Waterless Offset Printing

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1. History

Among the four classical printing techniques lithography is the youngest: August Senefelder made his invention in 1798, in Munich. He worked with two media, ink and dampening solution (gum arab in water at his time). More than a decade later our records know about experiments to use the planographic printing principle with only one print medium, only with ink. Between 1926 and 1930 in Vienna and Leipzig the technical pioneer Caspar Hermann tried modifications of the lithographic ink, which would print without any dampening solution. His formulations were complicated and their success rather limited. In 1930 Heinrich Renck tried the other way: He modified the printing plate to get rid of the second printing medium.

Commercial success of waterless offset printing began only in the nineteen-seventies. The chemical company 3M invented, patented and sold waterless plates. But they left the business after a period of low success. A Japanese company, Toray, bought the patent from 3M, produced and distributed waterless plates, and supported for several decades commercial diffusion and further technical development. The patents protected Toray´s activities and kept competitors off. On the other hand they held the general development back for many years, as it was promoted only by Toray.

Anyhow waterless offset reached a significant market share in Japan. In Western Europe marks-3-zet (Germany) was a distributor of Toray plates and invested intensive work for years into the acceptance of the new offset variant. They tried to offer a complete substitute to wet offset, with negative and positive plates and intensive educational work with their customers. Some printers took the new and fascinating over and invested years of exemplary troublesome development work.

Some years ago, after the end of the patent blocking, other plate producers entered into the business, offering their own developments, starting in well defined parts of the total offset market. There are e. g. Presstek waterless plates based on plastic foil for DI (direct imaging) presses. Also then KBA in Germany began to develop completely new concepts of waterless offset presses for small, medium, and newspaper sized machinery. By this they activated producers of inks and other products to participate with their products and to ease the way for waterless offset. Now, at the beginning of the 21.st century, waterless is established in several niches (plastic cards and labels, small runs in publication) and some low percentage share in sheet fed and newspaper printing. Especially the new machine technique boosts the future perspective in several further fields of application.

2. Printing principle and plate construction

Waterless offset is a planographic printing process with indirect transfer of the ink from the printing plate to the substrate. Generally in planography the printing (image) areas of the plate are wetted by the ink, non-image areas however not. We describe wetting processes by the means of surface and interfacial tensions. That means in a rough model that image areas with surface tensions about 35 mN/m are well wetted by the inks with approximately 30 mN/m. The non image areas are covered by silicones with rather low surface tensions of about 20 mN/m and thus the inks do not wet them.
It is unimportant if image or non image areas are slightly elevated or deeper, because the wetting principle is not mechanical, but based on surface tensions. The actually available plates in our market have the image areas made of thin films of polymers directly upon the carrier aluminum or polyester and the non image areas as thin silicon films (~2 µm thick) on top. According to market product we find variations in carrier material or further layers for surface protection or activation in the imaging processes.

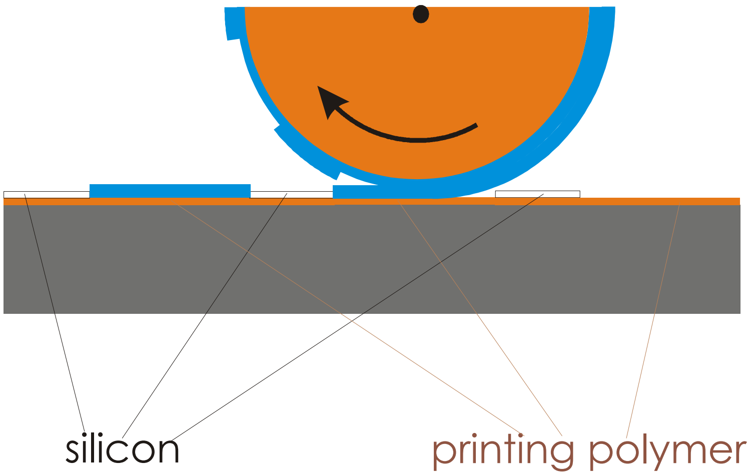

Fig. 1, In waterless offset image areas consist of polymer layers, non image areas of special silicones

