INDUSTRIAL AND SPECIALTY PAPERS

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Volume II—Manufacture

Prepared by a Staff of Specialists
Under the Editorship of

Robert H. Mosher
Director, New Business Development
Kimberly-Clark Corporation

and

Dale S. Davis
Professor Emeritus, Pulp and Paper Technology
University of Alabama

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CONTRIBUTING AUTHORS

Frank C. Campins, Chairman of The Board, Polymer Industries, Inc., Springdale, Conn.

Dale S. Davis, Professor Emeritus, Pulp and Paper Technology, University of Alabama.

Lawrence W. Egan, Vice President, Frank W. Egan & Company, Somerville, N. J.

J. F. Hechtman, Research Associate, Kimberly-Clark Corporation, Munising, Mich.

Jack E. Jayne, Research and Engineering, Kimberly-Clark Corporation, Neenah, Wis.

S. B. McFarlane, Jr., Vice President, Research and Development, Sun Chemical Corporation, New York, N. Y.

Richard Martinek, Director of Manufacturing Printing Papers, Kimberly-Clark Corporation, Neenah, Wis.

J. Eichhorn, Manager, Special Projects Packaging Department, The Dow Chemical Company, Midland, Mich.

Foreword

"Manufacture," which is Volume II of *Industrial and Specialty Papers*, covers production methods in this segment of the pulp and paper industry and is basically a revised and expanded edition of *The Technology Of Coated And Processed Papers* published in 1952.

"Technology"—Volume I of this series—has recently been released. Two more volumes are anticipated: Volume III on applications and a completely new Volume IV on new product developments and management techniques in the field of specialty papers.

Let the readers of these texts be reminded again that the first presentation in English dealing with the field of specialty papers appeared in two volumes, *Specialty Papers* and *The Technology of Coated and Processed Papers*, in 1950 and 1952 respectively, under the editorship of Robert H. Mosher. With many years of experience in the development and sales of such papers added to his original background in manufacturing, he is in a unique position along with co-editor Dale S. Davis to revise these important reference works in the literature of pulp and paper and to bring them up to date.

Their original appearance in the early 1950's marked for the first time and in one place the publication of the technology and art of specialty papers production. With the aid of eight well-known specialists in the field, "Manufacture" becomes the second of a much-needed four-volume series.

Sixteen years have elapsed since the original works were published. Many improvements in the properties of foils and plastic films, the development of simplified yet high-speed coating equipment, the rapid and extensive advances in reprographic papers, and the increased use of pressure-sensitive and release papers are some of the important reasons why the updating of the earlier work is so timely and significant.

This volume and its companions will be helpful to expert and student alike. The editors and authors have contributed much time and effort to this thoughtful revision and are to be sincerely complimented by all of us in the industry and by many without.

June 1968

J. C. Wollwage
Vice President of Manufacturing,
Kimberly-Clark Corporation

Contents

chapter 1

Paper-Converting Machinery

LAURENCE W. EGAN*

Paper-converting machinery includes all types of machines used to perform secondary operations on paper after the web of paper or paperboard has been formed, dried, and calendered on the papermaking machine.

The equipment used comprises the following converting machines and auxiliaries: unrolls, coaters, impregnators, laminators, printers, embossers, crepers, calenders, slitters, flocking machines, brush polishers, corrugators, printer-slotters, bag-making machines, winders, cutters, stackers, and folders.

Consumption of paper and paperboard has risen steadily over the years and per capita in the United States is the highest in the world. Each year a new record is set as more and more need is found for converting paper into more diversified products. In the field of packaging, the many uses of paper and paperboard have accelerated consumption in recent years.

Wood is one of the few raw materials that nature constantly replenishes. The major paper companies have insured that the increased consumption should be matched by perpetual forestation programs that guarantee a never-ending supply for the production of paper and paperboard.

The multitude of decorative and functional uses of paper and paperboard has created the need for many forms of paper-converting

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Publisher's note: All illustrations in this chapter are by courtesy of Frank W. Egan and Co. except where otherwise indicated.

* Revision of "Paper-Converting Machinery" by the late Frank W. Egan in *Technology of Coated and Processed Papers* (Ed. R. H. Mosher), Chemical Publishing, New York (1952).

machines dictated by the properties of the raw materials combined with paper, by the varied properties of the paper and paperboard itself, and to some extent by the much higher operating speeds realized in the several years.

Originally paper was sized, coated, and printed in sheet form. Increased demand and economies in handling paper in continuous roll form have led to unrolling devices, winders, and high-speed coaters. With few exceptions, the major tonnage of paper and paperboard converted today is produced on continuous roll-fed paper converting machines.

This chapter discusses the paper-converting machinery presently in general use.

UNROLL UNITS

Every converting machine that processes a continuous web must have an unroll unit. This can vary from the simplest form of unroll still in use on laboratory machines, pilot plants, and slow-speed converting operations to very complex flying-splice unrolls with constant tension and side-guiding features.

Rolls of paper come to the unroll generally wound on 3 or 4-in. inside diameter, spirally-wound paper cores, although the tendency in recent years has been to use larger diameter cores for better tension control. Paperboard is seldom wound on these smaller cores; usually it is wound on cores of 8, 10, or 12-in. inside diameter.

Notched steel tubes or aluminum tubes are used as cores, as well as notched metal-ended paper cores. At times a roll may be wound on an expanded shaft and delivered to a converting machine "coreless."

A shaft is inserted through the core of the paper and the roll is centered by means of cones. The most common is the ribbed cone made from cast iron and shown in Figure 1-1.

Normally affixed to the shaft is a simple friction brake, mechanical-

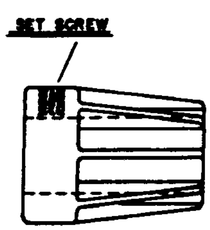

Fig. 1-1. Ribbed cone.

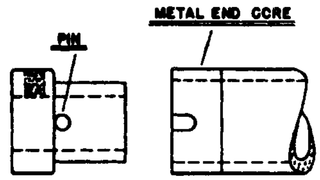

Fig. 1-2. Pin-type cone.

ly or pneumatically loaded, or a regenerative dc motor. This ribbed cone, however, does not permit the application of the normally desired tensions, particularly when the cores are of small diameter.

The pin-type cone shown in Figure 1-2 is designed to accommodate a metal-end core or a steel or aluminum notched tube-type core and permits the application of higher tensions.

