Guide to Coating, laminating, *slitting,* sheeting

C. Copping Cattie Adhesives

Coating methods and systems used in modern packaging operations can be divided into two major groups: (1) systems for applying an excess amount of coating to the web and metering the surplus with a flexible blade, rigid knife, air knife, bar or squeeze-roll arrangement (see Figure 1), and (2) systems that apply a total predetermined amount of coating to the web by means of reverse roll, kiss roll, nip or squeeze roll, gravure roll, cast, calender, brush, spray, curtain, or extrusion coating process (Figure 2).

Excess application systems

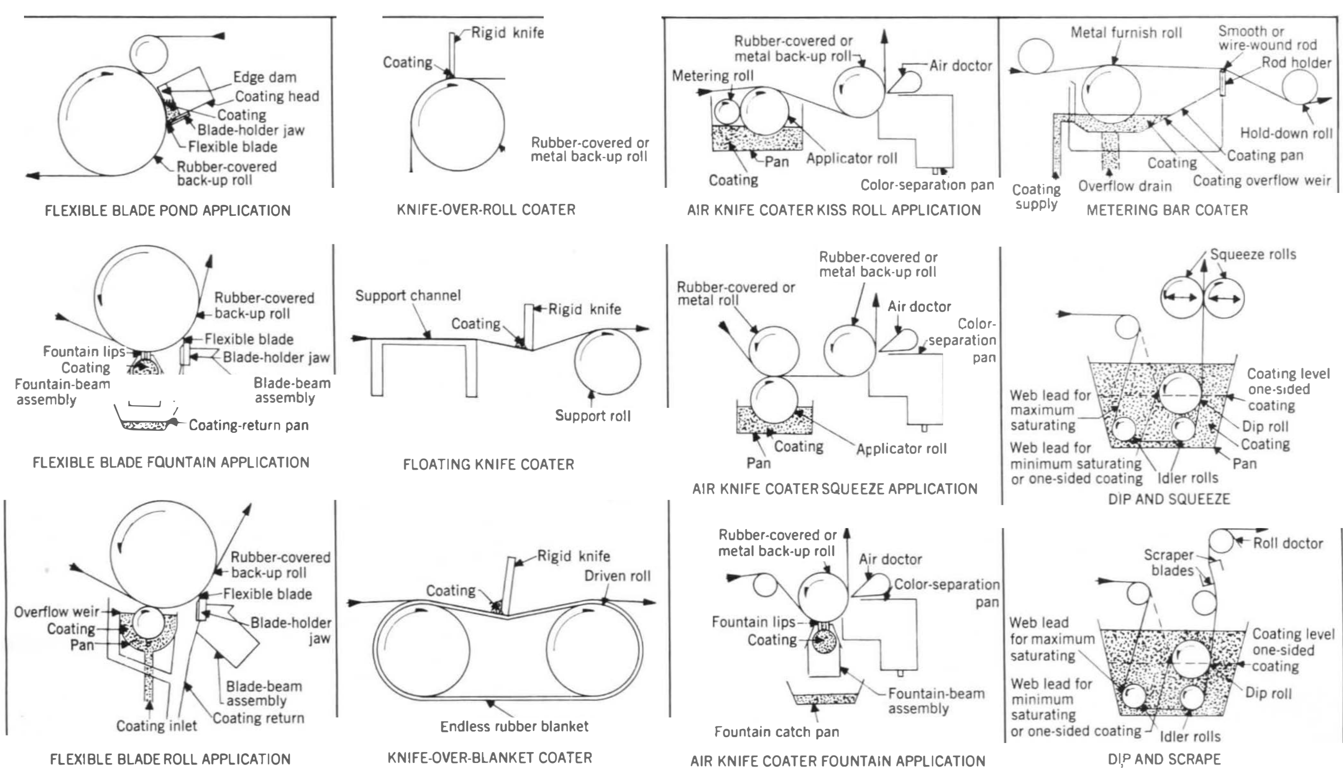
Applying an excess amount of coating to the web with a roll, fountain or pond system and metering the surplus coating from the web with a flexible blade operating under pressure against a rubber-covered backing roll is achieved with the *flexible blade coater*. The coater is capable of operating at speeds greater than several thousand feet per minute and is used principally for applying high-solids, clay-based coatings to paper and paperboard substrates. A smooth, print-receptive, clay-coated surface results from the sheet leveling and covering effect of the blade coater. This surface is ideally suited for printing and other such converting operations. The ability of this coater system to use high-solids coatings decreases the drying load appreciably, and it is possible in nearly all blade-coater operations to use high temperature and high velocity for drying without disturbing the coating. This means that more quantity and quality drying can be accomplished in less actual dryer length than with most other coater drying operations.

The blade coater has a tendency to scratch the coated sheet when using pigmented coatings because of particles lodging at the blade. However, the real success of a flexible-blade coating operation is very much dependent on the rheological properties of the coating color, the flexibility and smoothness of the coating blade, which may vary with the time of operation and the coating base stock.

The flexible-blade technique may be used (1) as a precoater in conjunction with another coater that applies the top coating or (2) as an individual self-contained operation in an on- or off-machine process. The feasibility of using the flexible-blade coater for applying emulsions, latices and other functional coatings has been given considerable attention because of the speeds attainable and the type of resulting surface obtained on some substrates. As a result, several operations for flexible-blade coaters are now being considered or are actually being used for the functional coating processes. Undergoing research and development also is the application of heavy coat weights at high speeds with a blade coater by applying the coating more accurately, using a lower blade angle, specialized coating formulation and/or a more coating-receptive base sheet.

The *knife-over-roll coater system* is capable of applying a wide range of coat weights and film thicknesses at slow speeds using principally medium- to high-viscosity coatings, mainly of the rubber and plastisol type. The coating equipment arrangement consists of a rigid steel knife with various tip configurations available for coat weight control. This knife is operated over either a soft or a hard backing roll, depending on the substrate and coat-

Figure 1. Coating processes—excess application systems



ing film thickness desired. Also, a system for applying the slight excess of coating required for proper distributing and metering action is necessary as part of the equipment. The design of the rigid knife edge or tip is quite critical in controlling coat weights. A sharp tip results in a light coat weight, and a rounded or wide edge allows application of heavier coat weights and thicker coating films. If the backing roll has a softer rubber-composition covering, the coat weight is usually regulated with blade pressure on the roll; but if the roll is a precision hard roll, the knife is operated with a fixed gap between itself and the roll. The gap is adjustable with varying arrangements of turn screws across the blade. The basic coating method is quite simple in principle and operation. Web tension, knife angle and contour, and the type of backing roll are the primary coat-weight control devices. The presence of coating scratches, the nonuniformity of coating films due to web caliper variations, and the difficulty in processing open-mesh fabrics because of coating strikethrough are undesirable features of this system. The method has recently warranted consideration for the application of iron-oxide type coatings on smooth, even films.

