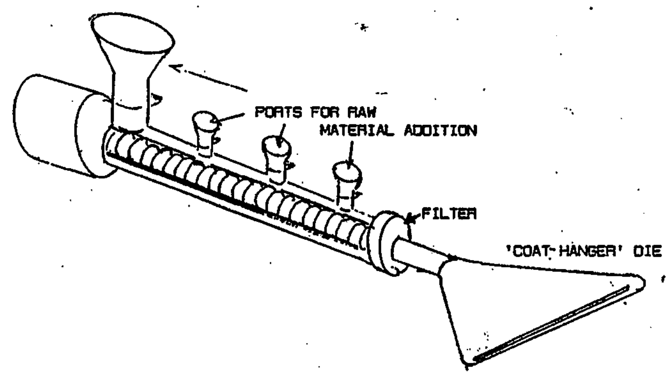
Solvent mixing requires a much greater horse-power than latex mixing, the objective here being to shear away the gel as the solvent penetrates the rubber, to expose the rubber not yet affected by the solvent. After the mixing process has proceeded sufficiently so that the rubber pieces are reasonably reduced in size, the mixing process can be speeded up by circulating the mix from the bottom of the mixing tank through a device which acts as a grinder/gel stripper, then recycling it back into the top of the tank. Note that as the rubber dissolves, the viscosity increases. Addition of the resin works in reverse, reducing the solution viscosity. Also, the work done in mixing increases the temperature of the solution, and so cooling during mixing will be necessary, particularly so if a cross-linking additive has been added. Otherwise pre-cure in solution may occur. A nitrogen blanket over the mixing adhesive surface is often used to reduce the risk of fire.

An adhesive mix which was not taken fully to completion can have very small particles of rubber present in the adhesive. Similarly a poorly mixed 100% solids adhesive can have poorly dispersed pigment or filler present.



SIGMA MIXER

It has already been indicated that a two-roll mill can be used to produce 100% solids adhesive systems. Another method for 100% solids adhesives is the sigma mixer, consisting of a chamber with two rotating 'square S' shaped blades. Solvent based batches can be made this way, but the capacity is rather small, typically up to 1,000lb. With a steam heated jacket, it can be used to produce a similar 100% solids adhesive system for calender coating, or with an oil heated jacket, and using block copolymer elastomers, it can produce a hot melt adhesive system. A nitrogen blanket is advised to prevent oxidation.

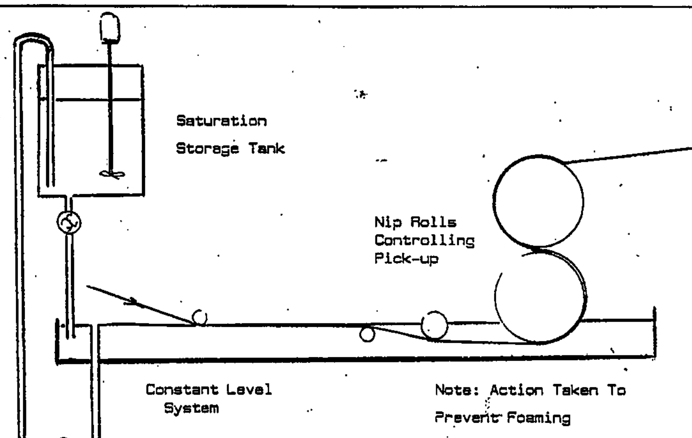


EXTRUDER-MIXER

The latest technique for hot melt adhesive systems is the use of an extruder, with feed ports for the various ingredients, this having the advantage of a continuous mixing system, which can be terminated at any time, with no residual adhesive batch to deal with. In some machines, known as a pultruder the extruder screw, of a special design, both rotates and cycles back and forth, for better mixing.

PAPER SATURATION

As with other latex coating processes, care must be taken to prevent both foaming and mechanical breakdown of the latex. The function here is to impregnate the paper with a polymer system to improve its physical properties. During the saturation process the entrapped air in the paper must be allowed to escape from the surface as the latex penetrates. One approach is to float the paper on the saturant surface prior to total immersion, then passing the saturated paper through a nip process to control the degree of pick-up. The pick-up is also controlled by the solids content of the saturant.