Preferred for even higher tensions is an expandable shaft that eliminates the use of cones. These shafts are designed to slip into the cores with minimum clearance, and metal buttons or lugs are expanded pneumatically to grip the core throughout its entire length, with the expansion and contraction accomplished through a fitting at the end of the shaft.

The disadvantage of the added weight of this type of shaft is more than overcome by the ease and minimum amount of time involved in changing from a depleted core to a new roll, as well as the added

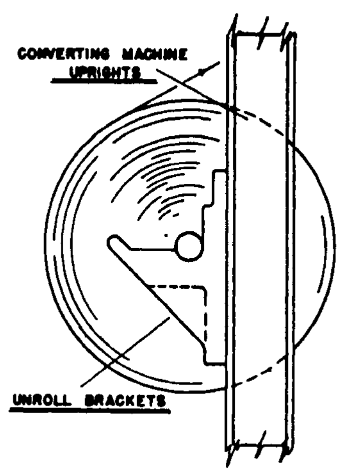

Fig. 1-3. Unroll bracket.

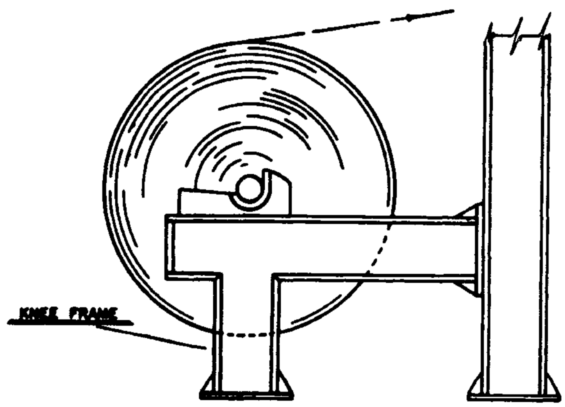

Fig. 1-4. Knee frame: unroll stand.

purchase that permits the higher braking necessary for the desired running tensions.

An unroll stand may consist of merely a pair of brackets mounted on uprights of the converting machine, as shown in Figure 1-3, or a simple knee frame can be used (Figure 1-4).

The unroll stand is usually a separate unit and can be arranged to take one or two rolls of paper, as shown in Figures 1-5 and 1-6. A dual unroll stand permits the making of a flying splice at low to moderate speeds, normally up to 300 ft/min.

These unroll frames are relatively simple in design and are made of welded structural steel, although cast-iron brackets or bearing housings are commonly used; the bearing surface itself is usually a bronze sleeve. The legs of the frame should have feet or plates that distribute

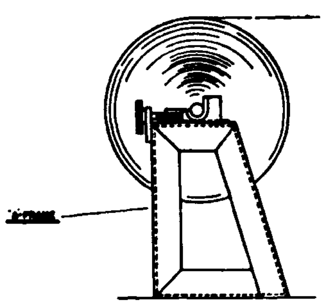

Fig. 1-5. A-frame unroll stand.

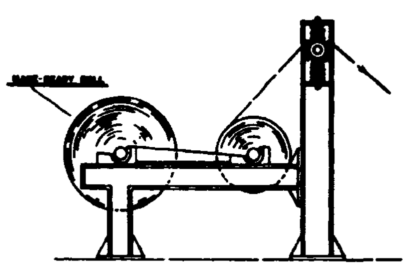

Fig. 1-6. Double unroll stand.

the load on the floor so that no settling of the unroll stand can occur. The two sideframes should be rigidly connected by a structural member.

Increased demand for high-speed continuous operation has led to the development of flying-splice unwind units. This need has arisen not only because of the loss of production realized when slowing down or stopping to make a splice, but because in many cases, notably in extrusion coating, the converting cooperation must continue at a constant speed to maintain a product within tolerable specifications.

The two basic types of flying-splice unrolls are the sliding and turret types shown in Figures 1-7 and 1-8.

In both cases the principle of effecting the splice is the same. The leading edge of the roll to be spliced is cut into a V. The point of the V is taped lightly to the roll to keep it from unravelling and glue is applied near the center of the V and near the edges. The new roll of paper is driven up to web speed by rubber rings for a sliding unroll, and by rubber rings, belts, or a separate dc motor for a turret unroll.

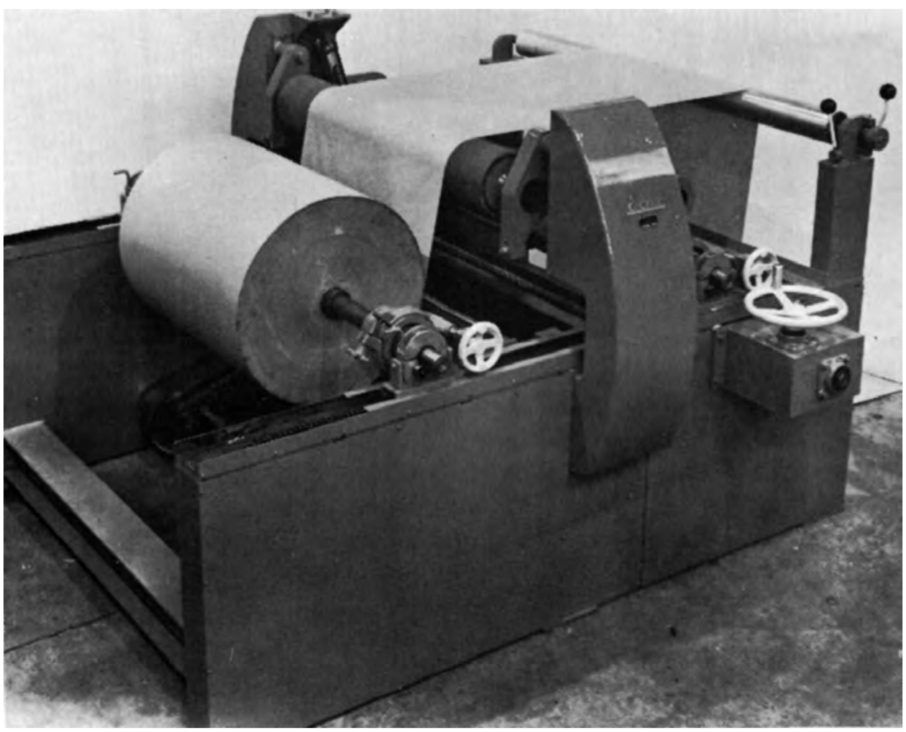

Fig. 1-7. Horizontal flying splice unroll.