The simplest form of rigid knife coaters is the *floating knife coater system.* This coating process involves scraping the surplus coating from a moving web operating under tension with no positive, direct backing support except the indirect effect of a support channel and roll in close proximity to the rigid knife. This coater is used extensively for coating fabrics or open-mesh materials because coating strikethrough will not affect the operation. Since only 3 or 4 mils of a medium-viscosity coating can normally be applied using this system, application of greater weights requires multiple-pass operations. The two major factors in controlling coat weights with this coater are: selecting the proper rigid knife-edge contour and adequate web tension control. Coating scratches and the uneven coatings resulting from baggy edges and centers are its principal shortcomings.

The *knife-over-blanket coater,* a compromise between the knife-over-roll and the floating knife, is employed principally on delicate webs or materials that tend to stretch. A driven endless belt (usually rubber covered) is used as the web carrier and as a knife backing mechanism. The coater uses medium-viscosity coatings primarily, with relatively light to medium coat weights being attained, as in the floating-knife arrangement. These coatings are more uniform than those produced with the floating knife because the variables of web tension and coating nonuniformity resulting from baggy areas are eliminated by control of belt rather than web tension. However, the system does not offer the accuracy obtainable with the knife-over-roll arrangement. The coated product is susceptible to streaks and scratches. (These, as noted, occur with the other rigid knife coaters.) This coater cannot be used for processing open-mesh materials because of coating strikethrough, which offsets on the belt system.

Air-knife coater. This system applies an excess amount of coating to a web, using a roll or fountain applicator and meters the surplus by removing it with an impinging knife-like stream of air. It should be noted that the ratio of the excess amount of coating applied in the air-knife operation to the amount actually used is generally only 1.1 to 1.6 : 1 as compared to the 15 : 1 ratio common to many flexible-blade coaters. The air-knife pressure is a principal determinant of coat weight. However, web speed, coating physical properties and air-stream angle are also significant factors in weight control.

The air-knife coating operation, which is capable of applying coat weights over a wide range, is generally limited to a maximum speed of 1,000 ft. per minute. Also, it is restricted to low- and medium-solids coatings at relatively low viscosities by the inability of the air jet to meter effectively higher-viscosity and solids mixtures. The restriction to the lower-solids and lower-viscosity coatings presents a problem of drying the applied coating. Care must be exercised to keep the drying velocities and temperatures in the lower ranges in the initial drying stages to prevent: (1) patterning in the coating from high initial velocities, which disturb the smooth coating, (2) film forming or crusting, caused by rapid drying in the first stages and (3) adhesive migration due to adverse drying conditions while the coating is in a semiliquid state.

The air knife has extremely wide application on nearly all webs, including films, fabrics, foils, paperboard and paper. It uses a variety of coatings (mostly aqueous), including common casein, protein, starch and latex clay coatings as well as emulsions, latices and other barrier-type coatings with both functional and decorative objectives. The coater is also used successfully in on-machine paperboard operations, in conjunction with either a blade or a bar coater. The blade or bar coater smooths and evens the sheet by filling valleys of the web; the air-knife system applies a smooth even film of coating to the already previously smoothed web. This characteristic of applying a uniform continuous film thickness of coating, regardless of the receiving-surface contour, makes the air knife ideal for both off- and on-machine operations with numerous coatings on a variety of substrates.

The ability to use higher air pressures resulting from improvements in air-separation pans and coating handling equipment has prompted higher speeds and greater versatility in air-knife coating operations, especially in functional and barrier coatings. New specialized coatings and processing techniques assure the air knife a definite future. The recent significant new applications are: (1) new synthetic latex adhesives producing lower-viscosity and higher-solids clay coatings, (2) PVDC emulsion coatings for increasing barrier and film-forming properties, (3) encapsulated or sensitized coating applications, (4) bubble coatings for opacity and (5) functional backside coatings for paperboard. Use of the air knife for organic solvent-based coatings has been somewhat limited in the past because of: the high volume of flammable solvent-laden air that needed to be handled; resulting coating solids change from solvent evaporation, and drying of the coated surface when the air knife meters the coating from the web. But the advent of new handling equipment and coating application techniques makes organic solvent-based coatings a very realistic area for future consideration.

In a *bar* or *rod coating process,* a smooth or wire-wound rod, which is usually rotated slowly against the direction of web travel, is used to meter the surplus coating that is applied in excess to the web with a one- or two-roll system running with or against the web. A smooth chrome-plated rod is employed as the metering device in the clay coating of paperboard, usually on the machine at relatively slow speeds. The coater, which produces a sheet leveling effect much like the flexible blade, is usually employed on paperboard in tandem units at selected stations on the machine or with other types of coaters, such as the air knife. The use of a smooth rod generally restricts the coat to the lower weights, necessitating dependency on solids, web tension and web speed to control coat weight. This coater, with wire-wound bar, has proved satisfactory for coating carbon paper in both strip and complete coverage operations, for hot-melt coating with heated equipment and for latex emulsion coating. The diameter of the wire winding, which regulates the amount of coating passing through, and the solids of the coating are the major coat-weight determinants. Because adequate flow-out is necessary to produce a smooth, wire-mark-free coated sheet when metering with a wire-wound rod, coating viscosity must remain relatively low. This limits coating solids to the low to medium range. With common clay, emulsion and latex coatings, the difficulty in maintaining even coat weights across the web, occasional scratching or streaking and generally lower speeds in most operations reduce the future potential use of this type of equipment.