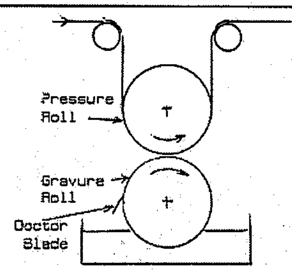
PAPER SATURATOR

The saturated paper should be fed from the saturator to the drier in such a way as to provide minimum tension to the paper, in order to maintain the crepe, then rapid drying applied, as for example with infra-reds, to rapidly reduce the water content of the paper, so that it can be taken through the drier without breaks. The use of a wet strength additive in the paper also helps this stage.

COATING

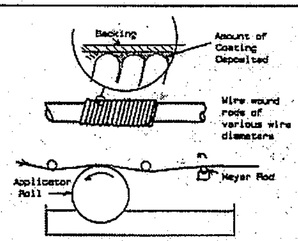
All coatings no matter which type, should be adequately filtered before immediate application, to prevent any small particles from causing a disruption in the coating, or possibly catching in the coating head, which will result in a continuous line of low or no adhesive.

Lighter weight coatings, such as release coats, backsize coatings, or prime coats can be applied using a gravure coater. The actual deposition will depend on the surface characteristics of the knurled gravure roller used, and the solids content of the applied



GRAVURE COATER

coating. A doctor blade is necessary to remove excess coating from the gravure roll. Though time, the gravure roller will wear, and there are commercial kits available to measure the degree of wear, by taking an impression of the roll.



MAYER COATER

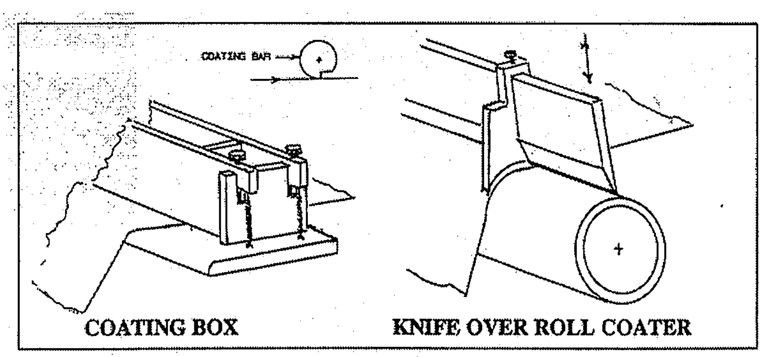
An alternate low coating weight coater is the Meyer coater, which first applies an excess of coating from an applicator roll, rotating in a bath of the coating to be applied. The coating is then doctored by a wire wound bar, the amount of coating being allowed to remain being determined by the gauge of the wire used on the bar. A plain bar can be used for very light coatings. There may be no need to use a doctor blade on the applicator roll, and this results in a flooded nip, but some wiping device may be needed to prevent a coating bead from forming along the edge of the web being coated.

As the Meyer bars used are usually of fairly small diameter, the bar needs to be supported along its length, to overcome any tendency to bend. While experience is a guide, the correct solids content of coating, size of rod to be used, and speed of rotation are usually determined by trial and error. The bar is rotated slowly to help keep it clean, but it still needs replacing and cleaning regularly during a production run to remove coating build-up. The Mayer coater lends itself well to very low solids coatings or to low viscosity coatings, particularly water-based. This method can also be used for low coating weight water based adhesives, as would be used in protectives, but, as in all cases of using a coarse wound bar to obtain a higher coating weight, adequate flow-out is needed following the Mayer bar to correct for the highs and lows in the coating, sometimes described as 'railroad tracks'. A plain 'smoothing bar' following the coater also helps.

A poor quality Meyer coating which has not fully flowed out before drying may still show the multiple highs and lows of the coating. This may be more obvious in a film release coat in which an ultra violet active agent has been added to allow the operator to see the coating distribution.

Low viscosity coatings can also be applied to a web using an applicator roll, as for the Mayer coater, but instead of using a Mayer bar, the amount of final coating can be determined by using an air knife, which is exactly as named, a fine jet of controlled pressure air, from a slot orifice, blowing onto the web, and removing the excess coating, returning it to the coating bath. The degree of air pressure determines the coating weight.

