In-Register In-Vacuum Pattern Printing -From Wish to Reality

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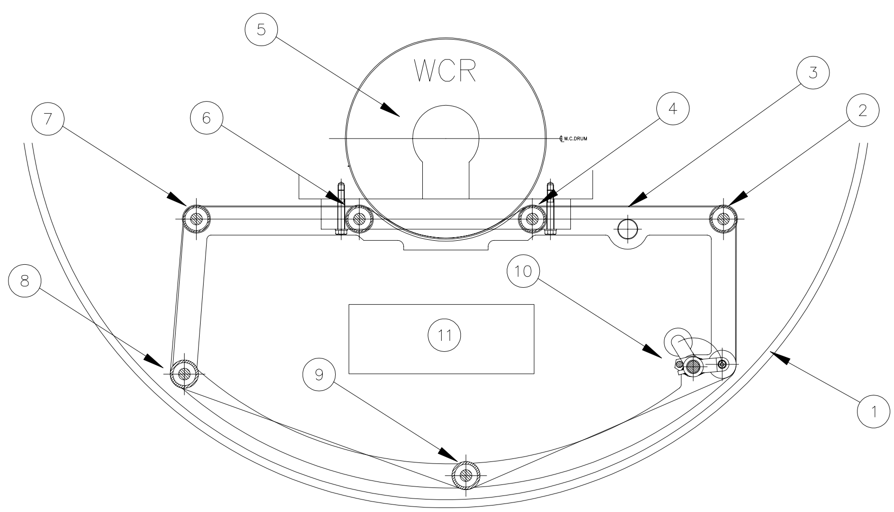
"The use of flexo printed oil within a metallizer is a well known method that enables complex patterns to be metallized directly in a single pass. In this new development this in-vacuum pattern printing process has been developed further so that the positioning of the pattern can be controlled to remain in-register with precision to a printed or embossed mark on the polymer substrate. This means that a pre-printed or embossed substrate can now have selective metallization applied to compliment existing designs. This is an important development as it assists the production of advanced packaging designs such as high security devices that depend on both the clear and un-metallized areas be in-register to highlight the different security features"

Methods of creating selective de-metallisation in-line during a roll to roll (R2R) vacuum coating process have been utilised for both decorative and functional applications such as sweet wrappings, capacitor and microwave susceptor structures since the early 1970's, where requirements for continuous clear bands of varying widths were required.

The first successful productionsed method of creating selective masking in the form of lanes pitched across the width of a metallised substrate was achieved using a mechanical mask system where a heat stabilised material would remain in contact with the substrate to be coated as it is wound through the coating aperture, thus shielding selected regions of the substrate from the deposited medium. This mechanical mask system is generally referred to as a *shadow mask system* and Figure 1.0 illustrates the main system components associated with such a shadow band system.



1	Vacuum Chamber	7	Grooved Roller (driven)
2	Grooved Roller (driven)	8	Idler Roller
3	Shadow Band Shield	9	Idler Roller
4	Grooved Roller	10	Tensioning Rollers
5	Process Drum	11	Process Source
6	Grooved Roller		

Figure: 1.0 a cross section of a typical shadow band masking system

Stainless steel or Kapton © are generally the materials of choice for the mechanical band masks in continuous or jointed form. To compensate for the increase in length of the shadow bands when the bands are subjected to the radiant and condensable heat from the process, an automatic tensioning roller system is generally employed.

The comparatively large material cost, system complexity and unreliable masking effect associated with this system caused the users to look for alternatives.

The oil boiler system was introduced in the 1980's and used as a simple, low cost, reliable and accurate method to deposit continuous oil lanes onto the passing substrate. The temperature of the deposited oil on the substrate surface, combined with the radiant heat from the evaporation source, would cause levels of the oil to evaporate off the surface of the substrate and the localised increase in pressure prevented the source material from being deposited in the region of the oil lanes. Various oils were tested over the years to evaluate their effectiveness in providing lane clarity, dimensional control of the oils lane and edge definition, but, due to issues with thermal stability, evaporation rates, viscosity, wetting/ surface tension, the oil of choice in the industry for this application is generally a perfluoropolyether (PFPE) based oil with the trade name of Fomblin © or Krytox ©.

