Technical White Paper

An improved means in maintaining high uniformity in transfer from gravure and anilox rolls

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The converting industry today is undergoing change at an unprecedented pace. Products, materials and processes are improving at a rate with which few of us can keep pace. Quality requirements are constantly increasing. At the same time competitive cost pressures drive a continual need to reduce material and labor costs, and increase quality and unit output. Opposing goals, such as speed versus quality and shorter runs versus less time consuming changeovers, are commonplace today. Environmental pressures force the use of water base inks and compounds that are - generally - more difficult to use and dry. Nonetheless, customer requirements continue to expand and the competitive pressures they generate compel us to search for more exacting process control, higher speeds and less downtime.

It is within the context of this increasingly demanding environment that this presentation will describe a device which can help the printer and coater gain greater control over the processes of flexo printing and gravure coating. Both processes have at their heart, an engraved roll that transfers a liquid, ink or coating compound to a substrate. This new device does not recognize the difference between an anilox roll and a gravure roll; both represent a surface, which has been carefully engraved with a pattern of a specific size, volume and geometry. Variation in the amount or volume of liquid transferred is normally accomplished by design variations in these engraved cells.

For the purpose of this paper we will assume that precision engraved rolls are acquired with the intent that the degree of precision purchased will translate to equally precise levels of transferred ink or coating, which for simplicity I will refer to as fluid. This expectation frequently falls short; not necessarily because the engraving is poorly done (although that is a possibility) and not because transfer efficiency is poor, but rather, because the cell itself has not been fully charged. The fundamental issue is the air that fills the cell volume. As long as my air is allowed to remain in the cell, the certainty of variable fluid transfer is assured. ALL air must be expunged from the cell before true uniform and repetitive performance can be achieved. After all, air is readily compressible and can be trapped in the bottom of the cell by a fluid. But at some point, depending on the external pressure and the viscosity of the fluid, compression ceases and X amount of cell volume remains unfilled. Frequently X can be a very significant number, not uncommonly ranging from 5% to as high as 30% in materials having a viscosity in the range 100 to 600 cps. In higher viscosity fluids, X can be as much as 50%. Retained air, exceeding about 30% of the cell volume, begins to cause severe anomalies, such as pinholes and very large coating weight variances.

Figure I is a graphic representation of a cell in four basic attitudes: **#1** represents the cell upside down in a conventional pan. The cell bottom is up and air is trapped. **#2** depicts a cell partially filled by a conventional means, such as a trailing doctor blade or rubber roll. Air is trapped beneath the fluid. **#3** is a cell with no air entrapped in the cell, however, the fluid level is below the cell surface which now requires substrate deflection into the cell cavity to make transfer contact with the fluid. As can be appreciated by this simple representation, any air volume within a cell can cause significant disturbances in uniform fluid transfer.

Keeping in mind the basic cell air retention just presented, let us now consider the principal existing design methods for filling a given cell with fluid and metering the excess from the engraved roll surface.