The *dip-coating process* is usually divided into two areas (1) application of surface coatings and postmetering of the surplus with squeeze rolls or scraper doctors and (2) saturation and impregnation operations, with the same squeezing or scraping techniques used to control the amount and degree of impregnation. When applying surface coatings such as a barrier coating on film, the web is led under a dip roll which is only partially submerged for one-sided operations, or completely submerged for two-sided coverage. The coated sheet then passes through a precise squeeze-roll gap with the coating material hydraulically centering itself. This results in a very accurate coating film thickness. The sheet can also be passed over scraper knives or doctors to meter the coating to the desired level. The more common use of the dip-coating technique is for saturating or impregnating a web. The web is passed under a completely submerged dip roll or a series of dip rolls, depending on the degree of saturation desired and the dwell time needed. When the sheet emerges from the tank, the surplus coating is removed either by a scraping bar or doctor on each side of the web, or by the web passing through a precise squeeze-roll gap that squeezes the surplus from the web to obtain the desired saturation. The degree of saturation or impregnation depends greatly on dwell time; viscosity of the saturant, which is usually quite thin and may be heated if desired; web tension; line speed; roll or scraper gap, and the general wet-strength and physical properties of the web itself. Since both sides of the web are usually coated, especially in saturating operations, the sheet is generally dried in a tunnel or tower-type oven.

Predetermined systems

The application of a precise predetermined amount of coating to a web is achieved by premetering the coating before its application.

The inherent ability to meter and apply a very accurate uniform film of coating on a smooth or an irregular surface using a wide range of coating solids and viscosities makes the *reverse-roll coating* process the most versatile of all roll coaters. The coater is capable of increasing the coating film thickness 20-fold without loss of film accuracy, and the coating application on most surfaces is a smooth deposit needing no further smoothing. The coater, which can consist of two to four rolls, is most commonly used with a three- or four-roll arrangement. One of the rolls is a rubber backing roll that is run at line speed; the other is the coating or application roll; the one or two remaining rolls serve to meter the coating more precisely. Coat weight and coating control are primarily regulated by the metering-roll gap and the rate of rotation of the application and metering rolls in relation to the web speed or backing-roll speed. The speed ratio of pick-up roll to applicator-roll speed is a factor if the four-roll system is used, as is the gap between them.

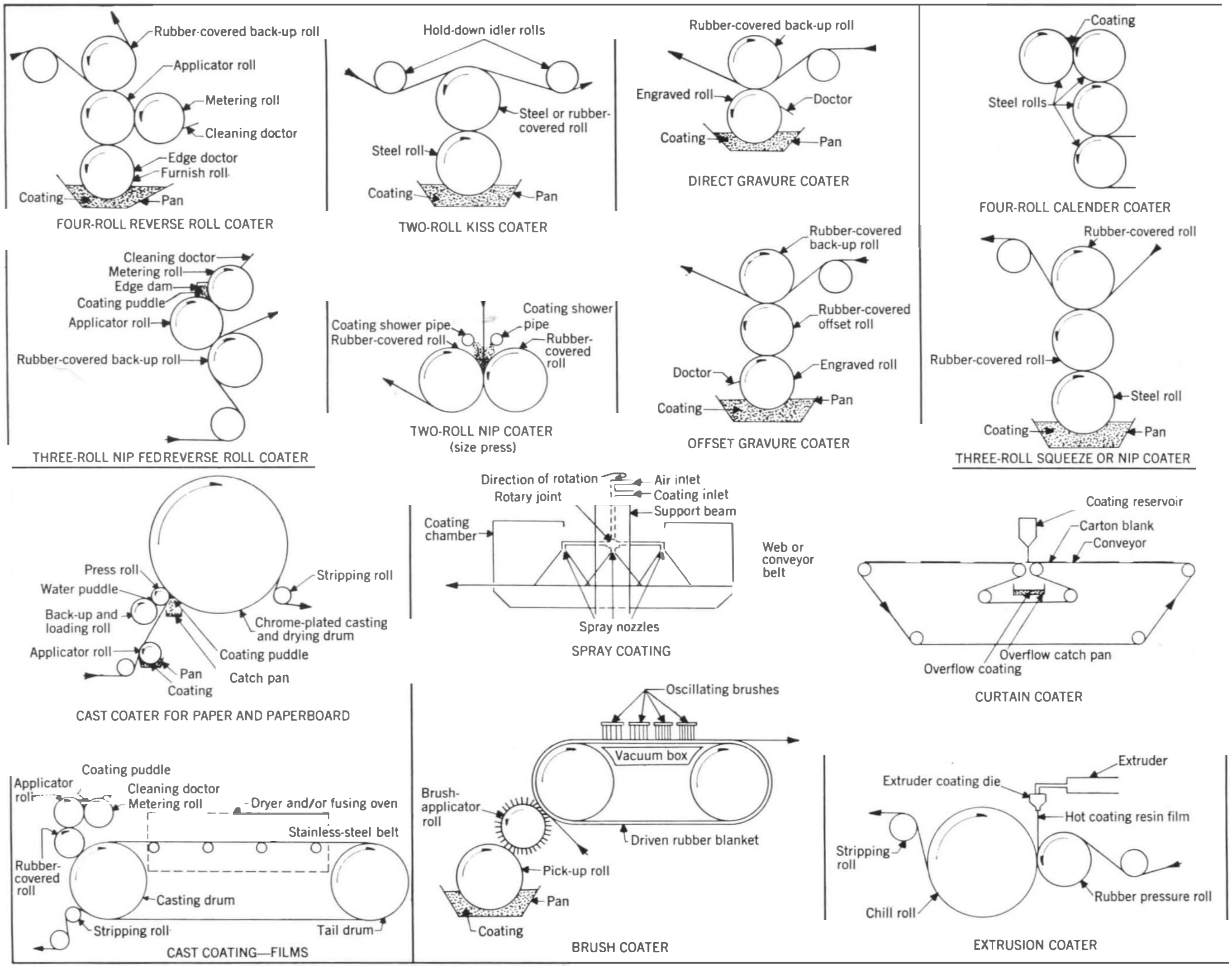
The coater operates on the principle of a reverse application of a precisely premetered coating film to a web held to a rubber backing roll with adequate tension to transfer the entire amount of presented coating to obtain the best coating finish. The coater rolls, made of chilled iron except for the rubber roll, are precision ground to 0.0001-in. tolerance and are mounted with 0.00015-in. TIR (Total Indicated Runout) bearings to assure the most accurate metering gap possible. This coater has a tendency to reproduce the substrate surfaces on rough materials and it should not be used on open fabric materials, since a coating strike-through pattern will result. The preciseness of the coating film and the lack of scratches in most operations applying coating materials—adhesives, plastisols, organisols, pigmented coatings, lacquers and others—make this a very desirable process even though it operates generally at lower speeds. The future of the reverse-roll coating process has been strengthened by recent developments including (1) use of zinc oxide electro-phototype coating expansion and (2) new equipment such as the fountain-feed system for applying solvent coatings that decreases solvent loss from roll exposure time, thus opening previously restricted coating areas using highly volatile solvents.