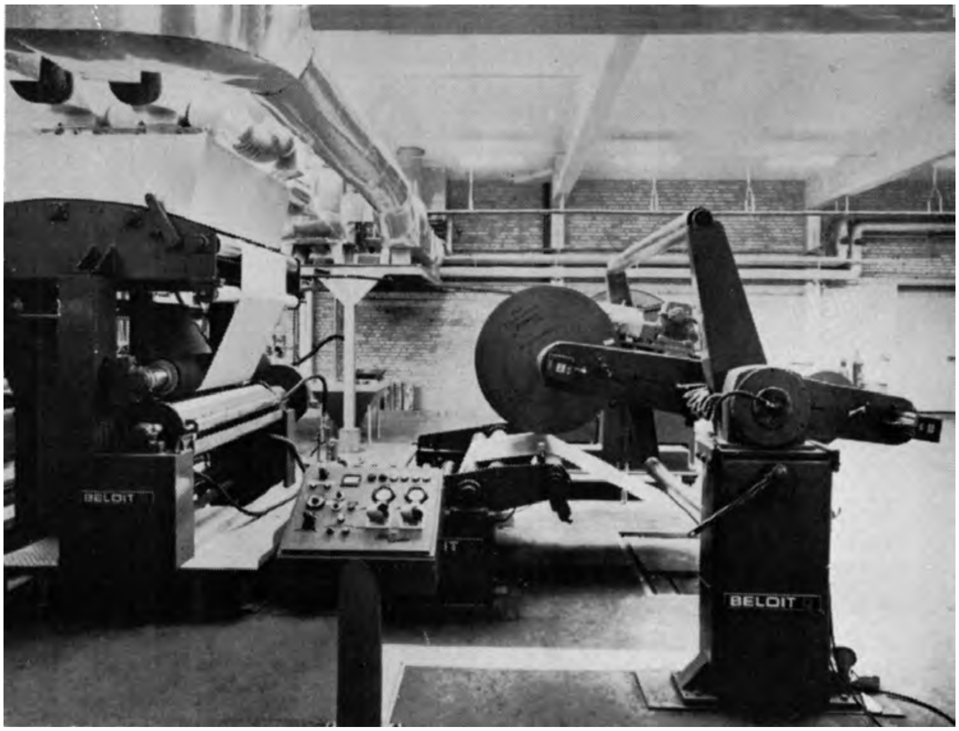

Fig. 1-8. Turret-type flying splice unroll with direct gravure print coater (*Courtesy of Beloit Eastern Corp.*)

The roll is moved into splicing position as the previous roll is expiring. The web path of the expiring roll is directed around a rubber covered "bumper" roll; when ready to accomplish the splice, either the new paper roll or the bumper roll is moved to effect contact. In most cases the tail of the expiring roll is cut manually or automatically to prevent a long run of a double web. In the case of paperboard it is sometimes possible to time this splice close enough to the end of the roll to avoid the use of a knife. (If the paperboard is thick in caliper, it is sometimes difficult or impossible to utilize a knife.)

The sliding unroll requires a through-shaft that can be of the expanding type, and the new roll is normally loaded by means of a crane. After the new roll has decreased in diameter sufficiently, it can be moved forward beneath the "bumper" roll and another new roll can be positioned on the machine and made ready for the next splice.

The turret can be designed for floor pick-up of a new roll. When splicing in either rotating direction is required, the turret must be capable of swinging through 360°, which requires loading of the new roll from a dolly or from a crane. The turret unroll can be designed with or without a central cross shaft. Eliminating the central cross shaft permits shorter arms that require a lower-capacity reducer for indexing the turret and that have the advantage of saving overall height and floor space. The turret unroll also has the advantage of the flexibility of using a cross shaft within the core of the rolls or of being the "shaftless" type with mechanically or pneumatically movable cones expanding to grip the core.

GUIDES AND TENSION DEVICES

It is necessary in most converting operations, and quite critical in some (as in printing), to align accurately the web of paper and to maintain constant tension at one or more points throughout the converting operation.

Starting at the unroll, the paper web can be guided manually by side-shifting the unroll shaft. For higher speed operations, when guiding is highly critical, or when rolls being delivered to the machine are badly telescoped because of internal stresses, automatic guiding is desirable. In this case the unroll stand is normally positioned on wheels and rails. The edge of the web is detected by a pneumatic device or an electric eye that actuates a hydraulic or electric power unit, which in turn shifts the unroll stand.

At other points throughout the converting operation, particularly after a straight-pass drier, a single-roll or a two-roll guide can be utilized.

The two-roll guide shown in Figure 1-9 pivots vertically in the center and is actuated by a pneumatic edge-sensing device or mechanical finger to align the web. A single-roll guide is used for guiding a web with a tacky surface. The roll, of course, contacts the opposite side of the web as guiding requires a small amount of web slippage in relation to the guide roll.

Good tension control requires starting right at the unroll stand. As previously mentioned, the unroll stands are equipped with brakes on the unroll shaft; to provide constant tension, the brakes must be adjusted continually as the roll decreases in diameter. Automatic adjustment can be accomplished accurately and consistently, by threading the web around a dancer roll or around an idler roll positioned on a strain gage. The slightest change in tension is "read" by a sensing

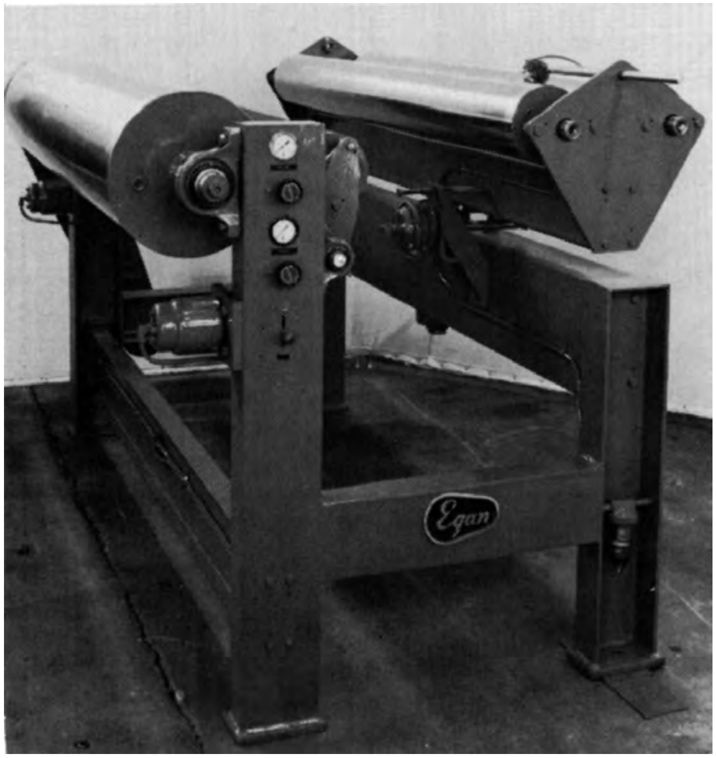

Fig. 1-9. Two-roll guide with pull roll station.

device that controls the hydraulic, pneumatic, or electric brake on the unroll.

