MODERN ROD COATERS

by

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In the last decade a new rod coating technology has been developed for coating on paper machines. This technology has also been adapted for use on converting and corrugating lines. The main advantages of these new coaters are wide coat weight range, ease of operation, precise coat weight regulation, and good cross machine uniformity.

Rod coating or "Mayer rod coating" has been in existence since the early 1900's.

In 1905, Charles W. Mayer founded the Mayer Coating Machines Company in Rochester, New York. The firm made equipment for manufacturers of carbon and wax papers, two new and growing industries. These machines used "equalizer bars" or "doctor rods", the fore-runners of today's precision metering rods. The rods were made of carbon steel wound with different sizes of music wire.

Mayer was issued a series of patents on his coating machines, including one in 1912 which covered his equalizer bars.

Coaters of carbon and wax papers found that they could easily change the thickness of their coatings by switching rods, so they began ordering rods with different wire sizes. Also, the early rods would rust and wear out, so Mayer found a ready and growing market for replacement rods, which became an important part of his business as more machines were shipped.

Mayer's success in the coating machinery business became the target of federal anti-monopoly laws, and he was forced to release his designs and patents to others in the 1930's. New companies sprang up, whose machines used doctor blades and roll coating methods, in addition to wire-wound rods.[1]

Wire wound rod coaters have for over 70 years been considered a simple, easy to operate method of coating. The main technological breakthrough has been the development of stainless rods, stainless wire and precision winding equipment. In the last several years, rods that were turned with threads instead of being wound with wire have also been developed.
The traditional wire wound rod coater has developed along the lines of Figure I, above. This coater applies an excess of coating to the web with an applicator roll. The applicator roll usually is supplied with edge wipers or "deckles" which wipe the coating off the roll at the edges. This allows the substrate being coated to be run with a dry edge for cleanliness.

TRADITIONAL WIRE WOUND ROD COATER

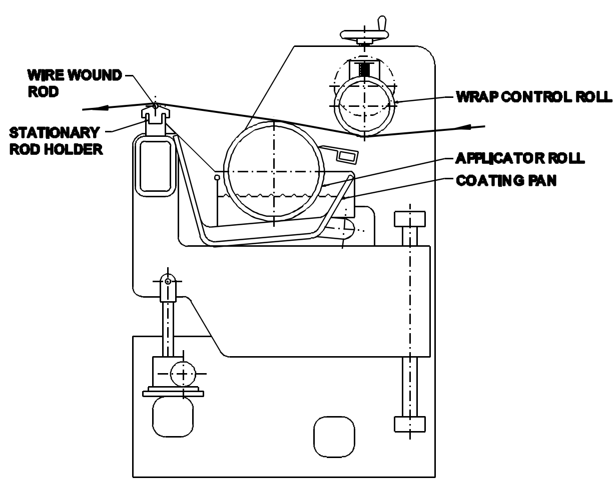

FIGURE I

[1] **Donald M. MacLeod, "Rod Coating Comes of Age", <u>Proceedings of the</u>**

TAPPI 1988 Polymers, Laminations and Coatings Conference, **September, 1988, p. 205**

The applicator roll is usually driven by a variable speed drive, which follows line speed at an adjustable ratio. The web passes over the applicator roll where it picks up an excess of 3 to 10 times the desired final coat weight. It then passes over a wire wound rod whose wire size determines the final coat weight. The wire rod is independently driven, usually counter to web direction.

The thickness of the coating is governed by the cross-sectional area of the grooves between the wire coils of the rod. The geometry of this system creates a wet film thickness which is roughly proportional to the diameter of the wire used. For example, you can roughly double the coating thickness by doubling the wire size.

The groove between the wires determines the amount of coating material which will pass through. The initial shape of the coating is a series of stripes, spaced apart according to the spacing of the wire windings. Almost immediately, normal surface tension pulls these stripes together, forming a relatively uniform surface, ready for drying in air or under heat.[2]

The coating that is wiped off is separated out from the coating within the pan, so that it can be deaerated and strained to remove contaminants, before returning to the application pan.