Pressure sensitive adhesive coatings, which could range in coating weight from the upper limit of the prime/backsize coatings to many times this value, need other application methods.

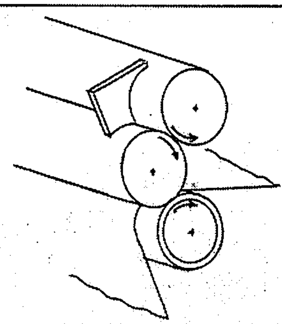


The oldest method of application consists of a knife, over a roll or plate, the wet coating weight being determined by the gap between the knife and the web. Coating heads are still in use where the adhesive is retained in a box, the front plate of the box being an adjustable and removable coating knife, the back plate also being adjustable and removable, so that the box can be taken apart for cleaning. This method lends itself well to coating several narrow webs simultaneously, by using spacers across the bed of the coating box. When a back-up roll is used in place of the box bed, this gives a knife over roll coater. The roll can be steel, providing a precision gap, but this suffers from the disadvantage that a slight change in the thickness of the web, such as a splice, or a particle, can cause a tear or break.

A little imperfection in the coating head will give a longitudinal mark in the adhesive surface

More popular are rubber back-up rolls, the type of rubber being one unaffected by the types of solvents used. Even slight swelling would cause dramatic coating weight variations. The knife designs vary from very sharp to half round, and can be sited either vertically to the web, or with a slight tilt-back, and either directly over the top dead center of the roll, or very slightly forward, which accommodates splices and particles a little better. The knife can also be replaced by a reasonably large diameter bar, which applies a fairly smooth coating. Adhesive 'trail' can occur after the bar, and so it is customary to provide a cut-out along the bar providing a sharp trailing edge, which overcomes most of this tendency. It is also common to provide a 'bull-nose' smoothing bar following this and other adhesive coating methods. This is a half-round bar of reasonably large diameter, which rides on the wet adhesive surface as a smoothing aid, while not removing any of the coating.

These 'trails mentioned can be seen in the finished coating as small blobs of adhesive with a long 'tail'



REVERSE ROLL COATER

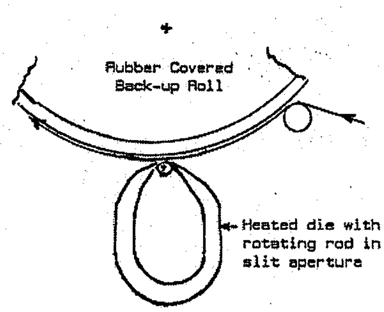
The knife or bar over roll coater is still popular, but has been largely replaced by the <u>reverse roll coater</u>. This is a three-roll device, the adhesive being applied between the top and middle steel rolls. The gap between these two rolls determines the amount of deposition on the middle roll. Too large a gap will result in 'railroad tracks' in the adhesive surface. The final coating weight is determined by setting of the middle and bottom rolls. The top roll turns slowly, to help keep the gap clean. The bottom roll, a rubber covered roll, carries the web to be coated, and so travels at web speed, and in opposite direction to the center roll. Its position with respect to the center roll is adjusted so that the coating on the center roll is wiped off onto the web. The amount of deposition is determined by the relative speeds of these two rolls, and so can deposit much more or much less adhesive than that on the center roll. It can be adjusted during the coating operation by changing the speed of the center roll. Naturally, the solids content of the adhesive must be taken into account, and also its viscosity and rheology for an efficient coating operation. Again, a following 'bull nose' smoothing bar may be used.

A poorly set reverse roll coater will have multiple longitudinal streaks or 'railroad lines' in the adhesive

For water based systems, the low viscosity of the coating, and the tendency to foam can cause problems. One technique is to feed the latex from a totally enclosed system, much like a slot die, onto the web, which is being carried over the surface of a roll. The latex is under controlled pressure, which determines the deposition.

Water based systems may be reactivated after drying by prolonged water immersion, when the clear dry adhesive will turn milky.