A *kiss coater* applies a coating to a web without assistance of a backing roll to support the web. The coater may consist of only one metal or rubber roll when used strictly as an application operation. However, most kiss coaters generally employ a two-roll system that can be mounted either horizontally or vertically. Two rolls enable premetering at the roll nip to control the amount of coating presented to the web. When a metal and a rubber roll are used, the rolls are squeezed together to meter the coating going to the top roll. To accomplish this metering action, the two rolls must run in opposite directions: the top roll travels with or against the web, depending on the type and amount of transfer desired. In some operations two metal rolls with a fixed gap are used to regulate the coating, depending on the coating and weight required.

Good tension control and complete contact with the top roll are essential for a uniform coat and the prevention of skips. Also, some post-smoothing devices such as reverse spinning rolls are normally used to eliminate the film split pattern obtained when the coating is kissed from the top roll. The kiss coater is used principally for applying hot or cold aqueous adhesives to gummed tapes or as a laminating adhesive medium coater. It is also used as an excess coating applicator in air-knife, bar and some flexible-blade operations where post-smoothing and metering are required as a separate operation.

The *nip* or *squeeze-roll coater* applies the coating to the web as it passes between the coater rolls. The coater may consist of two to four rolls. However, two rolls—both metal or a metal and a rubber one—are used for most operations. Usually, the nip coater is used for applying fairly thin coatings that are not susceptible to roll

Figure 2. Coating processes—predetermind application systems



patterning. Using the squeeze principle, the coating is applied and metered while operating with a flooded nip in most operations. The amount of coating that is actually applied to the web depends on rubber-roll hardness, nip pressure, viscosity and thixotropy of the coating, speed of operation and base-sheet characteristics.

This type of coater finds a major application for sizing paper and fabric, and it conforms to the typical size press common to the paper industry. The operation is usually a double-side coating process in which the coating is showered to both sides of the web, forming a puddle at the coating nip. The use of a third and/or fourth roll provides closer control and an additional premetering nip for the more viscous coatings.

The *gravure coaters* are usually constructed in a two- or three-roll vertical design. In the two-roll design or the direct gravure process, the bottom roll is engraved with a knurled pattern. Coating weight desired and the type of coating used determine the pattern engraved on the roll. This roll, which runs in a pan of coating, is doctored with a thin blade that leaves an even amount of coating in the knurled cells. The coating is transferred directly onto the web from the cells at the nip formed by the engraved roll and the rubber backing roll. Unless there is good coating flow-out, the direct gravure method often transfers the engraving pattern to the coated sheet. The three-roll or offset-gravure coating method is often used to eliminate this condition. As with the direct gravure coating method, the engraved cylinder is operated in the offset method in a pan of coating with a thin blade doctoring the excess coating. The engraved roll transfers the coating to a rubber-covered offset roll that applies the coating to the web at a nip formed with the rubber-covered backing roll. Occasionally, an additional roll may be employed in either operation to serve as a fountain roll to feed the gravure cylinder. This prevents coating splash and unnecessary agitation of the coating at higher speeds.

Gravure coating exhibits very precise control of a generally lightweight coat in both the machine and cross-machine directions. The coating-weight range obtainable is very limited by the engraved-cylinder pattern and this necessitates a roll change for different coat weights. The coater is used for applying lacquers, polyvinyl acetate, PVC adhesives, low-temperature hot melts and hot waxes, iron oxides and other coating operations requiring maximum uniformity of a moderately lightweight coating.

Processes labeled *cast coating* represent two distinctly different operations with quite opposite end products—one a clay coat and the other an organisol or plastisol coat. The first type is used