Imaging waterless plates runs with photomechanical techniques by solidification (negative) or disintegration of the printing layer substance. It can be done chemically, by spark erosion (older way of the early DI presses), or by thermal ablation (removal) with laser rays (infrared). Both thermal techniques work with negative copying and make part of the modern CTP (computer to plate, direct imaging from digital data) procedures. Among these thermal ablation is presently the sharpest and most precise imaging technique. This predestines it for modern fine screens, independently of periodic (AM) or non-periodic (FM) screens.

An offset ink, being printed as it is, not as an aquous emulsion, is transferred much easier from one roller to the other than an emulsified ink. That means in waterless offset the possible transferred ink layer is as thick as it was in old letterpress printing. This can help printing spot colors, if e.g. the PANTONE® color book shows heavily printed tones, and the conventional offset faces problems to print this in only one press unit.

Typically the inking rollers offer the plate surface a 6 to 8 µm thick layer of printing ink. A layer of 3 to 4 µm remains on the image areas and is passed via rubber roller to the sheet, leaving typically about 1 µm. The edges of the printing areas are sharp and precisely inked. Dot gain can only come from mechanical contact in the nips. This is one of the great strengths of waterless offset printing. Print related dot gain, as in the case of „wet offset" (over-coloring the printing areas into the non image areas) does not occur, or is minimum. As a result it gives a more consistent dot transfer onto the paper and much less color variation over the total run compared to wet offset. Applying only ink onto the plate - no emulsion - means the printing image stabilizes within a few roller rotations, resulting in very little maculature.

According to our current understanding, the function of the waterless offset printing process is that silicone, with a lower surface tension, repels the wetting through ink. However, the difference between silicone and the printing surface is only 15 mN/m. In general, following Zisman, the printing ink should have a lower surface tension than the printing plate.

The interfacial tensions between ink and plate surface respectively are difficult to measure and usually in practice they are ignored. This rough way however fits the general needs of our practice.
As the temperature increases, the surface tension of the ink (i.e. surface versus air) drops less rapidly than that of the used silicone. At rather modest temperatures, from approx. 35°C, ink can contact the silicone. This causes dotting or even widespread toning on the plate. For this reason, in waterless offset the printing plate or even the rollers have to be cooled.
The more energy is brought into the machinery (running speed and job length) the more often there are toning problems, and the more intensive must be the cooling. This has brought even a bizarre term. Some authors define a CTI, a critical temperature index. In fact, they give a maximum temperature above which the plate tones. In reality this is not only a simplification, but kind of a capitulation, because this temperature in practice depends on each of the components, so on the entire system.

One working hypothesis of the waterless plate inking mechanism is called WFBL („weak fluid boundary layer"), once proposed by Sun Chemical. It says that the inks contain liquid release agents. That means we print again with emulsions, not only with inks. In this model within the first roller passes the release agent is pressed out of the ink emulsion and left on the silicone surface. Thus it helps to repel the ink. If silicone oil is used, this sounds at least plausible, because the silicone oil would be a real release agent. With silicon free inks however it does not work at all, because the mineral oil does never wet the silicon areas of the plate. And if it would do so, it would not repel the ink, but act as a primer between the two layers. Mineral oils are the backbones of the inks.