In the last 25 years or so, with the advent of block copolymer systems, we can now produce solvent based adhesive systems which have a very high solids content, yet of low viscosity. Or we can produce 100% solids adhesive systems which have moderately low viscosity at temperatures around 150 to 180oC.(300 to 350oF), known as hot melt systems. The hot melt coater is designed to coat at these high working temperatures, the two commonest designs being a variation of the reverse roll coater, and a slot die system. In the three roll hot melt coater, the top two rolls now lie along the same horizontal axis, to act as a dam to hold the molten adhesive, the rolls being heated with hot oil. The principle of operation of the two coaters is the same. However, as there is no solvent to drive off, the speed of coating can be increased considerably.



HOT MELT COATER

In the slot die hot melt coater, the adhesive must be fed uniformly to the slot for good final adhesive profile, and this may be by a 'coathanger' design, or by feeding from either end of the coating head simultaneously. One coating head design has a rotating rod in the opening of the slot die. This not only gives a smoother coating, but also it helps continually remove and particle in the adhesive, which can be charred adhesive due to the continual heat exposure. Both hot melt coating systems need a cooling system follow-up for the coated web prior to wind-up.

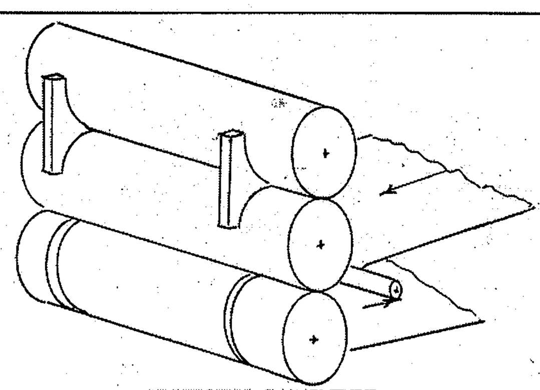
Note that unless an extruder-mixer is used, the hot melt system calls for a heated storage tank from the mixer, possibly a small heated feed tank, and a very good filter system, all connected with heated lines, and protected against oxidation, with an inert gas blanket system. Lower temperature 'hold' procedures are necessary when the system is not in operation, but still has adhesive in it, to prevent thermal degradation. Purging compounds are available to drive out any residual adhesive from the coating head, when the equipment is to be shut down for maintenance or repair.

The film strength of a block copolymer system is much higher than a natural rubber system. Nicking the edge of a film tape with a hot melt adhesive then very slowly tearing the film will show a small web of adhesive before the adhesive film breaks.

While the drying restrictions of solvent or water based systems limit the amount of adhesive that can be deposited in one pass, hot melt systems requiring no drying, and only cooling, which enables heavy coatings to be deposited. With the potential available for coating speed, and the amount of adhesive that can be deposited, the quantity of adhesive that could be needed to keep a particular coating operation running continuously with maximum efficiency can be enormous, and demands a high volume adhesive mixing process to support it.

Hot melt adhesive systems run at cooler than ideal temperatures can show an irregular multi-ridged adhesive surface. The ridges from a Meyer coater are uniform.

The final adhesive coating system is calendering, again a 100% solids process, permitting high coating weights, but here, conventional rubber systems at high temperatures are used. The rubber based adhesive is fairly plastic at the higher temperatures, and can be coated under high pressure. There are various calender designs used to produce adhesive tape, but the simplest calender consists of three large in-line rolls, each with a temperature differential from its neighbor. The top roll turns slowly, while the other two rolls travel at the same speed, the surface speed being the speed of coating. The temperature selection depends on the type of adhesive, and speed of the calender, but as an example, the top roll may be from 110 to 140oC, (230 to 280oF), the center roll from 60 to 90oC, (140 to 190oF), with the bottom roll cool, around 20 to 40oC. (70 to 100oF).


ADHESIVE CALENDER

The pre-heated adhesive is placed between the top and middle rolls, the gap between the two determining the adhesive coating weight, which adheres preferentially to the middle cooler roll. The tape base to be coated passes around the bottom roll, and is brought into contact with the adhesive on the middle roll by pressure applied to the bottom roll. The now adhesive coated backing is stripped from the center roll, then passed over cooling rolls, and finally wound into a master roll.