Coating processes and techniques

Coating process	Application method	Metering method	Speed,[1] viscosity,[2] coat weight[3]	Principal advantages	Principal disadvantages, limitations	Coating type, finished material
Flexible blade	Pond, roll, fountain	Flexible blade	S: 300-4,000 V: 2,000-20,000 C: 4-10	Smooth, even coating surface; handles high-viscosity and high-solids coating; high speed	Blade scratching, streaking; restricted to lower coat weights	Clay coating, paper and paperboard in both precoating and top coating operations
Knife-over roll	Manual or gravity feed	Rigid knife	S: 10-400 V: 1,000-30,000 C: 5-50	Relatively inexpensive equipment; handles high-viscosity coating	Coating lacks uniformity; scratches; inability to process open webs	Rubber and plastisol coating; paper, vinyl fabric webs
Floating knife	Manual or gravity feed	Rigid knife	S: 10-200 V: 500-15,000 C: 5-20	Low equipment cost, good bridging, smoothing; can be used on open-mesh fabrics	Uneven coating on baggy edges or centers; coating scratches; high tension required; low speed	Latexes on paper and cellophane; pressure-sensitive tapes; high weight applications with multiple passes
Knife-over blanket	Manual or gravity feed	Rigid knife	S: 10-200 V: 500-15,000 C: 5-20	Handles stretchy materials; low equipment cost	Coating scratches; not suited for open-mesh fabrics; non-uniform coating; low speeds	Plastisol coatings; fabrics; high weight applications with multiple passes
Air knife	Kiss or nip, roll, fountain,	Air-jet knife	S: 200-1,500 V: 100-600 C: 2-20	Excellent coverage on various webs, using numerous coatings; no scratches; versatile for long or short runs	Limited to low solids and viscosities; generally restricted to water-based coatings	Clay coating paper and paperboard; barrier and functional coatings, film, foil, paper
Rod	Roll	Wirewound or smooth rod	S: 200-1,200 V: 100-2,500 C: 2-10	Small, compact, relatively inexpensive unit; smooth coated surface	Even coat weights difficult; occasional scratches; restricted to low, medium viscosity and solids; relatively low speeds	Hot-melt coatings with wire rod; precoater for paper and paperboard, multipass board coating with smooth rod
Dip and squeeze	Pond dipping	Squeeze rolls	S: 50-1,000 V: 25-500 C: 5-50	Suited to wide range of materials; relatively high speed; very accurate coating on non-saturated webs; two-side coating simultaneously in saturating or surface process	Difficult to adjust for partial saturation, coating variation at high speed; low-viscosity coatings required	Hot-melt coating on glassine; barrier and functional coatings on paper, fabric, waxed papers, impregnated textiles
Dip and scrape	Pond dipping	Scraper knives	S: 50-600 V: 25-500 C: 5-30	Two-sided coating in one pass; low-cost equipment; simple design, operation	For webs with fairly high wet strength; wet streaks and edges; lint accumulation on scraper knives	Phenolic resins, lacquer; high-pressure laminates, coated film, packaging materials
Reverse roll	Roll	Roll gap	S: 50-800 V: 100-20,000 C: 1-30	Precise control of coat weight; wide range of viscosity, coat weight, solids; no coating scratches	Equipment is high cost, requires extreme accuracy in construction and good understanding of process by operator	Adhesive, plastisol, organosol, pigmented coatings on paper; functional coatings on paperboard
Kiss roll	Roll	Roll gap or pressure	S: 100-800 V: 50-2,000 C: 5-20	No coating scratches; provides dry edges or strips; simple in design, versatile in operation	Usually requires post-smoothing; coat-weight limitations on low range; coat-weight change results with speed change; good tension required	Hot, cold adhesives for gummed tapes; applicator for various other coater, laminating systems
Nip roll	Roll	Roll gap or pressure	S: 100-2,000 V: 100-500 C: 4-10	No coating scratches; can be used on variety of webs; high speed; simple in design and operation	Uneven coated surface; requires some post-smoothing; generally lower-viscosity coatings required	Adhesive coatings for laminations; size-press applications on paper machines
Gravure roll	Engraved roll	Engraving pattern	S: 50-800 V: 100-10,000 C: 1-15	Precise control of coat weights; very low coat weights possible; wide range of viscosities; used on variety of webs	Gravure pattern can show in direct method; limited to light- and medium-weight coatings; requires engraved roll changes for coat-weight changes	Hot-melt, functional coatings on paper, paperboard; decorative lacquers, tinting of foil, paper
Cast coating	Roll	Roll pressure	S: 75-250 V: 30,000-50,000 C: 10-25	Extremely smooth, glossy surface; high-quality coating	Low speed; high operating costs; high initial machine cost	Clay coating on paper, paperboard, cover stock and specialty packaging
Cast film	Roll or curtain	Roll gap or orifice slot opening	S: 50-300 V: 100-2,000 C: 10-75	Smooth surface produced; suited to short runs; change of widths and weights possible	Low speed; width limitations; relatively expensive release papers, belts, other production equipment required	Rubber, cellulose and polyvinyl resins; packaging film, functional liners, containers
Calender	Roll	Roll gap	S: 20-300 V: 30,000-50,000 C: 20-50	No solvents used; heavy coating weights possible	High equipment cost; uses only thermoplastic resins; limited to high weights	Applying vinyls to close-weave fabric and paper
Brush	Brush or roll	Applicator speed	S: 100-300 V: 100-500 C: 10-20	Smooth finish with excellent quality; can be used on rough surfaces	Not suited for solvents, solids; viscosity limitations in low range; low speed	Clay coating; specialty papers, high-grade printing papers
Spray	Nozzles	Coating supply rate and pressure	S: 10-300 V: 50-400 C: 3-20	Good coverage regardless of surface configuration; wide operating temperature range; applies two-phase and two-component coatings	Low viscosity restriction; loss of coating in overspray; marginal coating uniformity	Paint, vinyl; decorative and functional coatings on paper and paperboard
Curtain	Orifice slot or overflow weir	Orifice slot opening or flow rate	S: 300-1,000 V: 200-20,000 C: 6-40	Good coverage over irregular surfaces; suited for blanks or flexible webs	Film uniformity regulated by coating properties; cannot apply thin latices or emulsions	Hot-melt, lacquer, wax coatings; carton blanks, flexible webs
Extrusion	Extruder	Orifice slot opening	S: 300-1,500 V: 300,000-500,000 C: 4-40	Excellent coverage, wide range of applications, coat weights; can use various resins: polyethylene, polypropylene, vinyl, etc.	Limited in speed by cooling capacities and film-forming properties of resins	Protective, barrier, functional coatings; paper, paperboard

[1]Normal coating speed range, fpm. [2]Normal viscosity range, cps. [3]Normal coat weight range, lbs./3,000 sq. ft.

on paper and paperboard substrates to produce, with the application of certain hydrophilic clay-type coatings, a very high gloss and smooth finish coated sheet. The wet coating is applied to the web just prior to or at the point where the web meets the highly polished casting drum, which also serves as the drying drum. After it is completely dry, the finished coated sheet, which has a surface that is a direct image of the highly polished drum, is stripped from the drum and rewound. The usually slow speed of the operation is directly related to the size of the drying or casting drum. Drum size is limited by practical physical size standards, and this is the one serious disadvantage of the operation.

The second cast-coating process involves depositing a continuous layer of film-forming material onto a base. The base may be a roll of special release paper, foil, polyester, a continuous stainless-steel belt, or a casting drum. The liquid dispersion—an organosol or plastisol—is applied to the carrier or casting material, using the reverse roll, curtain or other type of coating process. The coating is dried and/or fused while in contact with the casting surface. The finished sheet of film, which has a surface similar to the casting belt, is stripped from the carrier web or casting surface and wound into a continuous roll.

The *calender coater* finds its greatest use for heavy coat weights. It is used mostly for applying high-viscosity vinyls to paper or closely woven fabrics. Coating equipment usually consists of three or four rolls. The coating is applied in a direction away from the coating-supply nip, to make use of roll working and metering of the coating. The restriction of calender coating to application of higher coat weights seriously limits its area of use, and the type of substrates that can be used is limited by the tension required to insure a proper operation.

The oldest commercial coating process in use today is *brush coating*. This process, which is restricted to slower speeds and off-machine operations with relatively low solids limitations, is used because it produces excellent quality coated papers. The equipment consists of a brush or roll applicator that applies, with the use of various control devices, a moderately precise amount of coating to the web. Post-smoothing is performed with progessively finer brushes that distribute and smooth the coating while the web is on a rubber blanket or some type of supporting medium. Brush coating now is limited to applications requiring a fine quality coated sheet and its use continues to decrease.