Coating uniformity on Mayer rod coaters is dependent on having a completely flat web in intimate, even contact with the surface of the wire. The only force available to ensure contact is provided by web tension. Unfortunately, it is generally impossible to ensure tension uniformity across a web of even moderate width, which can cause

LOW SPEED COATER PAN
NORMAL COATING FLOW PATH
RECIRCULATION RATE 3:1 TO 10:1

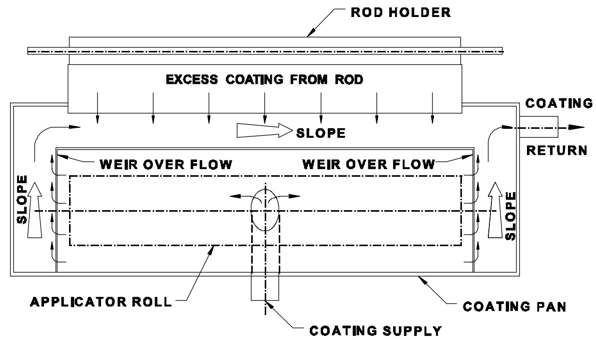

FIGURE III
TOP VIEW

large variations in the metering capability of the rod. This, in turn, causes coat weight non-uniformity. Additionally, because web tension is constant, and the force necessary to resist the hydraulic force that develops under the web increases with line speed, the Mayer rod coater becomes unstable at speeds above 200-300 MPM. The actual point where control is lost depends on the coating rheology, the web tension, and the wrap angle over the rod.

What was needed was a way to keep all of the benefits of rod coating, while eliminating its speed and uniformity limitations. The solution was to make a rod coater that operated independently of web tension variations. It utilized the concept of a rod pressing against the web supported by a backing roll.

There are a number of manufacturers of this type of equipment. Most manufacturers utilize some form of air pressure loading. These designs allow the rod to float freely in side guided holders.

An air bladder under the holder provides uniform cross machine pressure. Other older designs utilize mechanical loading by attaching the holder to a flexible spring blade.

Modern rod coater designs are primarily divided into two groups, for low and high speed operation. Low speed operation, below 300 m/min., generally encompasses the converting industries and recycled paperboard machines.

A typical low speed air loaded rod coater is shown in Figure II, above.

LOW SPEED AIR LOADED ROD COATER

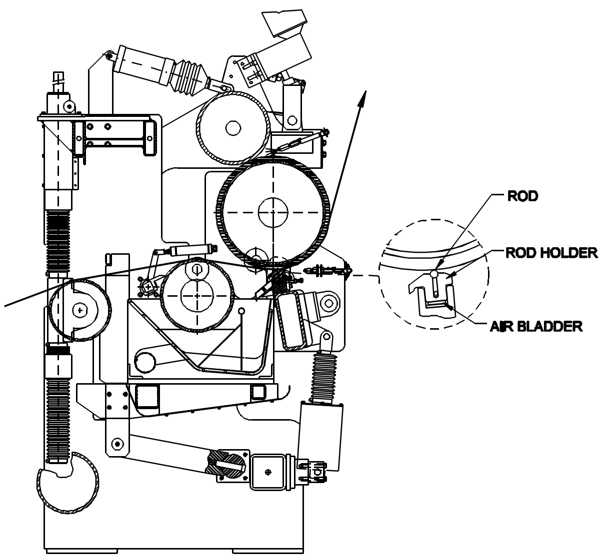

FIGURE II

This coater utilizes most of the traditional wire rod coater design. It has an applicator roll with variable speed drive and a pan which separates the coating returned from the rod from the fresh coating in the pan.

The main difference between the coaters shown in Figure I and II occurs after the web leaves the applicator roll. On air loaded rod coaters, the web wraps its uncoated side to an elastomer covered backing roll, which supports the web as it passes through a nip created by the rod and the backing roll.