Any imperfection in the calender applicator roll will show itself as a mirror image in the adhesive surface

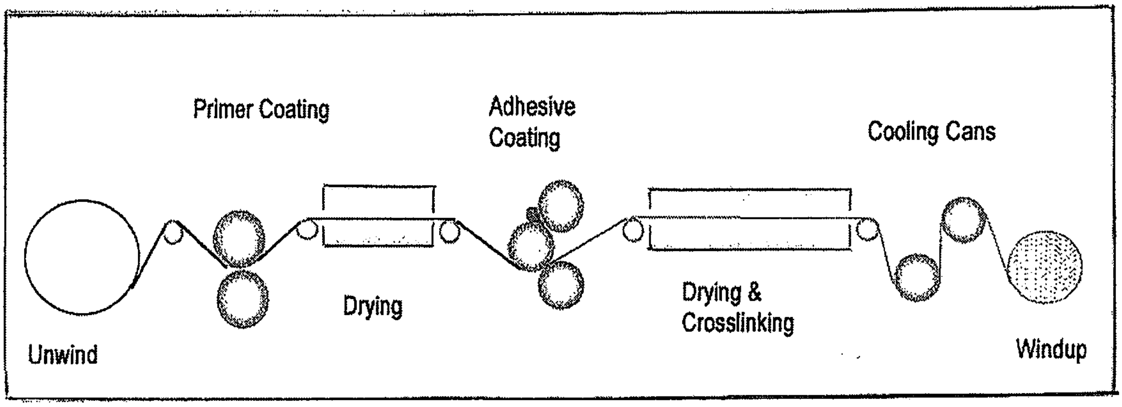
The tremendous pressures involved will cause slight bending of the rolls, and so the surfaces must be ground to a suitable profile to compensate, and to ensure an even deposition of adhesive, known as 'crowning'. There are calenders which allow the top roll to be rotated slightly in a horizontal plane around a center axis, as well as the vertical displacement, and this can help correct a high center coating weight, this being known as 'crossed axes'. The calender is the universally accepted method used to produce cloth tapes such as duct tape, and pipe-wrap tape.

All of the coating systems described can be automatically controlled by continuous electronic measurement of the coated and uncoated web, as with a beta gauge system, the difference between the two readings providing the adhesive coating weight. This information is then computer analyzed to determine where it lies with respect to pre-set standards, and any corrections necessary fed to step-motors connected to the coating head controls, known as a 'closed loop' system. With a calender, the coating weight can be read directly from the calender roll, using a back-scatter method.

DRYING AND CURING

While low boiling point and so easily evaporating hydrocarbon solvents are used to dissolve rubber based adhesives, they are also flammable, demanding great care in processing. Most backing materials used to produce tape are capable of carrying a static charge, and passing such materials over rollers, fundamental to processing, can generate such a charge. Static eliminators become a key element in web handling in the proximity of solvent based adhesives.

Likewise, it takes very little solvent vapor in the air to create a potential for explosion. The minimum amount of solvent to create this situation is known as the lower explosive limit, (L.E.L.) Therefore, removing solvent from an adhesive must be at a rate which never allows this level to be achieved, with a typical target being only a fraction of the L.E.L. Each zone of a drying oven must be fitted with an 'L.E.L. meter' in order to monitor this, which triggers a warning device which sounds, or shuts the equipment down, if such a situation were to develop.



One further caution is that attempting to remove the solvent from an adhesive too quickly can cause considerable bubble formation in the adhesive, giving a spongy adhesive with poor cohesion, resulting in adhesive transfer on removal. Also, with a heavier adhesive coating, it is possible to dry the outer layer of the adhesive, which then prevents the escape of solvent from the body of the adhesive. Residual solvent, even at low concentrations, will act as a powerful plasticizer to the adhesive.

An examination of the adhesive surface under a magnifying glass will indicate whether bubbles are present. Air bubbles are usually small and uniform. Solvent bubbles can be very variable in size. Solvent bubbles are very common in masking tapes and also between the glass threads in solvent adhesive coated filament tapes.

Therefore, in order to dry pressure sensitive adhesive systems properly, a multiple zone oven is necessary, the first zone being a low temperature zone, or even simply a means to draw away the initial evaporating solvent. The temperature of each succeeding zone is then raised, with the fore-mentioned points being addressed, until full drying is achieved. Prime, backsize and release coats, being light-weight coatings, can be dried effectively in a single zone.