Figure 2 is a typical trailing open doctor blade, with **Figure 2A** illustrating a highly flexed blade and **Figure 2B** showing a very rigid, sharp angle blade. In all three circumstances the fluid is in a pan, with the bottom portion of the roll submerged. This is what happens in sequence: First, the roll surface enters the fluid at speed and carries on its surface a boundary layer of air. This boundary layer phenomenon will occur on any turning surface and will increase in density and thickness as surface speed increases. At speeds of 150 fpm and higher this surrounding boundary layer can become dense enough to actually force the fluid in the pan away from the roll surface until the cell is at the 6:00 position or beyond. At very high speeds, e.g. 700 fpm, the boundary layer may remain more or less intact until the cell actually leaves the pan and turns up to the blade. In any event, the air in the cell cannot escape because as it rises, it hits the solid cell wall. By the time the cell is positioned such that the air can escape the cell surface, it is covered by a dense fluid, which retards normal escape. Simultaneously, the roll surface is covered by a gross layer of fluid that will be removed by the doctor blade. A somewhat flat angle on the blade creates a hydraulic force against the gross fluid layer, tending to "butter" or "putty" the fluid into the cell. The problem with this design is that the air in the cell is obligated to fight its way through the fluid, which increases in density as the blade puts more pressure on the gross fluid layer. Only because the fluid stream under the blade is highly turbulent does the air find an opportunity to escape. At increasing line speeds the escape opportunity is reduced as a result of decreased dwell time of any individual cell under the blade and the concurrent increase in hydraulic pressure. Equally important is the effect the higher pressure has on the blade itself higher pressure tends to cause more blade deflection, which in turn reduces crisp clean surface metering. Thus, this system, at higher line speeds, tends to degrade in coating uniformity because of reduced air elimination in the cell itself and because of less effective surface metering. A very rigid blade and a sharp angle of attack can minimize poor surface metering, but is of little value in obtaining better air elimination. However, this approach carries with it the likelihood of much higher roll surface wear, which itself is a cause of declining transfer uniformity.

Figure 3 shows a typical flexo deck using a rubber-metering roll in lieu of a doctor blade. In this arrangement the surface of the engraved roll is metered by squeezing the rubber roll against the engraved roll. Operators typically apply more pressure to reduce the fluid carried by the engraved roll. To a point this is effective, however once the squeeze pressure causes the rubber surface to flatten, the amount of fluid carried out of the nip can actually increase. The engraved roll and cell behavior in this arrangement is virtually identical to the behavior described in **Figures 2, 2A & 2B**. The only practical difference is that the two roll, nip system tends to be a bit more efficient in forcing fluid into the cell as a result of higher realizable hydraulic pressures and somewhat longer dwell time of a cell in the high-pressure region. Once again, the negative effect of line speed can be easily seen as air exchange efficiency breaks down. As cylindrical surface speed increases, the boundary forces increase and dwell time decreases further deteriorating the air/fluid exchange efficiency.

A further problem in both of these designs is the open-to-air turbulence which exists under the blade or at the nip point. This turbulence, in many water based systems, translates to serious foaming problems, which commonly require additional chemistry in the form of anti-foam and defoaming agents. These agents often impede the properties of the coatings or inks being used. Yet without them, this open-to-air turbulence will convert the fluid into a thick foam which will prevent effective fluid transfer altogether.

Figure 4 represents a typical dual enclosed doctor blade system in wide use on many gravure coaters and flexo printing presses. These systems represent a significant improvement over the trailing doctor blade and two roll flexo station. All such designs have in common a chamber which is enclosed top and bottom by two doctor blades. The ends are closed by means of a seal material, which directly contacts the engraved roll surface and/or ends. The back is closed by means of the body of the unit itself.

The first benefit is that the open pan is replaced by an enclosed unit which eliminates most of the evaporation of solvent or ammonia etc. common to open methods. This factor alone is often worth the cost of a doctor blade unit. Viscosity control becomes much easier and the value of reduced solvent cost is very significant. A second benefit is the reduced likelihood of vagrant contamination getting into the fluid system. A third benefit is that the first blade a cell contacts is a trailing blade which efficiently breaks the boundary air layer - that plagues other methods. A fourth benefit derives from a reverse angle blade at the exit point which yields a metered or doctored roll surface that is extremely clean and crisp. Industry professionals will recognize the importance and value of these benefits and their contribution to improved fluid transfer uniformity and reduced operating costs.

Two troublesome issues are not addressed in conventional design, single cavity systems. While there is clearly improvement in fluid transfer uniformity, chiefly the result of the efficiency of a reverse angle doctor blade versus a trailing doctor blade, the issue of more effective cell filling is only partially resolved. Further, the problem of foam development remains unresolved. A look at the dynamics within these existing designs aids our understanding of the cause of these remaining problems and suggests solutions.