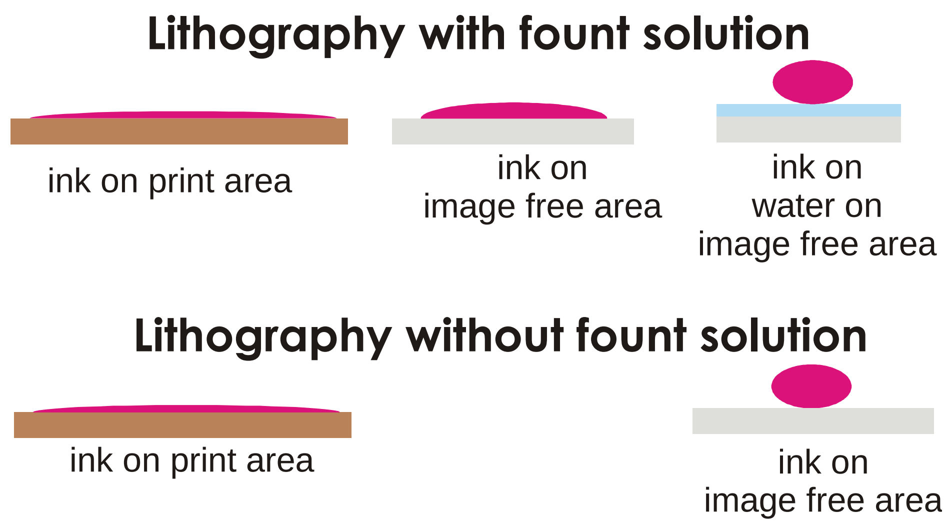

Fig. 2, In wet offset the ink wets easily also the non image areas, if there is not enough fount solution present. In waterless offset silicone repels the ink without an extra help.

3. Printing presses

In the initial years of waterless offset printing, which extended into the nineties, old and with increasing frequency, also new printing machines were used. No way always the dampening system was completely removed, but rather plate cooling was organized, for example, with blast air. Only with the GTO DI built by „Heidelberger Druckmaschinen AG" a genuine waterless sheet-fed offset press design came into existence. Other machine manufacturers soon followed. However the DI technology remained a niche, small, but for some producers interesting and profitable.

In sheet fed presses for conventional offset, more and more temperature control systems for the oscillating rollers are incorporated. Constant quality is asked more and more in medium and large print jobs, which cannot be achieved under varying room temperatures. This also helps waterless offset.
In sheet fed offset starting with smaller size presses and up, KBA Planeta introduced the models Genius and Karat, which worked solely waterless. Additional to the waterless offset, the KBA concept includes another innovation, the short inking system (Gravuflow). The ink is applied to the printing plate via a chamber blade and a screen roller. This clearly simplifies the machine construction because the long roller construction and the costly zone control become obsolete. The enormous potential of this is still upgradeable. This path was crowned by the fact that a very similar concept was realized in high speed newspaper printing machines - the currently commercially successful KBA Cortina after long and certainly difficult years.

4. Waterless printing inks

Even in the late eighties, ink manufacturers still developed waterless offset inks from the materials they were familiar with since the beginning. There were inks that could be used in both processes. However, due to the toning risk at higher temperatures, only highly viscous, putty like and highly tacky inks could be used for the waterless offset. Surface tensions are difficult to measure in pasty inks. lt was noticed, however, that the viscosity reduced at increasing temperatures. Consequently, the ink manufacturers performed tests and discovered that the toning risk could be reduced with higher viscosities and tacks. However, such inks were difficult to print because they were hard to take out of the can with a putty knife and caused heavy picking (pulled fibers from the paper). Japanese printers therefore used different settings for cold (beginning of the day) and warmed-up machines.
In a first step with new ingredients ink developers tried to solve the toning problem by adding some percent of silicon oils. This is still today a wide spread way. But it is only a partial solution to the problem, because it is not always satisfactory. And silicon containing inks cannot be recycled in the mass of conventional inks.

In general waterless inks still lack the big sales quantities of conventional inks, a mass flow bringing batch sizes big enough for special pigments and the recycling of leftovers. Also a diversification to all purpose, glossy, rub resistant, food packaging grades can emerge only with a certain sales quantity. The development of inks with conventionally formulated ingredients shows already quite good results, because it is possible to use more polar binders than in wet offset with its emulsification risks. A consequent new way tried some years by Sun Chemical Hartmann and Kast & Ehinger (now Flint group) in Germany, was stopped – unfortunately: inks based on totally polar substances mixable or at least washable with water. They dried too quickly and became too viscous. So they were too difficult to control in their machine performance, and the developments had to be stopped. But the idea is so promising, because surface tensions of such inks would be high, more than 40 or 50 mN/m. This makes a comfortable big difference to silicon surfaces and lets a lot of tolerance with rising temperatures without toning risks. And once under control, the quick drying will be an advantage in comparison to wet offset.