Where tensions greater than can be attained through the unroll shaft are desired, a series of tensioning rolls are provided. These consist of two or more rolls, preferably rubber-covered to increase the coefficient of friction; the rolls are driven at a speed 1-2% slower than the desired web speed. Another method is to utilize a pair of nip rolls, one of which is driven and the other pneumatically loaded against the driven roll to control the nip pressure. In this case use of a steel and rubber-covered roll is normal. Where tension is critical throughout a complete converting line of multiple stations, a series of these nip rolls is used for controlling tension.

COATERS

The ten basic methods of coating are: dip, knife (blade), cast, roll, brush, air-knife, spray, print, extrusion, and strip. Some of these types have many variations. The rheology, viscosity, and percentage solids of the coatings; the desired coating weights, desired operating speeds, and type of substrate all combine to determine the type of machine required for a specific coating operation.

Dip Coater

Figure 1-10 is the simplest form of coater. It consists of a lead-in roll, an immersion roll, and a pan that contains the coating. If the web of paper is to be coated only on one side, the coating in the pan is maintained at a low level by means of an overflow. When two sides are to be coated, the coating is raised so that the immersion roll is fully covered.

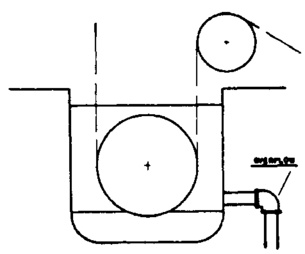

Fig. 1-10. Dip and flow treater.

This type of coating machine is used to manufacture photographic coated film and paper, blueprint paper, insulating papers and cloths, plastics, coated cords, and electrical wiring.

The dip coater is inexpensive to build because of its simple construction, but is expensive to operate. The coating must flow freely, i.e. it must have a low solids content; this means that solvent must be used in excessive quantities. The coater does not produce uniform coating because it is subject to two variables: (1) the varying porosity and caliper of the web, and (2) the varying viscosity of the coating resulting from temperature changes or evaporation of solvent and separation of the coating in the pan.

Knife Coater

Figure 1-11 shows a simple knife coater—often called a daub mill or floating knife—generally used to fill or coat cloth. The web is led over the roll, under the knife, and over the backing bar, and the coating is fed on the face of the web and in front of the knife. The width of the face of the knife, the angle at which it is set, and the tension on the web determine the thickness of the applied coating.

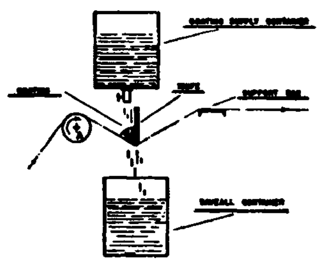

Fig. 1-11. Floating-knife coater.

The coater shown in Figure Fig. 1-12 is called a rubber spreader, because it is commonly used to coat cloth with rubber and requires a small amount of solvent. The web is led over the roll (either plain steel or rubber-covered) and underneath the knife, which is directly above the roll. The rubber compound is fed on the face of the web

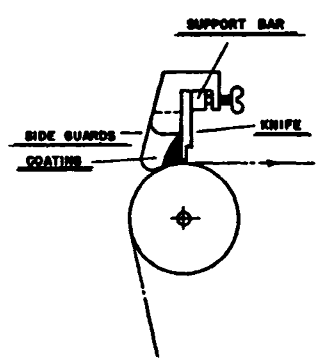

Fig. 1-12. Knife-roll coater.

in front of the knife. Side guards confine the coating to the face of the web to be coated.

In Figure 1-13 the web to be coated lies on a belt, taking more of the tension off the web. The belt is supported by two or three rolls.

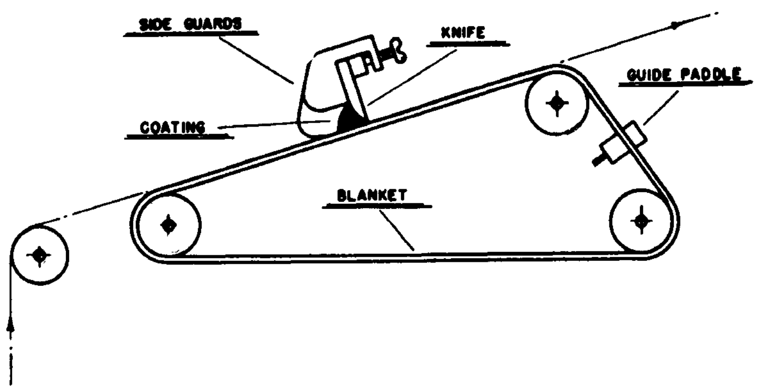

Fig. 1-13. Knife-blanket coater.

Figure 1-14 shows a knife coater of the upside-down type. Here the coating is applied by means of a roll, the knife removes the coating from the high spots of the paper, and what remains in the low spots of the paper flows out and covers the high spots. This method has been used to coat rubberized cloth, embossed artificial leather, and blueprint paper, and to give light coatings to paper stocks.

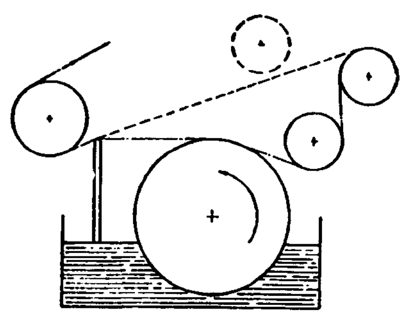

Fig. 1-14. Upside-down knife coater.

None of the knife coaters shown produce a uniform coating, (with the exception of the one in Figure 1-13), because of slack edges and varying caliper in the paper where there is a fixed opening between the machined knife and roll as in Figure 1-12.

The knife coater in Figure 1-13 permits application of lacquer of high solids content. It also handles varnish, shellac, and other types of nonabrasive coating.