To facilitate our search, we will select a cell on the surface of the engraved roll and follow it through the enclosed unit. First, the trailing blade eliminates the boundary layer of air away from the cell surface as it enters the enclosed blade unit immediately, a layer of fluid coats the cell surface through which the air contained in the cell must now migrate. At this point the mechanics are somewhat similar to those discussed earlier except now the "pan" is on its side and the bubble of air in the cell can now more readily slip out and up along the surface of the roll. As the air slips out, the vacated space is immediately filled by fluid. As the cell further advances, it rises above the nominal fluid bed level. This level is defined by the position of the exhaust port location until it comes to the reverse angle blade, where the final doctor blade, in a reverse angle mode, meters or doctors the exiting cells surface, leaving virtually no fluid above the roll. At this point it is obvious that, the only fluid available for transfer to substrate or plate roll is now within the cells.

In the fill operation of these units, remarkable uniformity is obtainable in fluid systems with relatively low viscosity, preferably solvent based. In these fluid systems, line speeds are typically low and foaming is not likely to result. Complete cell air evacuation is a function of viscosity and dwell time in the unit. Foam is a result of a fluid, air turbulence, and dwell time, all of which are present in single-chamber dual enclosed doctor blade units, in wide use today.

Figure 5 is a representation of a hybrid, enclosed doctor blade design. As can be readily seen, the cavity configuration is altogether different from any standard design. The key difference in the new designs is the "flat" located in the center of the unit, which gives rise to fluid flow characteristics engineered to dramatically change the operating performance of any properly engraved roll.

Let's again track a single-cell through the unit, study the fluid dynamic, and note the differences between this design and the other methods previously considered. First, the trailing doctor blade deflects the boundary layer of air (as does a standard design). Next the cell moves into the first zone - the supply zone - which is fully charged with fluid by means of pump pressure, and is instantly flooded by the contained fluid. The pressurized supply cavity (approx 2-4psig) assures the air in the cell cannot escape in that zone. Meanwhile, the roll surface carries a layer of fluid with it (much as happens in a standard unit). Typically this layer is quite dense. In the new design, the fluid is carried into the narrow zone created by the flat center barrier. In that the radial surface of the engraved roll is, of course, round, and is adjacent to the straight flat of the barrier, basic geometry shows the distance between the roll surface and the shoulder of the flat is greater than the distance between the roll surface and the centerline of the barrier. Through this dynamic, a wedge is created.

Three separate things simultaneously occur across this "flat". I)- As fluid moves through and into the wedge, the fluid stream becomes linear as opposed to circular/turbulent in the supply zone. As linear flow develops the energy developed through the compression of the fluid stream can be harnessed and employed. 2)- The linear fluid flow is forced into the wedge by the rotation of the engraved cylinder and the fluid pressure within the supply chamber. These forces cause hydraulic pressure to rapidly rise to a peak at the centerline of the barrier "flat". 3)- The now linear and pressurized fluid stream accelerates in flow velocity.

The combination of linear fluid flow, rapid hydraulic pressure increase, and accelerated velocity combine to drive the fluid into the cell by means of the increased hydraulic pressure and draw the remaining air out of the cell by means of the venturi effect provided by the accelerating fluid stream. As the air leaves the cell, every other cell in line with it is also expelling its air volume, as does every in the line immediately behind the cell. In this manner a layer of exhaust air forms between the surface of the engraved roll and the excess fluid in the stream between the roll surface and the barrier flat. A now laminar flow of air/fluid crosses the balance of the barrier flat and goes into the last zone, the exhaust zone. Little fluid remains on the surface of the engraved roll due to the splitting action of the exhaust cell-air layer created. Such excess as does exist is cleanly metered by means of the final reverse angle doctor blade.

The net result of this internal fluid behavior is such that all cells are completely filled leaving no resident air behind and the surface of the roll is neatly doctored. In that the escaping air is released into a separate film layer, in a non-turbulent environment and is allowed to freely exhaust, there is no foam development.