Spray coating is a unique process because of its ability to achieve a variety of special coating patterns and effects. This system applies coatings over a wide temperature range on any type of surface regardless of its roughness or configuration. Both two-phase and two-component applications for multicolor and pattern effects are possible, making spray coating an irreplaceable process. This is so despite the restriction to low-viscosity coatings, loss of coating from overspray and only a generally acceptable coating uniformity. Some patterning and nonuniformity of coating results on moving webs, so the head's carriage, attached to an overhead support beam, is moved slowly over the surface to be coated; also, the heads are rotated slowly to reduce this problem to a minimum. Spray coating is most commonly used in operations where roller or knife coating equipment cannot be used.

The *curtain coater* extrudes a laminar film of functional coating under pressure or by free discharge through a slotted orifice or over a weir. Coatings can be any moderately thin, evenly flowing material: hot-melt blends, lacquers and some latices. Four factors—speed of the falling coating film or curtain, the horizontal speed of the product, the coating formulation and the curtain thickness—determine the finished coating film thickness. Because of the gravitational limits of the falling coating-film speed, there is a limit to the thinness of film that will remain continuous; thus effective line speed is limited. A major limitation of the curtain coater rests with the film-forming ability of the coatings used. A coating that does not flow evenly will not give good results, for skips or heavy areas will result. Many new hot-wax-blend formulations have been specially designed for use with the curtain coater and this has opened an even larger area of hot-wax coating on carton blanks. Good coverage and comparable or better physical properties will result at relatively low coat-weight ranges. Curtain coating is being used increasingly to coat materials for flexible packaging. Many of the newer hot-melt blends are being run at moderately high speeds approaching 1,500 f.p.m.

The *extrusion coating* process uses a plastic extruder to convert a thermoplastic resin from a solid pellet into hot melted form. The resin is extruded as a continuous film through a slotted die onto the web at a nip formed by a metal cooling drum and a rubber-covered pressure backing roll. Since the hot film is applied against the metal cooling roll, a highly polished roll will give a high-gloss coated surface when cooled or a dull finish if a matte roll is used. As noted in the curtain-coater process, the extruded film must be a continuous molten sheet and an evenly flowing film with adequate cohesive strength to become stretched and thinned as required by this process. The applied film thickness obtained in extrusion coating is determined by the opening of the die slot and the relative film-to-web speed. The coating's ability to stretch up to 40 times as thin as the film extruded through the slot opening and a pressure discharge into the roll nip allow operations at higher speeds than those attainable with curtain coaters. Because of limitations in extruder output and in cooling capacity, a slower operation results in some instances, especially with thicker films.

There are several promising developments in extrusion coating. The use of a perforated roll with a vacuum behind the paper instead of a chill roll achieves greater adhesion of coating and paper at higher speeds. Also, it eliminates the cooling-roll problems common to a standard operation, and a generally better quality film results. Extruder sizes are generally shifting to smaller diameters—with high power input, longer screw-metering sections, longer slot-to-land relationships and simpler internal die designs. Important, too, is better control of melt temperatures, especially with infrared radiation pyrometers on polyethylene melts.

Laminating

Laminating processes are commonly divided into two major categories: *wet* and *dry bonding* (see Figure 3). Equipment is designed to meet the specific requirements of each of the two different methods.

Wet bonding

This method is used when one or more of the substrates is permeable to the passage of coating solvents. It is employed, for example, in laminating paper or paperboard together or with foils. Wet bonding uses solvent or aqueous-type bonding agents, including silicates, starches, resin emulsions, latices, as well as water-soluble glues.

Paperboard laminating. Roller-type applicator units, such as the squeeze or kiss method are quite satisfactory for applying the usually high-solids converted starch or a comparable adhesive to nonuniform, thick paperboard or a similar material. After applying adhesive to one or more of the plies, the webs are jointly passed through steel or chilled-iron press or combining rolls, with adequate pressure provided to assure good bonding. Such a laminated sheet does not usually need drying, for the solvent is absorbed into the substrate. Many times a sheet cutter is employed instead of a winder as part of the machine line, especially when handling heavy plies, to avoid deformation in winding the sheet. An example of this type of lamination is the combining of heavy structural paperboard plies up to ½-in. thick for drums.

Specialty laminating. Wet bonding for many functional laminated products such as smooth papers or paperboard and paper-backed foils often requires an application of a finely metered thin adhesive film to the more absorbent base web.

Equipment for this operation includes direct and offset gravure, three-roll nip or kiss with post-smoothing. The press or combining stations must be more precisely designed. Rubber and steel combining rolls are used, with the latter usually fixed and the rubber roll pneumatically loaded. A successful operation with delicate webs requires proper means for drying the lamination to avoid blistering. With foil-backed paper or paperboard, drying must be accomplished through the paper or paperboard substrate and this can usually be done satisfactorily with cylinder or air drying directly on the machine line.

This operation is commonly used for paper-backed foil in cigarette packages, foil label stock, foil bags and other such items, which are laminated for both decorative and protective, functional purposes.

Dry bonding

This method incorporates (1) the use of either an aqueous or solvent adhesive film that is dried prior to laminating or (2) a plastic-type adhesive film.

Solvent laminating. Aqueous or solvent laminating adhesives such as resin lacquers, rubbers and various solvent cements are applied in precise amounts by means of direct gravure or reverse-kiss adhesive application. After the adhesives are properly dried to remove all solvent or water, plies are combined in a pressure or a pressure and temperature nip. The laminating section includes a pneumatically loaded rubber roll and a fixed steel roll. This process is used for foil paper inner wraps and for combining films with papers and paperboards.

Extrusion lamination is a form of dry bonding that uses no solvent in the laminating medium. A flat die extruder is used to discharge a melted curtain of polyethylene, polypropylene or other thermoplastic resin into a nip between two substrates to be laminated. To set the heated adhesive, the laminated sheet is cooled by a specially designed combining and cooling-roll section. The cooling section replaces the drying or heating section generally required in wet bonding. The extruded laminated coatings produce a high water- and moisture-barrier coating that is tough and flexible.

A typical use of extrusion lamination is for preformed packages combining paper with foil or cellophane.