Genpac Coater

Another variation of knife coater is shown in Figure 1-15, and is known as the Genpac coater, developed for applying hot melts of relatively high viscosity onto paper and other substrates. The hot melts consist of a resin–wax blend and the viscosities are too high to

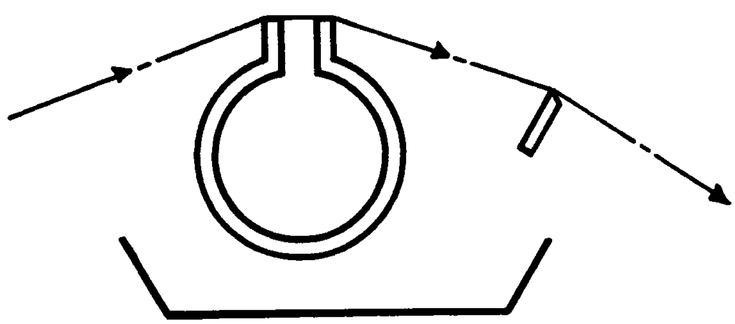

Fig. 1-15. Genpac coater.

be handled by any roll-type applicator. The melt is pumped into a slot with the paper web traveling over the slotted aperture where the excess coating is applied; following this, a knife is utilized to remove the excess coating.

Trailing-Blade Coater

One of the major developments in recent years for primarily applying clay coatings to paper and paperboard is known in the trade as the blade coater or trailing-blade coater. This design uses the knife principle, although in this case the knife is thin and flexible, whereas the aforementioned knife coaters employ a stiff or thick knife.

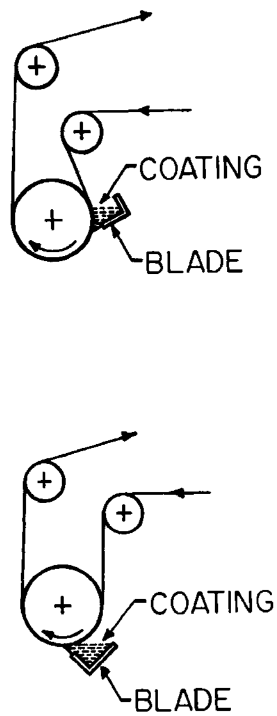

Fig. 1-16a. Trailing blade coater.

Trailing-blade coaters are shown in Figures 1-16a and 1-16b. The web is supported by means of a relatively hard rubber-covered backing roll and the simplest version is with the blade positioned at approximately 3 o'clock on the roll with the blade and its holder supporting the coating such that the application and metering are accomplished at the same point.*

In another variation the coating is applied by means of an applicator roll or directly from a pan with the trailing blade on the ascending side of the roll.

Still another variation replaces the single or double-roll applicator with a slotted tube applicator similar to the Genpac unit described above.

Trailing-blade coaters handle clay coatings in the range of 60-70% solids and are capable of operating at speeds in excess of 2000 ft/min.

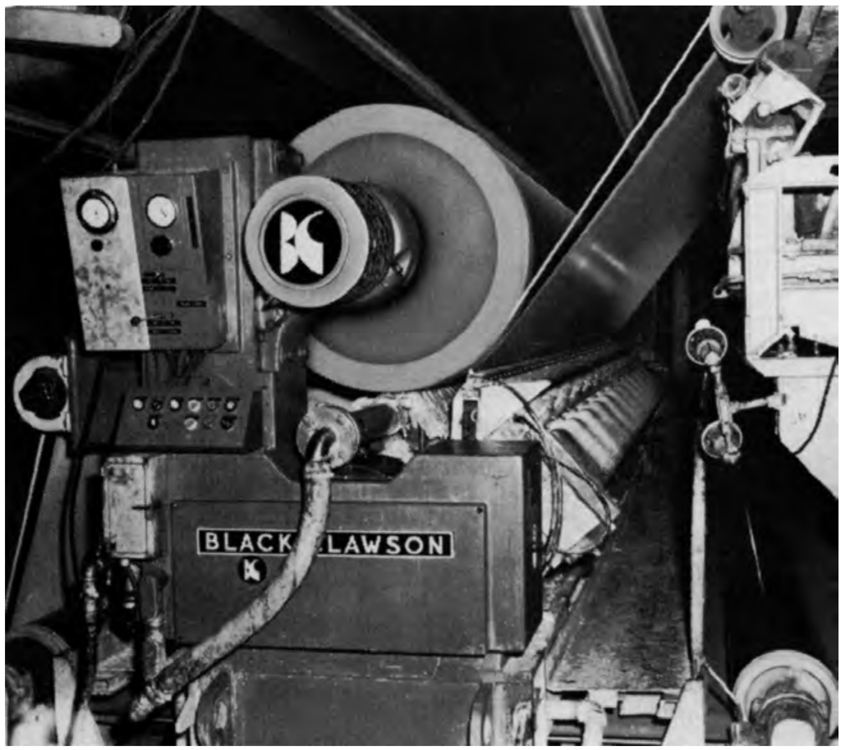

Fig. 1-16b. Trailing (fountain) blade coater (*Courtesy of the Black Clawson Co., Dilts Div.*)

Cast Coater or Casting Machine

The coater in Figure 1-17 resembles the knife coater; in some cases, the knife rests directly on the casting drum or belt. For accurate coating, standard practice calls for a flow box with a controlled orifice.

When casting a coating on a single drum (Figure 1-18) the operation is slow, but the resulting film or coating is superior to that obtained by the belt method of Figure 1-19 because the drum can be finished better than the belt. The drying or cooling units are not shown for reasons of simplicity. Photographic films, sausage casings, and transparent wrappings are made on casting machines. Sometimes a coating is cast on a belt that will permit the dried film to be stripped.

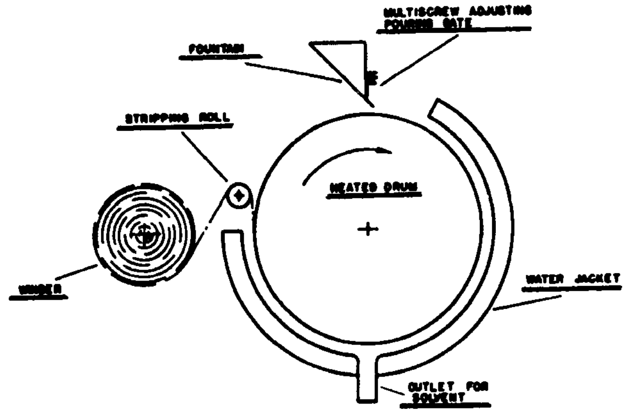

Fig. 1-17. Drum-type coating machine.