Collateral benefits of this design are: I) - dramatically less fluid in the unit than any other system, which enhances tumover/exchange rate. 2)- The hydraulic force action in this design can be employed to clean the roll surface cells ' by merely substituting a cleaning solution for the applied fluid. The hydraulic pressure and venturi effect exist even if the cell is full of fluid from the last revolution. 3)- The hydraulic pressure rises as roll surface speed increases. As a result of this effect, full cell transfer occurs very uniformly over a very wide speed range with little, measurable shift in color intensity or coating weight.

The downside to this design is that the architecture of the barrier is roll-diameter-sensitive and the specific shape of the barrier and dimensions of the supply channel may need to be tailored to viscosity levels. Very high viscosity (1000 to 4000 cps) materials can be run very successfully provided appropriate modifications to the design are made.

By means of the use of this design (which is the subject of several pending patents) the converter can maintain very uniform transfer - typically in the range of ±2% to ± 5% over very broad speed ranges - typically 150 to 1200 fpm using solvent or water base fluids and even 100% high viscosity fluids. This improvement in uniformity promises less material consumption and higher line speeds with drying time the chief limiting factor.

Thus with this new, enclosed doctor blade design, proper engineering and operator training, it is possible for the forwarded thinking converter to increase line speeds, improve quality, conserve raw material and reduce downtime. Results should include operating savings and net capacity gain on existing equipment.

Figures referenced in this speech (1-5)