The system comprises of a boiler tube which is positioned across the width of the substrate in the vacuum chamber and has a configuration of holes cut in the tube to suit the position and width of the lane requirements. The tube is heated by the aid of external power source up to a pre-determined optimised temperature, and an accurate positioning system moves the tube into position to obtain the transfer of oil vapour from the inner cavity of the tube onto the passing substrate during processing. To prevent oil contamination onto the web path rollers, the oil boiler is generally located in a free span region of the machine, although the position is generally near to a support roller to prevent film movement changing the distance to the boiler exit slots which in turn would result in lane width inaccuracies. Refer to Figure 2.0 for a simplified overview of a typical oil boiler system.

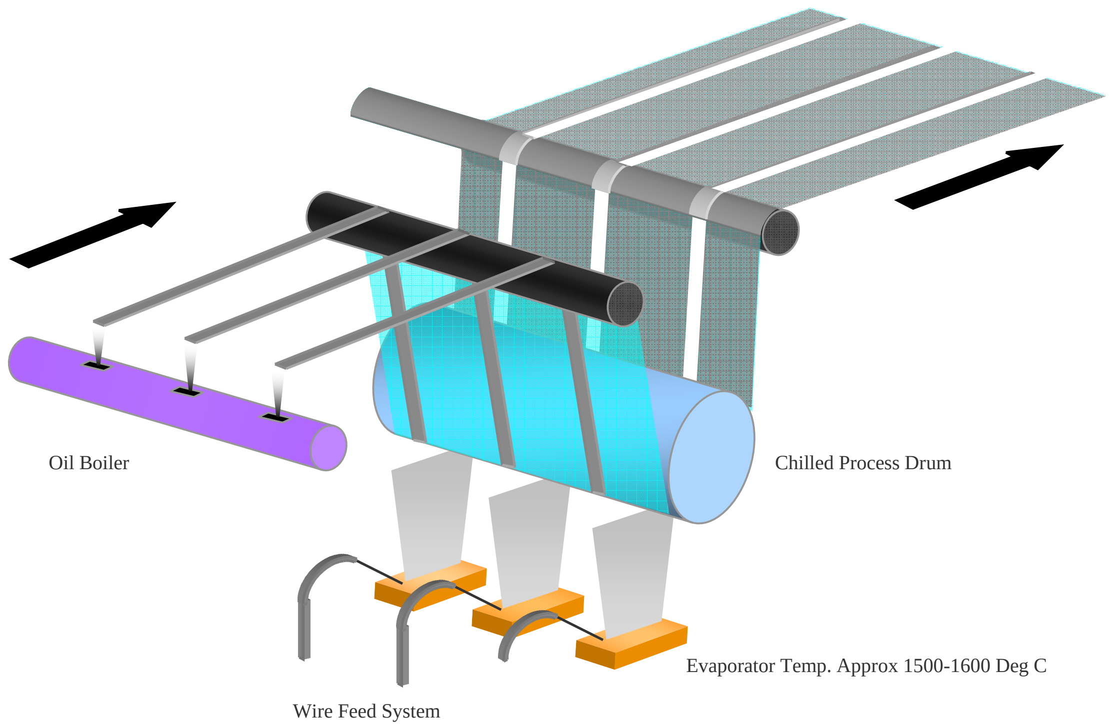


Figure: 2.0 A simplified schematic illustrating a simple oil boiler system

Both the mechanical masking system and the oil boiler system have been used in production for many years and have provided effective in-line methods of creating continuous clear bands at line speeds of up to 1200 m/min, but, their limitation is only for continuous lanes and a large number of other applications require clear windows and none continuous images as part of their package or structure.

Not alone in this area of development, General Vacuum Equipment Ltd developed an in-line pattern printing technique using a simple 'flexo' print unit to transfer the oil medium onto the passing substrate to create non continuous clear windows/ features as required by the application. Unlike standard printing techniques, where the printed medium (ink) is generally the area the end user wants to view, oil printing has the reverse effect, where the printed medium of oil, creating a clear window. A potentially costly and time consuming mistake can be made when ordering print sleeves, and one easily overlooked when dealing with multi-layer applications!!!