Pan designs for both coaters are similar. Figure III, above, shows a typical pan for coatings that are not overly susceptible to problems caused by large recirculation ratios. The coating enters the center of the pan's main chamber under a diffusion baffle, and flows outward over weirs at each end of the pan. The overflow coating mixes with the coating coming off the rod so that every surface of the pan is continually washed. This type of circulation eliminates eddies and dead zones that might cause buildup. Figure IV, above, shows a pan with reduced recirculation rate for agitation sensitive coatings. In this configuration, the coating coming off the rod is channeled by a baffle plate to the ends of the main portion of the pan. Due to its lower density, caused by air entrainment, this coating is first to overflow the end weirs. Since the coating is reintroduced to the pan outside the coated area of the web, only fresh coating is brought to the rod for metering. This drastically reduces the recirculation rate without affecting coater performance.

The rod on the coater shown in Figure II is held in a precisely machined plastic holder element,

LOW SPEED COATER PAN
REDUCED RECIRCULATION PATH WITH BAFFLE PLATE
RECIRCULATION RATE 1.25:1 TO 3:1

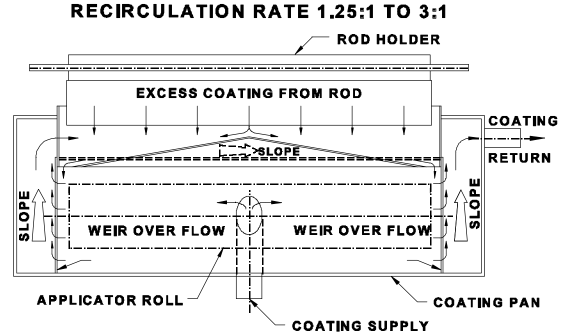

FIGURE IV
TOP VIEW

which is free to float in a retainer slot. It is pushed against the backing roll by a flexible air bladder whose pressure can be adjusted from 0 to 2.7 bar (40 PSI).

The rod, plastic holder, and air bladder are limber enough so that at pressures above .2 bar (3 PSI), the rod is uniformly loaded against the backing roll regardless of backing roll deflection. Since the web is on the roll prior to the application of metering force, web tension has no effect on coat weight. The backing roll is driven by its own variable speed drive following line speed.

For a given coating formulation, coat weight is dependent on four factors: paper absorbency, applicator roll speed, rod size, and air bladder pressure.

The applicator roll is generally run in the direction of web travel at 15% to 60% of web speed, applying an excess to final coat weight ratio of 3:1 to 10:1. Running in the direction of the web reduces film split pattern and tends to provide a more uniform excess by smearing it on the web. In general, the application roll should run just fast enough to allow some coating to run back down the incoming side of the roll.

The rod size determines the coat weight range that the coater will operate over. Smooth chrome-plated rods between 1/8" (3.2 mm) and 1" (25.4 mm) provide coat weights between 2 and 25 gm/m^2 with a wide variety of coatings. Much heavier coatings can be achieved by using wire wound rods rather than smooth rods.

To date, machines are in operation coating a variety of waterbased, solvent based and solventless coatings. Viscosities from 20 cps to 20,000 cps and above have been run successfully, at speeds of 50 FPM to over 3000 FPM. Coatings have included silicones, adhesives, fax, carbonless, varnishes, clays, calcium carbonate, titanium, waxes, and other proprietary formulations.

By changing from one rod size to another, a completely different coat weight range is available to react to the needs of a changing marketplace. If the rod is changed from the smooth type to a wire wound or grooved rod, the coater becomes an entirely different type of coater.

A smooth rod coater is a leveling coater. The coating that is applied tends to fill in the low spots of the paper. Depending on the paper roughness, this tends to leave far less coating on the high spots than in the low spots.

A wire rod coater is a contour coater. It meters volumetrically so that the same amount of coating flows out on any part of the web. The coating flow coats the fibers, roughly following the sheet contour.