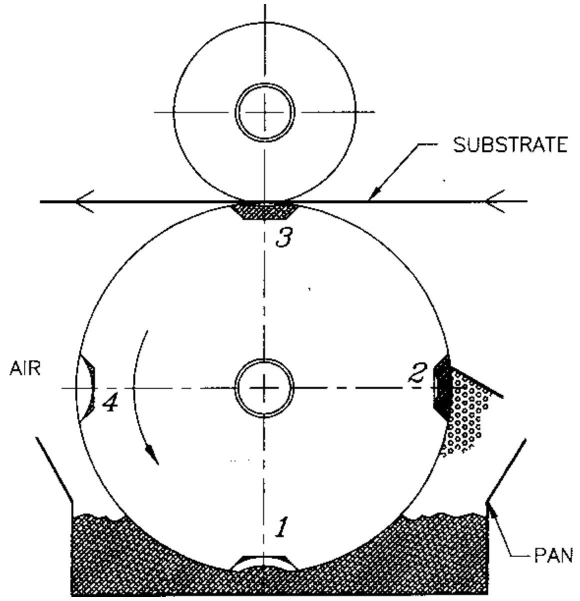

Figure 1

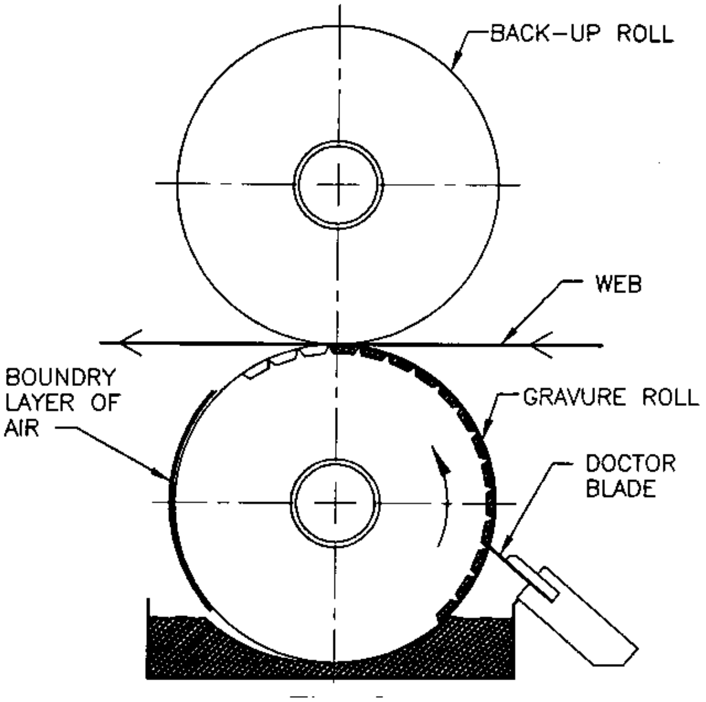

Figure 2

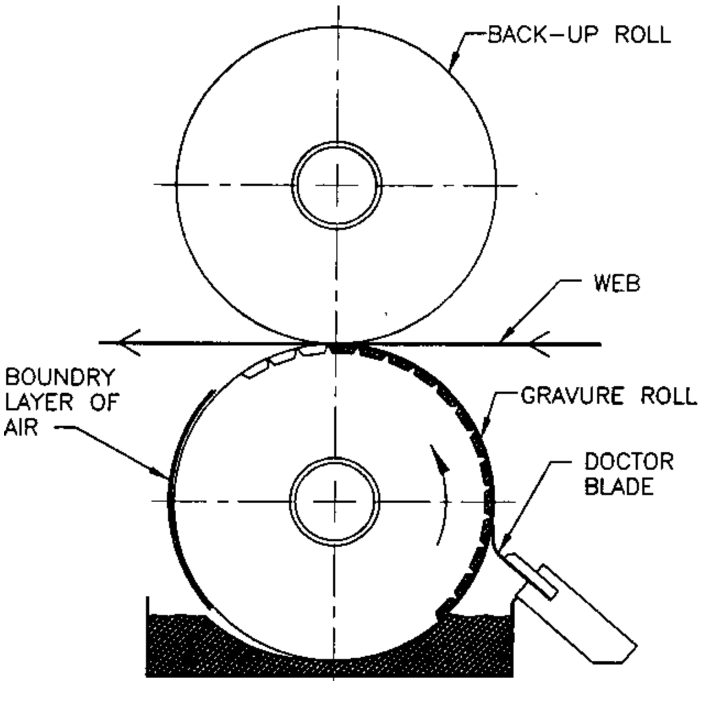

Figure 2A
highly flexed “butter” angle

Figure 2B
rigid/sharp angle

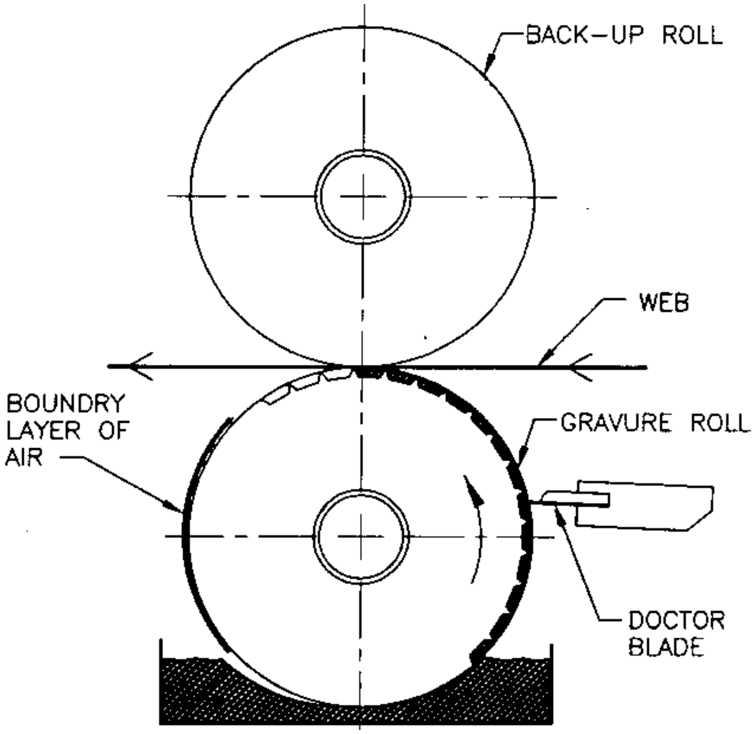