The main system components of the printing unit are illustrated in Figure 3.0, and consist of a method to enclose and heat up the print oil medium, and a roller train consisting of an anilox roller, transfer cliché plate and a metering method to limit the amount of oil being transferred through the roller train. The metering method can be achieved with the aid of wipe down roller as illustrated in Figure 3.0, or alternatively with a doctor blade method. The print assembly is located in the winding zone of a standard PVD metalliser where surrounding vacuum levels of 10^{-2} to 10^{-3} mbar are experienced. For a print unit which doesn't require any form of registration or alignment to the incoming web, independent accurate drives for each roller are not required and contact with the main process drum can be used to initiate and maintain rotation of the associated rollers of the print unit. A simple positioning system allows for print system to be brought into contact with the drum, or retracted when pattern printing is not required.

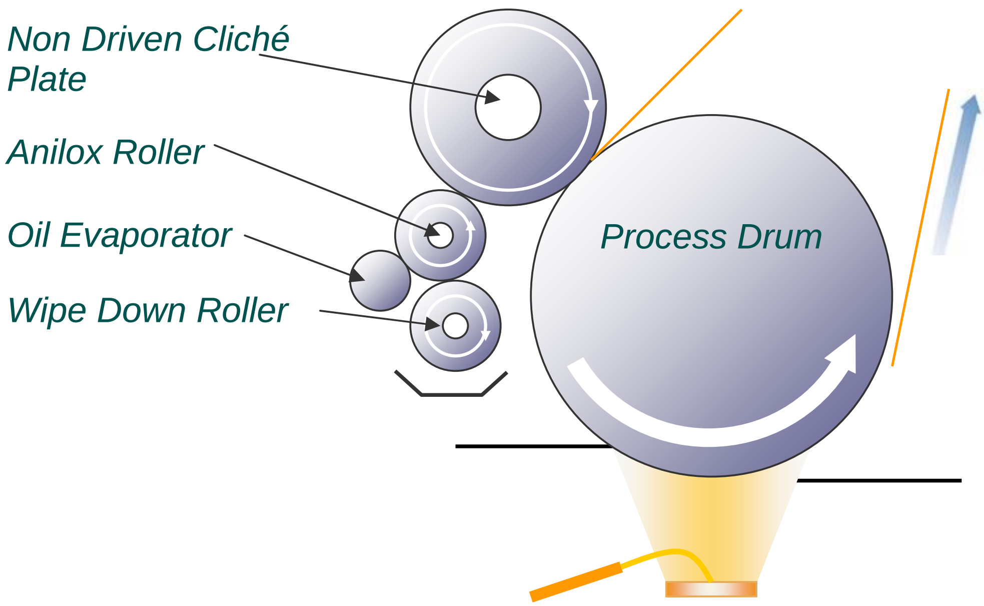


Figure: 3.0 A simplified schematic to illustrate a pattern printing system

Unlike the subtractive off-line methods of laser ablation or photolithography to create selective removal of the deposited material, in-line pattern printing can provide effective clear windows at very high line speeds, and processing speeds of 1000m/min have successfully been achieved in production using this technique for both decorative and functional applications. Examples of such applications are for printing fuse networks onto both metallised susceptor and capacitor structures as well as printing clear windows which allows the consumer to view the contents of the pack, whilst still maintaining adequate levels of barrier protection.

Recent developments into pattern printing have involved investigating the minimum oil printable feature size that can be achieved with this technology to evaluate it's potential for the area of thin film electronics and/or security, and also looking at creating larger areas of de-metallision generally for the area of packaging.

From the work conducted, it was found that a large number of parameters affected the pattern printing process and ultimately the quality of the pattern printed product. A list of the main key parameters are given below:-

- **Boiler Temperature**
- **Contact Pressures**
- **Oil Metering**
- **Process Drum Temperature**
- **Oil Characteristics**
- **Anilox Cell Volume**
- **Cliché Plate Material (Surface Tension, Deformation)**
- **Deposition Rate/ Heat Load**
- **Evaporator Temperature/ Heat Load**
- **Line Speed**
- **Substrate Surface & Type (Dyne Level)**

- **Pre Treatment**

With the ability to selectively print complicated clear images within a standard metallised sheet, the next technical challenge, primarily driven by the market was to achieve register/alignment of the pattern printed layer to a pre-printed substrate, or alternatively to align various patterned layers of a multilayer coating process.