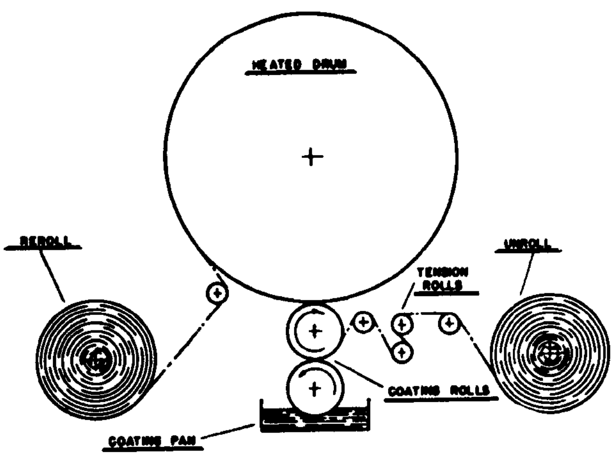

Fig. 1-18. Drum-type cast-coating machine.

Normal Roll Coaters

Figures 1-20 to 1-23 illustrate some of the many available types. Figure 1-23 shows two paths that the paper may follow on a roll coater. Figures 1-20 and 1-23 illustrate pressure coating. If the rolls (A and B) are ground true and are both made of metal, the coating varies as the paper varies in caliper. If roll A is rubber-covered, it generally produces a more uniform coating.

If the web follows the path in Figure 1-23 (dotted line) kiss coating

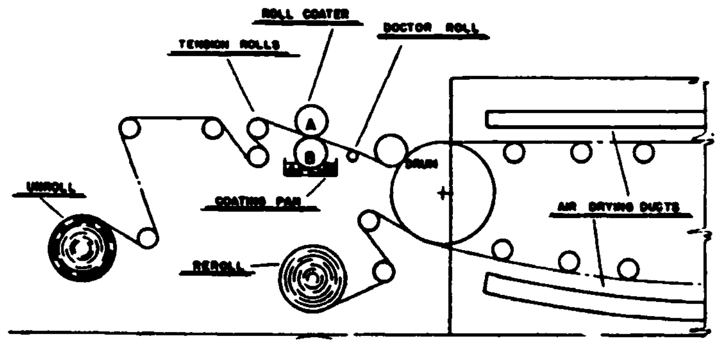

Fig. 1-19. Belt-type cast-coating machine.

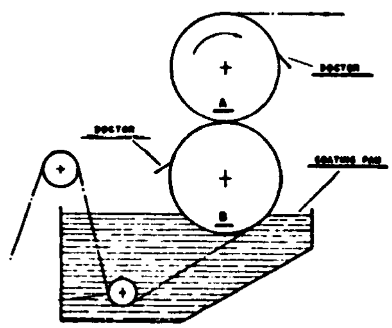

Fig. 1-20. Double roll coater (1).

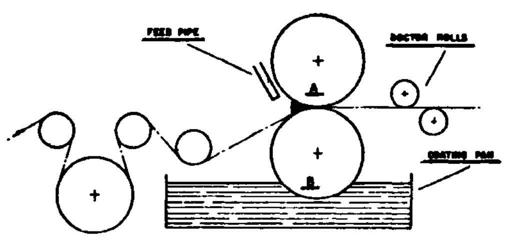

Fig. 1-21. Double roll coater (2).

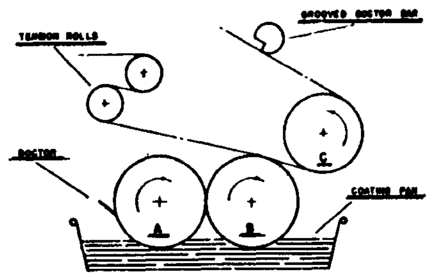

Fig. 1-22. Horizontal roll coater.

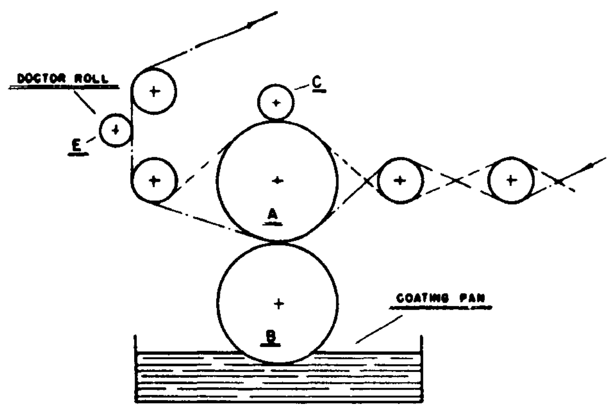

Fig. 1-23. Vertical roll coater.

is produced. This type of coating is more uniform, but varies with the tension applied to the web, particularly where there are slack edges and air is carried between the face of the roll and the paper. Kiss coating, however, is preferable, even if a light rubber-covered roll is used to hold the paper against the face of roll A, because the coating splits as it leaves the nip of rolls A and B, and splits a second time at the nip where the paper leaves the surface of roll A.

Where wide coating machines are used, rolls A and B must be large in diameter, which causes coarse ribs in the coating as a result of the breakaway angle. The surface tension of the coating also has a bearing on the coarseness of the ribs. Roll E of smaller diameter produces fine ribs as the breakaway angle is smaller. The roll may be run in the same direction as the paper and at one-tenth of its speed.

Figures 1-20 and 1-21 show a double coater in outline. In Figure 1-20 the web is dipped into the coating and then run between the rolls. In Figure 1-21 a feed pipe is used to supply coating to the top side of the web; the tension roll E is driven at constant speed.

Reverse Roll Coater

Two variations of the reverse roll coater are shown in Figure 1-24a. This coater is an extremely accurate and versatile machine for applying wet coatings in the thickness range 0.001-0.020 in. It can apply coatings with viscosities varying from slightly more than that of water to more than 100,000 centipoises, at speeds up to 1000 ft/min.