In *wax* or *hot-melt laminating*, the hot adhesive coating layer is usually applied by a reverse kiss, dip, curtain or fountain-type coater. The laminating equipment commonly consists of a pneumatically loaded rubber roll with a fixed steel roll to combine substrates. An adequate chill-roll section is required to set the adhesive. Two advantages of the hot-wax adhesive laminating method are: (1) no solvent drying or recovery is required, since these adhesives are 100% solids and (2) machine operating speeds are not limited by drying or recovery operations. The addition of polymers to the waxes produces tougher films, better cohesive and adhesive characteristics, and good moisture-barrier properties. This type of lamination lends itself to the production of moistureproof wrappers of all types, liners and pouches, and carton overwraps.

Figure 3. Laminating processes—wet and dry bonding

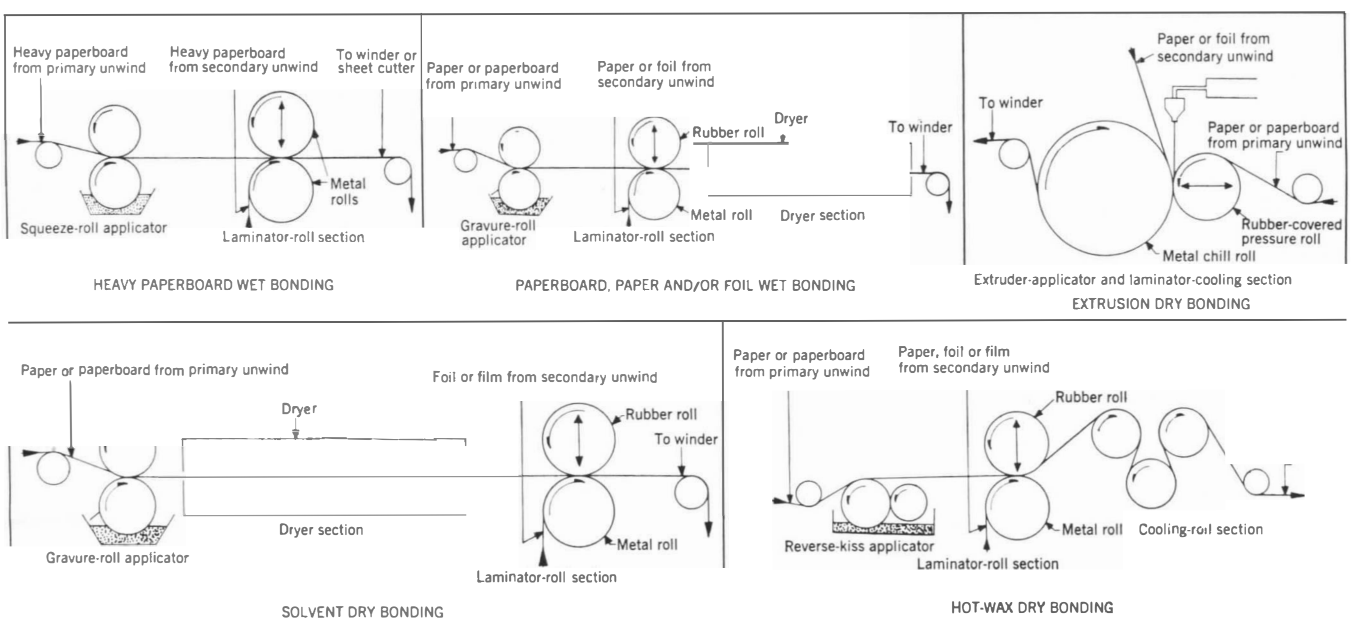


Figure 4. Slitting methods

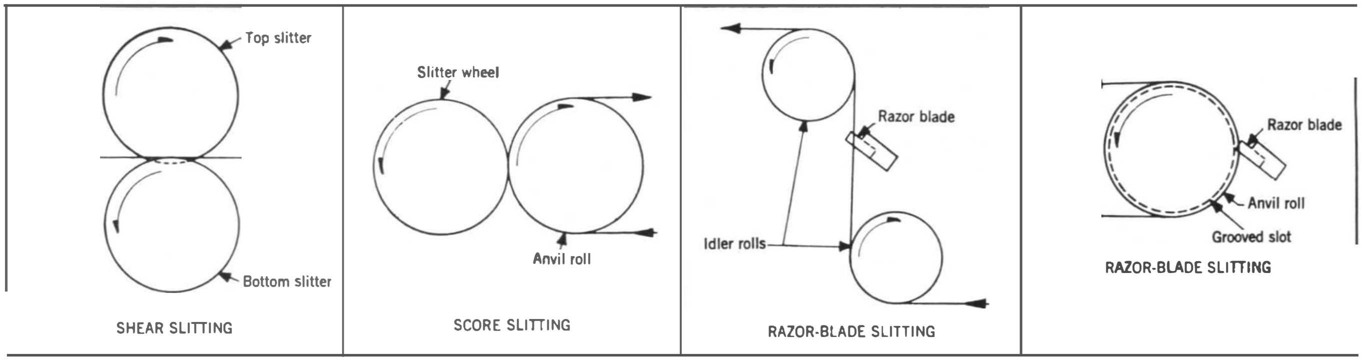
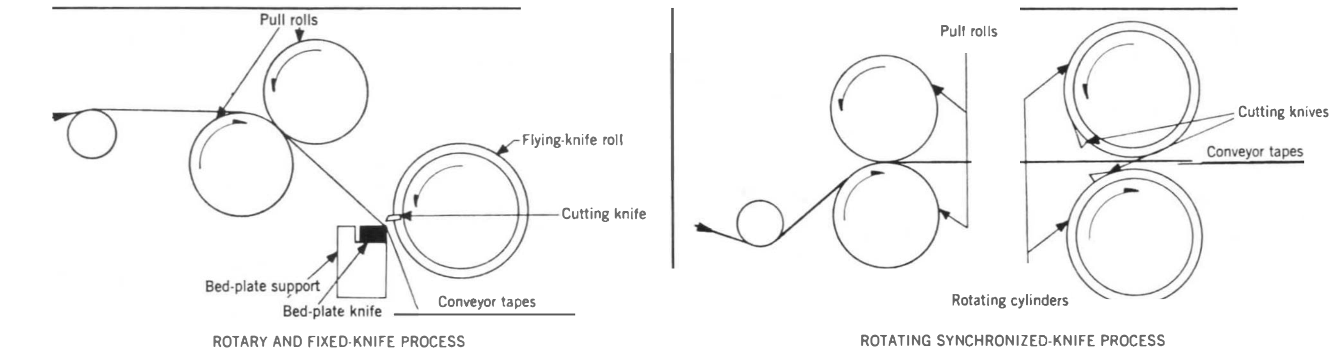


Figure 5. Sheeting processes



Another type of dry bonding is *heat lamination*. Polymer-coated paper, cellophane or foil are frequently combined with other substrates by preheating the coated web either prior to or in conjunction with pressure application. This technique is usually employed after the polymer-coated web has been printed.