Figure 3
standard 2 roll
flexo deck

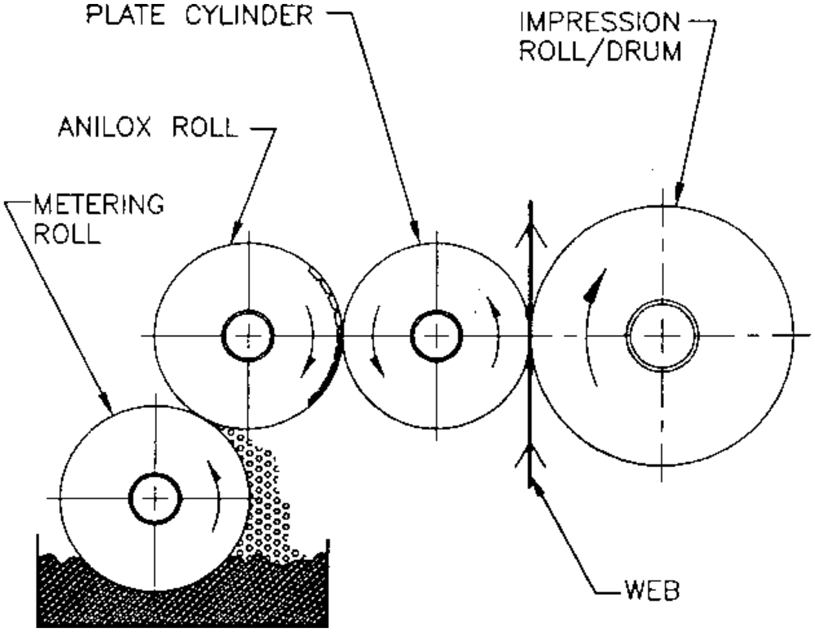

Figure 4

Traditional single zone chamber

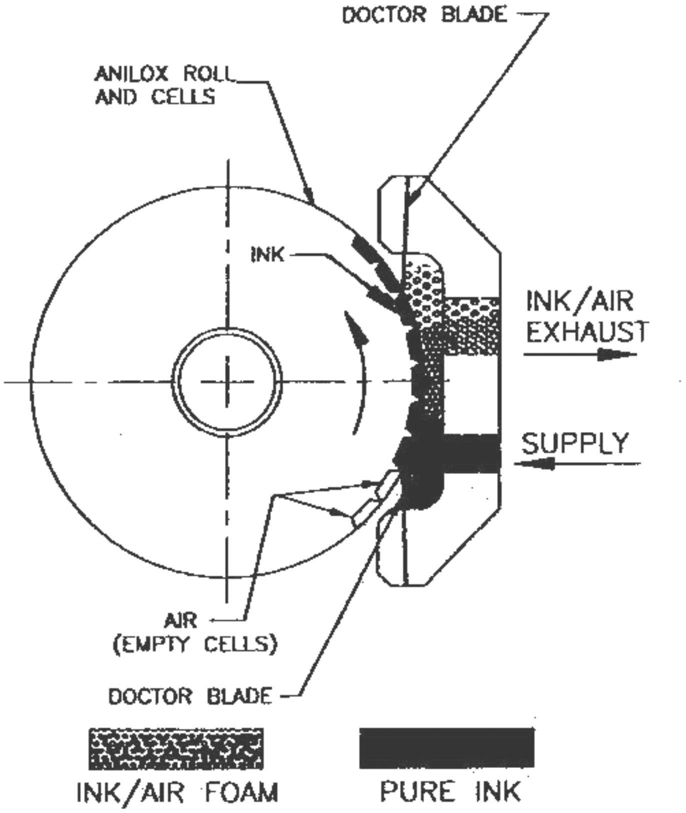

Figure 5

3-zone InkJector™ chamber

U.S. patents 5,826,509 & 5,988,064