Figure 4.0 below provides a simplified schematic of the print assembly. The unit incorporates individual servo drives to synchronise the rotational speed or angular position of both print and anilox rollers with the web and process drum.

The print medium is an oil vapour which is generated in a boiler mounted adjacent to the anilox roller. Surplus oil is removed from the surface of the Anilox roll by a full width Doctor Blade. Contact between Anilox roller and Print roller is position controlled by an accurate dual stepper motor system with 'skew' facility. This provides for optimal oil distribution across the face of the pattern sleeve. A similar stepper motor system, also with 'skew facility' is used to position the Print/Anilox roll set in relation to the process drum for even impression across the pattern width and allows for positional increments of 1/100mm.

The Registration system selected for the Development work was the market leading *Registron SU-5100* ™ supplied by Bobst, Switzerland.

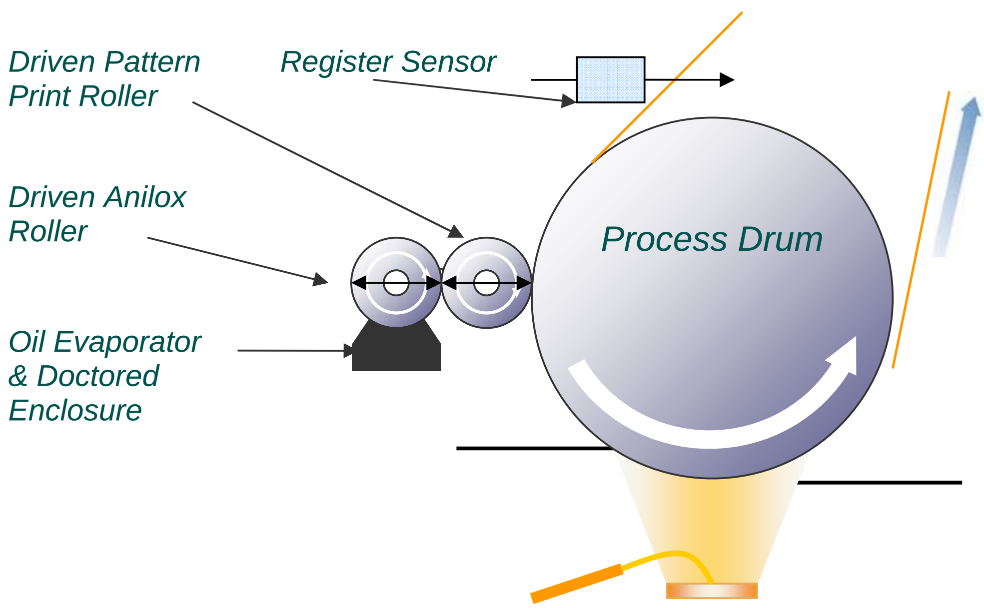


Figure: 4.0 A simplified schematic to illustrate a pattern printing system with registration capabilities

The synchronisation of the print roll and anilox roll can be adjusted such that oil vapour is printed onto the film, in-register with pre-embossed patterns. A register sensor is used to detect a '*register mark'* in the salvage edge of the pre-embossed film and make automatic adjustments to maintain machine direction registration.

To promote the transfer of the oil print medium from the cliché plate to the substrate, large contact pressures were required to assist with the oil transfer which created a nip between the print sleeve and the process drum. This had a detrimental effect when trying to maintain registration, as when the rotational speed of the cliché plate was changed to create a length match with the pre-printed print length, the nipping action of the cliché plate onto the substrate would change the printed length. For thicker gauge substrates, or when larger differences between pre-printed print length and the circumference of the films were found the system would saturate on current limit, or eventually release the nip action and slip through the oil to create distortion of the oil printed images. This phenomenon is thought to be due to the hydrophobic nature of the print medium and methods of preferentially increasing the surface tension of the substrate relative to the print rollers may help to reduce the contact pressure. Pre-stretching the substrate using 'in-setting' prior to the printing station, can also help to overcome this issue.

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