Slitting

The three most common methods of slitting (see Figure 4) are:

1. Shear,
2. Razor-blade and
3. Score cut.

Shear cut, the most common method, produces a clean-cut edge with very little dusting and requires minimum maintenance. The shear slitter consists of a pair of driven overlapping sharpened or bevelled blades that form a scissors-type arrangement in continuous rotating form. Recently, shear slitters were made available with a self-sharpening feature that uses a bell-shaped top, which is an expandable item.

The shear slitter requires longer set-up time for changing strip width, but generally cleanliness, quality of the slit and usefulness for a wider range of substrates are clear advantages. Uses are for paper (kraft, fine and coated), board, gum tape, bag paper, cellophane, saran, polyester, vinyl, heavier acetates (over 4 mils), foil and backed foil.

Razor-blade slitting is used for films and plastics because of the clean cut edge produced.

Slitting may be accomplished with razor blades between two closely spaced idler rolls or the blade may operate in a grooved back-up roll. All four corners of the blade are used, and the blade is expendable.

A vibration that sometimes sets up in the razor blade itself will impart a slight "nicking" of the material edge, which has a tendency to weaken the web for further processing, especially when slitting cellophane. However, razor-blade slitting is common for vinyl, saran, polyester, cellophane and light acetate films (up to 4 mils) as well as for foil.

Score cut slitting can produce a satisfactory quality slit if the wheels are properly ground and polished. The score slitter consists of a hardened wheel with a V-type edge slightly rounded at the extreme tip. The wheel is pressed against a hardened-steel backing roll and the material to be slit passes between wheel and roll. Score slitting is not actually a cutting-type action, but a process that severs fibres by wheel pressure applied by a spring or by air.

Disadvantages of this type of slitting are: maintenance must be adequate to achieve a quality cut and applications are limited.

The advantages are its low initial costs, simplicity of operation, and the ease of changes for strip width, which make it appealing for these applications: gummed tape, waxed papers, glassine, scrim-backed papers, some plastics, insulating tapes and masking tape.

Other methods of slitting include the *burst* type, *rotary blade* and *top slitter*. The burst-slitter operation passes a web around a serrated roll with a score-type slitter piercing the material in the center of the serration on the back-up roll.

The process is used primarily on foil. It produces a slightly lower quality cut than that achieved with the shear method, but blade life is considerably longer. Rotary slitters, usually a saw-toothed circular blade, are employed primarily in top slitter operations. Slitting is performed as close to the running nip as possible, or the material is actually slit after it is wound on the winding core. The disadvantage of frayed edges limits this application to rough papers, such as wrapping paper.

Sheeting

The sheeting process, which converts a continuous web into sheet form, uses three basic types of cutter-knife arrangements: (1) the conventional rotating and fixed knife; (2) double rotary synchronized knives, and (3) a track-mounted rotary knife (see Figure 5). The system used is determined principally by the physical properties of the substrate and/or coating and the quality of cut and production speed that are required.

The conventional *rotating and fixed-knife arrangement* is most commonly used in multiple-web operations on predominantly light- and medium-weight base sheets. The process is not generally used for heavier webs because it produces a relatively poor-quality cut. The rotating or fly knife contacts the web from edge to edge, producing a shear-type cutting action when brought in contact with the backing support of the stationary-bed knife. The stationary knife may be adjusted for cutting clearance, depending on the web to be cut. Both knife edges are made of heavy tool steel with carefully ground sharp edges; these edges are generally at a slight leading angle with ½ in. or more of lead being used, depending upon web width and speed of operation. This leading angle produces a square and straight-edged cut on the finished sheet, while operating in a moving position. Some cutters employ straight-edged knives that require interval stoppage of the web or a coordinated web and cutter movement during the cutting operation. Sheet length in this operation is controlled by the rotational speed of the fly knife in relation to the speed of the web.

A second type of cutter employs two *synchronized knife cylinders* that rotate in close proximity to the web to be cut. The web is fed horizontally between the knives and is cut when the knives meet with a shear-type cutting action at approximately a 90-deg. knife-to-paper angle. This action produces high knife pressures, ideally suited for sheeting heavier papers and paperboard with a minimum of knife dusting. Because of the lack of sheet support, due to the rotating bottom knife, the process is limited to the heavier grades with adequate sheet stiffness for self support. These knives have a leading angle determined by web speed, web width and cutter-blade speeds. The sheet length is controlled by accelerating or decelerating the knife cylinders, depending on the length desired. However, the actual cut is made at web speed.

The *track-mounted rotary blade* is used primarily for sheeting rigid materials. This method employs a rotary knife blade or saw mounted in a track designed to cut the web in a diagonal pattern across the material—to produce a square and straight edge on the finished product. This process is generally slower than the other cutter operations, but is desirable for heavy laminated products and other similar materials.

A considerable amount of auxiliary equipment before and after the actual cutting or sheeting operation is necessary for a successful and efficient operation: single and multiple unwinds together with pull rolls, for web speed and tension control; spreader rolls, for wrinkle control; idler rolls, for web conveying; and shear type slitters, for trimming sheet width to deliver the web in a continuous, uniform operation to the cutter unit for conversion into sheets.

After the cutting process is completed, the sheets are conveyed on parallel acceleration tapes to the stackers. The stackers are equipped with layboys to jog the sheets into place, with paddles gently evening their edges. In higher-speed and multiple-sheet operations an overlap delivery system operates a first set of tapes at slightly higher than line speed and a second set at a reduced speed to slow down delivery of sheets before entering the stackers. This results in overlapping the sheets as they are processed.

Other types of auxiliary equipment include web guides, static eliminators, sheet inspectors and weighing systems, automatic ream counters and markers, mechanical figures for catching the sheets when skids are being changed and associated drive equipment.

The current trend in rotary cutter equipment is toward narrow to moderate widths, enabling more rigid knife assemblies and thus, longer-lasting knives with cleaner cutting action. An innovation being considered is use of a laser or high-energy beam to cut sheets. Equipment cost and beam transversing are problems that are limiting applications at present. END