There is still another special feature of waterless: in wet offset we print an emulsion with rather low tack, in waterless a pure ink. Therefore we do not have any more the tack rise between two printing units and the bit advantage of offset in trapping ink layers wet-on-wet. Therefore waterless inks have to be graded in tack, the first high, the second less, the third lower and the fourth still lower – like in the old letterpress technique.

5. Typical applications

Many oft the existing models of DI (direct imaging) presses print preferably small jobs of publication. So it is mainly process printing (four color printing) without varnish, mostly on paper.
There is another market niche, which now is covered nearly completely by specially constructed presses (Metronic Genius, CD Print etc.), combining waterless offset with short inking system and UV curing equipment: CDs and DVDs, bank cards, and plastic labels (cosmetics) are usually printed with UV curing waterless inks. These inks stick well to the substrates and are immediately ready for further processing: no fountain residues disturb on the glazed surfaces.

High class pictures, especially with non periodic fine screenings use the advantages of waterless in excellent way with clean highly detailed designs (high resolution, low dot gain). They are printed on nearly identical presses like products of conventional offset – only without dampening units. Main applications are high quality publications, catalogues, and illustrated books.
Newspaper printers now have installed a significant number of printing units (KBA Cortina), and in folding boxboard there are some hopeful beginnings.

6. Waterless versus wet Offset

6.1. Strengths of waterless offset:

- Low starting waste, e. g. 20 sheets instead of 200
- More accurately printed dot, finer drawing, lower dot gain, suitability for fine screens up to 300 l/cm instead of 120 l/cm in wet offset, for FM raster, and even for finely pixelled dots of periodic raster, higher print contrast
- Fine negative lines remain still open
- Higher consistency of color tones in process printing areas, because dot sizes are more constant over a total job
- Thicker ink layers can be transferred to the sheet, useful for modern hi-fi process printing
- Simpler construction of machinery without dampening units
- Less investment without conditioning and control of dampening solution
- Less maintenance for the presses
- No corrosion of cylinders etc. without the acid fount solution
- No voc problems (emission of low volatile components), because no isopropanol is used
- Less tricky sources of errors, especially for the oxidative drying of inks
- No swelling of paper by water, less register risks, better printability for short grain sheets
- Even metallic ink cannot corrode any more

6.1. Weaknesses of waterless offset:

- The printing process still suffers from toning problems with rising temperature
- No fount solution cools the machine by evaporation, temperature control system required
- Sometimes the addition of silicone oil is necessary, often it is used preventively
- Some of the silicon containing inks are still very viscous and tacky
- If not exclusively used cost advantages only partially, higher quality has to be paid
- Plates are more expensive than in wet offset
- Plates are still more easily scratched
- Plates are difficult to correct after processing
- The pure, tacky inks (no emulsion) cause more hickies and debris problems
- Paper fibers etc. are not any more transferred back into the fount unit
- Inks need special binder chemicals, not yet mass products, so not all spot colors or special ink systems available
- In heatset paper would be even more dehydrated
- Up to now waterless offset covers certain niches: small jobs, publications, and plastic films / cards, starting in newspaper printing, but hardly any packaging, e. g. for food