Heat exchange at the coated web is key, and modern ovens impinge the web with hot air from a series of slots or nozzles along the length of the oven, often referred to as 'vertical impingement'. The solvent laden air is carried off through adjacent vents to some solvent recovery system, following cooling. This is possibly an activated carbon adsorption system, or it may be pyrolysed, the heat energy generated being recycled into the system. While the conventional system in the past has been to carry the web through the drying oven on rollers, modern ovens now 'float' the web through the oven, by balanced air pressure either side of the web. It is even possible to produce a web coated on both sides simultaneously this way.

Solvent coating ovens are cleaned internally at regular intervals. They should then be purged thoroughly before reuse. Otherwise very small carbon or rust particles can wind up on the adhesive surface.

To overcome the explosion hazard, an alternate system is to replace the hot air in the oven with nitrogen. This not only eliminates the risk of fire or explosion, but there being no L.E.L. to contend with, the concentration of solvent carried by the nitrogen can now be very high, enabling continual recycling of the hot nitrogen, to build up the concentration, with slight bleed-off to recovery. The solvent is recovered by cooling, the high solvent concentration providing a more efficient method than the carbon bed system. The nitrogen system does demand a well-sealed closed oven system.

Water based systems have no flammability hazard, and so can tolerate a high concentration of water in the drying air, before being expelled to the atmosphere. With the difference in evaporation rate of water to solvent, bubbles in the adhesive are no longer a major problem. Further, infra red heaters can be used safely for drying, with their penetrating ability, which heats the system in bulk, rather than the hot air system which heats from the surface, followed by conduction.

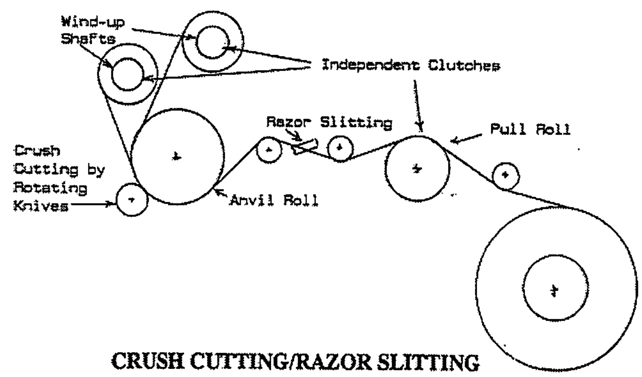
If the adhesive is designed to be cross-linked, once the adhesive has dried, the cross-linking process can take place in succeeding even higher temperature zones. The temperature of the last zone of the drying section should not be so high as to prematurely initiate the cure reaction. Good cooling should follow prior to wind-up into a master roll. The cooler the tape is at wind-up the easier it will be to unwind at the slitter. Some ovens devote a final zone of the coater as a cooling zone.

The degree of cross-linking of a pressure sensitive adhesive can be determined by the change in solubility of that adhesive when immersed for one minute in what is normally a solvent for that adhesive in the uncured state. Uncured it will be soluble. Fully cured it will be insoluble and rubbery. There are all of the various possibilities between these two. For a natural rubber based adhesive, use an aliphatic hydrocarbon (hexane, heptane), for butadiene styrene including block copolymers, use toluene, for acrylics use methylene chloride.

Cross-linking by radiation is now established as an accepted cross-linking method for pressure sensitive adhesives. This can be by ultra-violet light of a suitable wavelength, calling for both a cross-linking activator and a photoinitiator in the adhesive formula. Because of the limited energy and penetrating power of the ultra violet, the method lends itself to the low coating weight acrylics and other lighter weight coatings,. Electron beam coating, either by a curtain coater, or by a sweeping electron beam, while much more expensive, has a greater depth of penetration, and requires only an activator. Work being carried out in Industry with this method of cross-linking pressure sensitives is still very confidential. The method is extremely rapid, cross-linking being able to take place in fractions of a second, with no thermal input. The advantages of this method over the conventional are obvious.