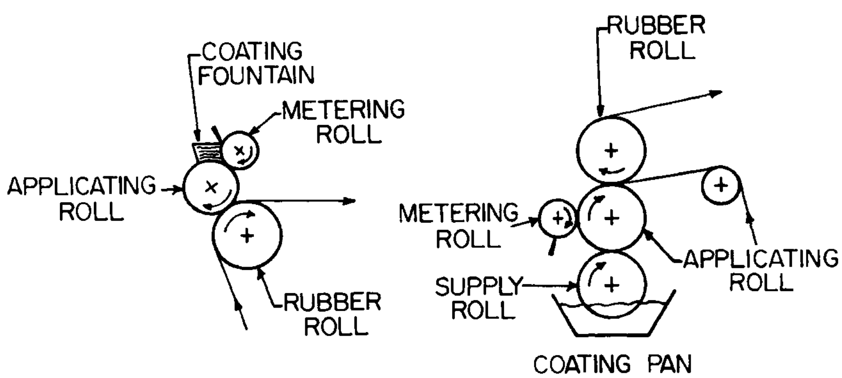

Fig. 1-24a. Reverse roll coater.

In the three-roll arrangement (Figure 1-24b) the coating is contained in a fountain made up of a back dam and side dams, which can be adjusted to coat a substrate with dry edges when desired. The metering roll, casting roll, and resilient backing roll are all driven in opposite surface directions, from which the name "reverse roll coater" is derived.

The metering and casting rolls are made of chilled iron and are ground to an accuracy of 0.0001 in. Precise adjustments are provided to control closely the distance between the metering and casting rolls. The casting roll, provided with a variable speed drive so that it can be driven from slightly less than web speed up to three times web speed, rotates through the fountain and the metering roll "doctors" the

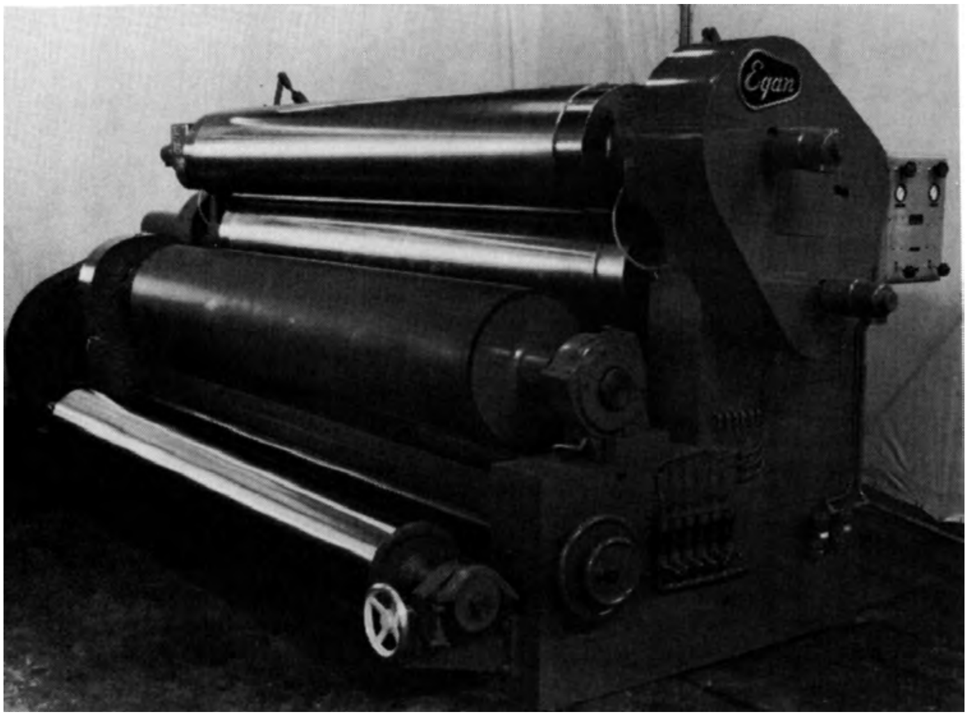

Fig. 1-24b. Three-roll reverse roll coater.

amount of coating that remains on the casting roll. This coating is then "cast" onto the substrate.

The resilient backing roll accommodates variations in web caliper so that an even coating is applied to both high and low areas of the substrate. Varying the aperture between the metering and casting rolls and varying the speed of the casting roll comprise the two major factors in controlling the coating weight.

The four-roll reverse roll coater, sometimes referred to as a pan-fed reverse roll coater, operates in a similar manner. The bottom roll can be dispensed with for slower speed operation as its function is merely to provide an excessive coating to the casting roll.

For coating with higher viscosities and for coatings containing volatile solvents, the three-roll unit is preferred. In the former case the configuration is such that gravity assists in applying higher viscosity coatings. For solvent coatings it also provides minimum exposure of the metered coating prior to application to the web. The reverse roll coater can apply lacquers, varnishes, emulsions, suspensions, hot melts, and adhesives. Clay coatings have been tried on this unit with limited success.

Brush Coater

This is the oldest form of coater. In the 1830's a sheet was laid on a table and the coating was brushed on by hand.

The brush motion of the early units was of the sun and planet design —the bed was flat, the brushes small and round, and revolved as they traveled in an orbit as the planets revolve around the sun.

In a brush coater, the coating is first applied and then brushed out; several methods are used to apply the coating. Figure 1-25 shows the round-brush method commonly used. Figure 1-26 shows a felt-covered roll and Figure 1-27 a felt blanket. The round brush is the best of the three, even though the bristles wear and break off. The felt cover on the roll and the felt blanket fill up with coating, harden, wear rapidly, and are difficult to clean.

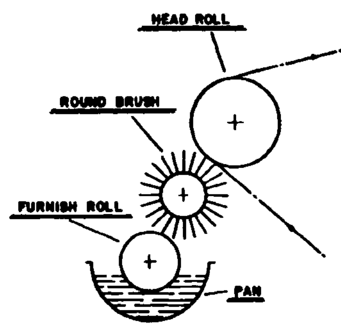

Fig. 1-25. Round brush coater.

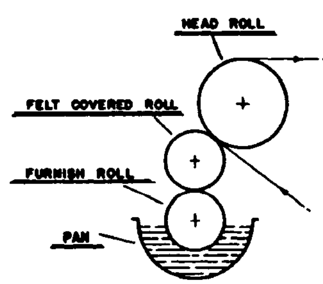

Fig. 1-26. Brush coater with felt-covered roll applicator.

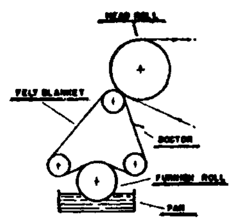

Fig. 27. Brush coater with felt-blanket application.