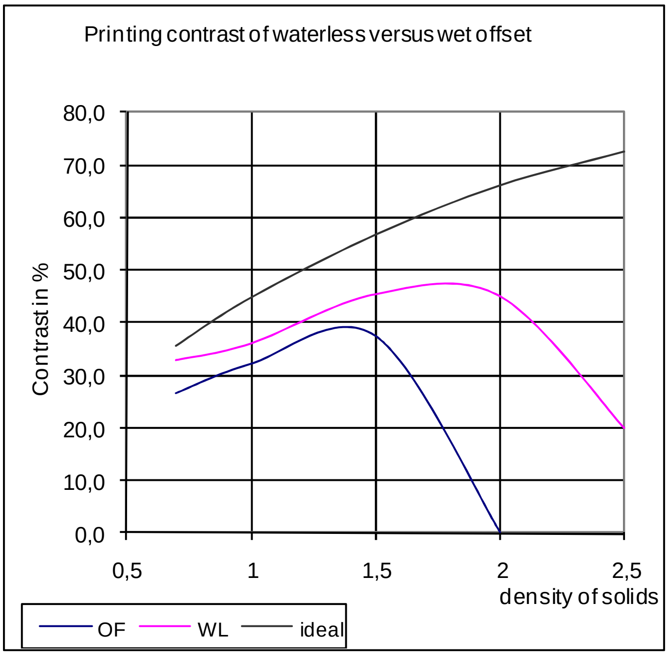

Fig. 3, comparison of print contrast between typical waterless and wet offset ink; the black graph shows a theoretical ideal without any dot gain

7. Some typical misunderstandings in literature

In this very special sector of technology there is hardly any reliable technical literature. Main sources of information are – even for university professors – advertising articles given by producers of machinery, inks or other materials. Some of them are almost dubious. This led to some adventurous explanations and hypotheses. From this point of view some of the most strange proposals should be discussed here.

7.1. Alternative name “dry offset”

This expression is already occupied by letterset (letterpress offset = indirect letterpress, e. g. cup and tube printing). It does not make sense to use one expression in one technical field for two different items. However especially in the printing machine business people use it.

7.2. Alternative name “Offset without fount medium”

It is imaginable to print waterless with inks, which contain a release agent. So they are emulsions again, because a release agent would per definitionem not mix with the ink vehicle. It is be placed upon the silicon surface with the first roller passes and assists in repelling the ink. This is proposed by the WFBL (weak fluid boundary layer) theory given once by Sun Chemical. The help of the silicon oil makes this hypothesis at least reasonable. The silicon oil would take over the work that a fount solution in wet offset does.

7.3. Alternative name “Offset without fount unit”

There were already several projects of selling a ready emulsion instead of two separate components, called “single fluid inks”, which were to be printed without an additional dampening system. However, these trials did not survive commercially.

7.4. The mineral oil acts on the plate surface as a release agent.

This working hypothesis can only be adapted to proper emulsions, e. g. inks with silicon oil. The mineral oil of an offset ink would never wet the silicon areas, because its surface tension of approx. 27 mN/m is much too high. Silicon shows only 20 mN/m. The wetting liquid has to have always lower or at least equal surface tension in comparison to the solid. And further more a surface wetted by mineral oil would be the ideal contact for the ink, because the mineral oil is the backbone of the ink.

7.5. Waterless offset called “gravure printing without doctor blade

Some people say waterless showed so sharp dots (without dot gain), because printing areas were lower than image free areas. And for this reason ink would be kept exactly within the borders of the dot. So it had kind of a gravure characteristic. Compared to that in wet offset the image areas were elevated and had something like a letterpress characteristic, ink excess pressed out of the dot area. This error is easily disproved, because also in wet offset there are plates, which have the printing layer below the non printing layer, e. g. metal plates using copper and zinc. This construction did not give the possibility to print the extremely fine raster, which we can realize in waterless. Waterless offset clearly makes part of the planographic printing techniques.

7.6. Waterless offset is environmentally friendly.

There is no technical process at all, which we can call environmentally friendly. To be correct we have to distinguish between more or less environmentally harmful, necessary and reasonable bigger or lesser evils. Work without isopropanol is a good point. The absence of waste waters can at most be an economical argument, because professional offset printers dispose of their wastes following technical rules – not dumping them simply into the sewerage system.

Bergheim/Erft in Germany, June 2009