This type of rod provides better opacity, but the surface smoothness is not as good as with the smooth rod.

Many coating operations combine one or two smooth rod coaters with a contour coater to make an extremely smooth sheet that also has good coverage without mottle.

Coat weight adjustment is accomplished by totally separate means depending on whether a smooth rod, wire wound rod, or a threaded rod is used in the coater.

Smooth rod coating is accomplished by floating the entire rod on a film of liquid above the surface of the paper. Coat weight depends on the thickness of the hydraulic wedge that develops between the rod and the coated substrate. This is very similar to a lubricated bearing.

To increase coat weight, using the same rod size, the coating can have its viscosity increased by using viscosity modifiers, or by increasing solids content, which increases the viscosity as well as reducing the water content.

There are several mechanical ways to increase coat weight. The simplest way is to decrease the pressure in the air bladder under the rod. The normal air pressure range for air loaded rod coaters is 5 - 25 PSI with the majority of coaters operating between 5 - 10 PSI.

In general, as soon as enough pressure is developed to deform the backing roll covering, increasing the rod pressure decreases coat weight, and decreasing rod pressure increases coat weight. There is a very sharp change in coat weight between 5 and 15 PSI (depending on paper absorbency it can be anywhere from 30% - 70%). Above 15 PSI, the effect of increasing rod pressure tapers off quickly, until at approximately 30 - 35 PSI no additional reduction is possible.

A very interesting condition can occur at very low rod pressures where the rod is just balanced against the paper without deforming the backing roll covering. The metering force is equal to the rod load divided by the area of contact. Since there is very little area, we are dividing a small number (the rod load) by a number almost equal to zero. The resultant unit force can be very high. The end result is that as rod loading is increased slightly, the rubber backing roll cover deforms, which increases the area of contact at a faster rate than the rod loading increases. Thus for a short increment, coat weight may actually increase with increased rod load. This quickly changes back to the standard conditions where increasing rod loading pressure decreases coat weight.

Changing smooth rod size affects coat weight by changing the width of the nip created between the backing roll and the rod. For any air pressure, a larger nip area causes the metering force (calculated by dividing load by area) to decrease as the rod size is increased. This provides a larger coat weight each time rod size is increased.

Wire wound or grooved rod coating works by a different principle. Instead of floating on a uniform film, the wire, wound, or grooved rod may, in fact, contact the paper on the high points of the wire or grooves. Coat weight is obtained by the amount of coating that can squeeze through the small openings created between the wires or grooves.

To allow more coating to pass through the openings, you decrease the viscosity. This is illustrated by the standard Zahn cup viscosity test. The lower the viscosity, the sooner the cup empties.

If two wire wound rods of different diameter but the same wire are used, a slightly higher coat weight will be provided by the larger rod. However, a one or two thousands (.001" or .002") increase of wire size on the smaller rod will usually provide the same coat weight.

For most rod core sizes, the major effect on coat weight is provided by wire size alone. The viscosity required to run a wire rod is low, so no significant hydraulic wedge can develop to float the rod off of the sheet. If there is no wedge to adjust, pressure change will have little effect. When larger rod core sizes are used (5/8" to 1") the larger nip allows more of a wedge to develop. The force of this wedge is easily overcome. At most, with a 1" rod, rod bladder pressure will effect the coat weight by 10 - 15% with wire sizes from .010" to .020" diameter.

As wire diameters decrease (from .010 to .000), rod bladder pressure has an increasing effect on coat weight. As wire diameter increases, rod bladder pressure has little or no effect. The general rule is to run a bladder pressure under a wire rod that is high enough to ensure uniformity. It can be increased 3 to 5 PSI to trim coat weight slightly. Any additional pressure will increase rod wear. High pressure may also cause streaking by deforming the paper where it contacts the rod.