The brushing-out sections consist of four to ten brushes, depending on the speed of operation and the quality of coating desired. Good practice calls for mounting at least one brush on the head roll, for the closer the first scrubber is to the round application brush, the better is the resulting coating.

The brushes can be positioned on the coated paper traveling against a cylinder or preferably supported by a rubber blanket (Figure 1-28) and can be in a horizontal position, an inclined position as shown, or in some cases drawn over an arched support.

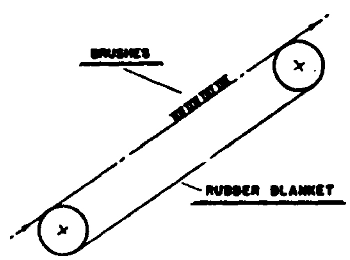

Fig. 1-28. Inclined-bed brush coater.

Although several brush coaters are still producing high quality art papers today, they are gradually being replaced by the air knife coater.

Air-Knife Coater

The air-knife unit is sometimes referred to as an air-brush coater or an air-doctor coater.

Figures 1-29a and 1-29b show a coater that consists of an applicator roll positioned in a pan that applies an excess of coating. This roll is normally driven in the same direction as the web path but at ¼-⅓

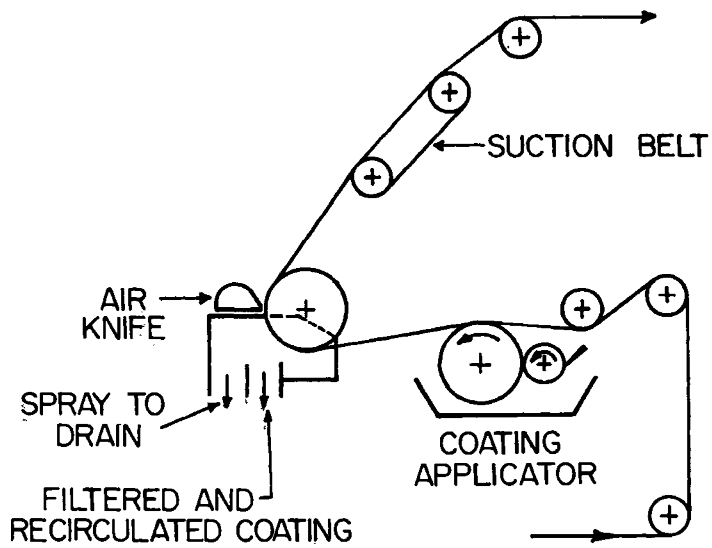

Fig. 1-29a. Air knife coater.

web speed. A doctored metering roll is positioned to the right of the applicator roll with provisions for adjusting the aperture to control the amount of excess coating applied. This kiss-type application applies the excess coating in ridges; sometimes a small-diameter reverse driven doctoring roll is used between the applicator roll and the backing roll of the air knife coater to distribute the excess coating evenly. The backing roll, or "breast" roll, supports the web, whereas the ultimate metering is done by the air knife itself. This roll is chrome plated for ease in cleaning and is usually an idler roll, although at times it is driven. The air knife itself is a tube with a slotted orifice, and is usually made of bronze with stainless steel lips forming the orifice, because noncorrodible materials must be used. Adjustments are provided every 4 in. across the width of the air knife to control accurately the slot opening.

A multistage turbocompressor supplies air free of pulsations to the air knife and a blast gate is provided to vary the pressure in the air knife, which is one of the main controls of coating weight. The pressure can range from 1-5 lb/in.^{2} depending upon the viscosity of the coating being applied, the thickness of coating desired, and the speed of operation.

The air knife "blows off" the excess coating and leaves a contoured

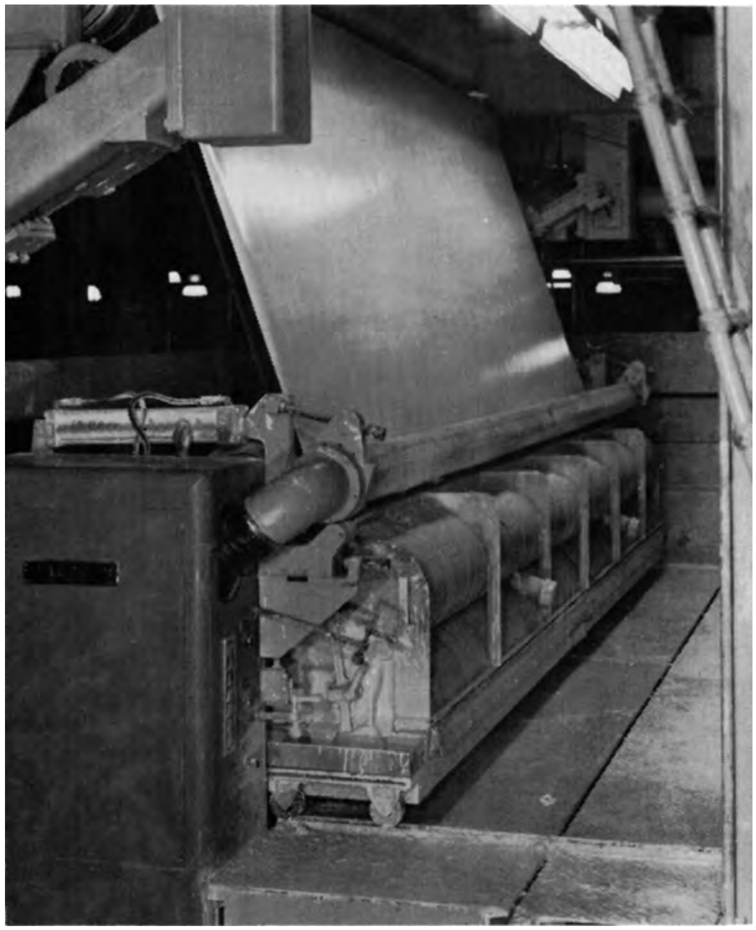

Fig. 1-29b. Air knife coater (*Courtesy of Waldron-Hartig Div., Midland-Ross Corp.*)

coating on the web. The excess coating is collected in a catch-pan and after settling and straining the coating can be reused.

For speeds in excess of 600-700 ft/min, an exhaust system and spray collector provide a negative pressure in the catch-pan, which minimizes the fog of coating in the area of the air knife.

For clay coatings, the air knife can operate in excess of 1000 ft/min. with sufficient drying capacity and can apply coatings in the 35-50% solids range. Dry-coat weights applied can vary from 5 to 30 lb, 3000 square-foot ream. The coater is also used for the coating of Diazo

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