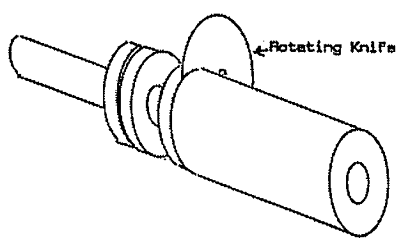
SLITTING

The choice of slitting technique to be used will depend on the nature of the material to be slit. Materials such as paper, fabrics, laminates, and so on can be crush-cut.



CRUSH CUTTING/RAZOR SLITTING

This is done by using rotary knives pressed against the adhesive tape which is backed up by a driven hardened steel anvil roll. Plastic films, on the other hand, if cut this way, would have a rough edge, and would break easily under tension. Here we must use a razor-slitting technique, consisting of razor blades, Teflon(R) coated to prevent sticking, mounted and spaced in a suitable housing, which slits the moving web into tapes. Neither of these methods is acceptable for foils, the preferred method being two contacting rotating discs, known as shear slitting.



LATHE SLITTING

In any conventional slitter, there is a pull roll which strips the bulk tape from the master roll and acts as a tension isolator between unwind and wind-up. Following slitting, alternate tapes are wound on cores secured to two shafts, each shaft having its own tension control.

Examination of the slit edge of a plastic tape under a low power microscope will indicate whether the tape was crush cut or razor slit

The modern slitter holds the cores onto the wind-up shafts by expansion of the shaft, usually by air pressure. Removal of the pressure allows easy stripping of the rolls of tape from the shafts.

Worn bearings in the shafts of a slitter will result in very slight side to side play while the tape is being wound. This will be seen by examining the sides of the roll, A well-slit roll should have fairly flat sides

In slitting masking tape, dull knives will result in a lighter than normal color to the sides of the roll.

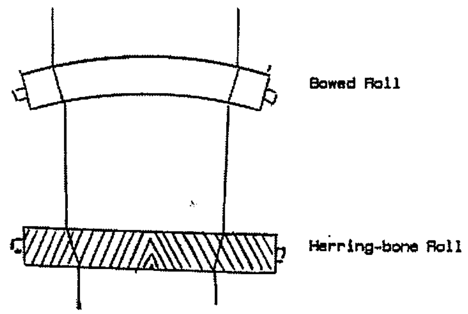
As sight differences in thickness of either backing or adhesive, can result in some tapes being soft while others are wound firmly, this problem can be resolved by using what is known as differential wind-up, the system being arranged so that each roll of tape can move independently on the wind-up shaft. The shaft now travels faster than the speed of wind-up of the tape, the differential acting as an independent brake to each tape roll.

A tape which has been wound too soft can initially be deformed with a slight thumb pressure. Later it will distort and gap. A roll which has been wound too tightly will telescope with time. If a core is available, examine the inside of the core for indentations or other marks which would come from character of the slitter shaft.

Finally, for small quantities of specialty widths, the tape can be taken from the master roll and wound into wide logs of suitable length, then these are slit to the required width on a lathe-type slitter, using either a large rotating knife, or a bayonet style blade. The rotating knife can be either free-rolling, or can be driven in either direction, at various speeds to accommodate the needs of the material being cut. As the blade must displace tape to enter the log, there is a tendency for 'dishing' with wider width cuts, which can be off-set slightly with the correct knife profile. The blade is usually lubricated during slitting, usually using a weak soap solution, to prevent adhesive build-up, and this also helps to keep the blade cool. There is also a touch-up stone fitted, to gently 'dress' the blade after each cut.

Log slitting is popular with converters, who can then carry small inventories of each type of tape, yet meet customer needs for small orders of specific sizes at short notice.

A log slit tape will have a clean flat surface to its edge, which will extend uninterrupted across the core edge. There might also be some indication of 'dishing'.



WRINKLE CONTROL

As a final note, the tension in the machine direction of any processed web can cause contraction in the cross direction. This can be corrected by using a bowed roll, or in some cases, a herring-bone roll, the latter being a roll with spiral grooves or slots, beginning at the center of the roll, then travelling in opposite directions to the ends of the roll. This can spread the web passing over it sideways in the same way as a bowed roll. Also, in any of the coating processes, there may be a tendency for a web to travel to one side. This can be controlled by fitting an edge-guide control. This senses any sideways movement, then redirects the web by a slight angular roll movement. Both systems need sufficient entry and exit length to function properly.