There are several other benefits to air loaded rod coating. The rod turns slowly against the direction of sheet travel. This allows it to continually clean itself, in order to run without streaks. Additionally, the rod has a polishing effect that tends to orient coating particles in the same direction, which improves coated surface smoothness. Because the backing roll supports the sheet under the rod, coating can be accomplished at higher solids and viscosities than ever before.

Figure V, above, shows a high speed coater arrangement. The three main differences between it and the low speed coater are the backing roll size, flooded nip applicator roll configuration, and the backing roll wash/moisture addition unit.

The backing roll size is adjusted to provide sufficient recovery time for the elastomer cover on each revolution. This reduces heat buildup and lengthens the time between covering regrinds. On large machines (over 120" wide) the deflection of the roll is also a consideration in determining roll diameter.

The flooded nip application roll runs with a precisely adjusted gap in the range of .005" - .020" to the substrate. This premeters the excess being applied to the web, and reduces the effect of any air entrained in the coating. Coaters with this type of applicator roll are running on paper machines in excess of 1000 m/min.

An additional premetering doctor can be used on the flooded nip roll for even higher speeds or for ultralight coat weights. The premetering doctor can reduce the excess to the point that the rod meters off very little coating. Running in this mode utilizes the rod more to smooth and equalize the coating, than to reduce its thickness.

Higher speed coaters are generally wider than their older, slower predecessors. This requires an application pan design with higher recirculation rates and better distribution to achieve a more uniform metered application to the web. A typical high speed coater pan design is shown in Figure VI,

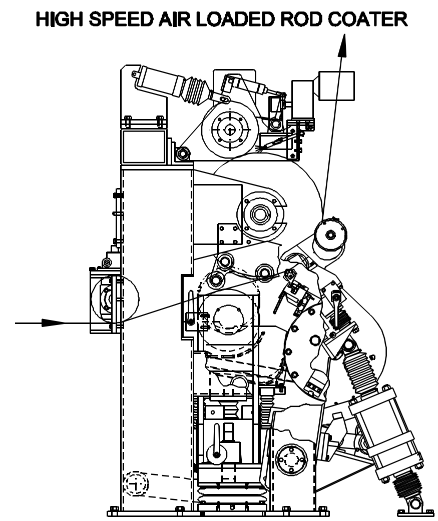

FIGURE V

below.

NORMAL COATING FLOW PATH
HIGH SPEED COATER PAN
RECIRCULATION RATE 5:1 TO 15:1

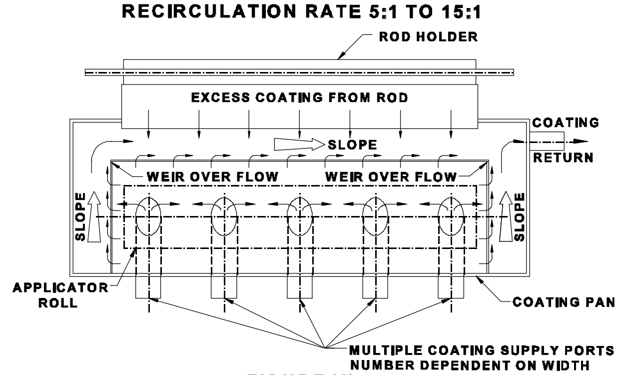

FIGURE VI
TOP VIEW

The wash roll/moisture addition unit sprays a fine mist of water on the backing roll, which is removed by a chrome-plated roll. A doctor blade running on the chromed roll removes the excess water and any dirt particles by directing them into a sloped drain pan.

The water mist keeps the backing roll cool, extending its life. The doctored mist carries away dirt or coating buildup that might affect coating uniformity.

Another useful function is to apply a metered amount of moisture to the back of the web. With the doctor blade out of engagement, the wash roll can be run as a simple premetered size press. Side funnels must be added to carry away the excess water that flows out the ends of the nip. Water volume and nip pressure determine the final moisture addition. This is very helpful as a means of curl control.