

ANALYZING SURLAND'S EMULSIFICATION TEST IN TERMS OF HLB THEORY

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ABSTRACT

The water-pickup behavior of a lithographic printing ink during Surland's emulsification test depends upon the identities of both fountain solution and ink. It also varies with the quantity of fountain solution present during mixing, with the amount of dampening concentrate in the fountain solution, and with the concentration of wetting agent in the dampening concentrate.

A pseudo-first-order reaction rate theory was initially used to analyze emulsification test results. The HLB (Hydrophile-Lipophile-Balance) theory appears to be a better way for explaining the widely varying water-pickup behaviors. The pros and cons of this HLB approach are discussed. Implications in keyless lithographic printing are mentioned.

BACKGROUND

A conventional lithographic printing plate comprises two different areas on essentially the same plane: the hydrophobic/oleophilic image area and the hydrophilic non-image area. Materials constituting both image and non-image areas have a higher surface energy than that of lithographic inks. As a general rule, a low energy ink readily wets both of these high surface energy areas and will produce a solid print regardless of image format. In practice, this is prevented by using a second fluid known as fountain solution. This aqueous fountain solution preferentially wets the hydrophilic non-image area and prevents the non-image area from accepting ink. However,

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the introduction of the immiscible aqueous fountain solution complicates the printing process. In addition to the interactions of ink with image and non-image surfaces, there are the interactions of fountain solution with image and non-image surfaces and the interactions between ink and fountain solution. The last of these is generally referred to as ink-water interactions and is being investigated by the authors and others (Karttunen and Manninen, 1979; Surland, 1980 and 1983; Tasker et al, 1983; Cunningham and Moore, 1984; Koniacki et al, 1985; Chou and Fadner, 1986; and Fadner and Bain, 1987).

A concise mechanism of lithography proposed by Wilkinson et al (1975) describes the spreading and receding phenomena of an ink drop as a function of water film thickness on the plate. There exists a water film thickness range within which neither spreading nor receding of ink on the image areas occurs. This water film thickness range corresponds to the ink-water balance latitude during a press run. This range depends upon the difference in hydrophilicity between image and non-image areas, the surface roughness of the plate, the volume of ink, and upon additives present in both ink and fountain solution (Wilkinson et al, 1979a). It is also affected during lithographic printing by shearing action and by hydrodynamic pressure existing in the roller nips (Wilkinson et al, 1979b) and by the fact that a sufficiently continuous water film is required on the non-image surface to serve as a weak fluid boundary layer for ink release (Gaudioso, et al, 1975). In general, it is easier to run the press, and the waste is less with a wider ink-water balance latitude.

Wilkinson's model mechanism does not, however, explain the necessity of a lithographic ink being able to pick up aqueous fountain solution. Generally, the lithographic printing process involves sequential application of fountain solution and ink from their respective fountains through separate distribution roller systems and form rollers to the plate. The imaged ink film is then transferred to a blanket and finally to the printing substrate. The form rollers are set against the plate cylinder so that a contact pressure arises in each nip. This contact pressure helps transfer any fluid carried by a form roller to the plate. Since the fountain solution is thereby forced onto the plate, it comes into intimate contact with both image and non-image areas. When the fountain solution film splits, it is unable to completely

recede from the hydrophobic image area. Many tiny drops are left on the image surface, because the fountain solution is a weak, low-viscosity fluid. Fountain solution remains a film on the hydrophilic non-image surface. When this dampened plate is subsequently forced into contact with inked form rollers, these water drops on the image surface have to be completely absorbed by the ink in a very short time, otherwise they will interfere with ink transfer and result in snowflakes on the print. This is the reason why lithographic inks are formulated to pick up a quantity of fountain solution. Due to the immiscibility of the two fluids, the absorbed fountain solution takes the form of a water-in-ink emulsion.

A portion of the fountain solution on the non-image area is simultaneously emulsified into the ink film on the form rollers. If the fountain solution film is not thick enough or the ink emulsifies too much of the fountain solution, the remaining fountain solution film is unable to form the barrier that is required to keep the non-image area free of ink and scumming occurs. If the fountain solution film is too thick or the ink emulsifies too little of the fountain solution, excess fountain solution is forced to flow under pressure over the image areas and causes wash marks. These speculations are consistent with Wilkinson's model mechanism of lithography, but also take into account both the existence of and the rate of emulsification.

Absorbed fountain solution is transferred back with the residual ink down the inking train and the press soon prints an emulsion instead of a dry ink. The fountain solution content of emulsion ink increases with printing time until a steady state is established or until the ink is unable to take any more fountain solution and fails to print (Fadner and Bain, 1987). Consequently, the success of lithography in terms of ink-water interactions strongly depends on two parameters: emulsification rate and emulsification capacity. A quantitative measurement of these two parameters is believed to be essential.

Various techniques for determining ink emulsification in the laboratory can be found in the literature (Fetsko, 1986). The most popular and reproducible method was developed by Surland (1980, 1983) using a modified Sunbeam Mixmaster. In this method, 15 ml fountain solution is added to an initial 50 grams of ink in the mixing bowl and

is mixed for one minute. The amount of emulsified fountain solution is determined gravimetrically by difference after pouring out the unemulsified fountain solution. This procedure is repeated nine more times to construct an emulsification curve. It is occasionally necessary to add more fountain solution during the first few minutes of the emulsification test to assure that a reasonably constant surplus (5 to 10 grams) of unemulsified fountain solution is present during each mixing stage. Based on "thousands" of inks tested, Surland (1980) classified the emulsification curves into five types and correlated each type with its press performance. He also defined two constants from the shape of emulsification curve: the time to reach an equilibrium state and the equilibrium value. He related the former to the ink-water balance latitude on the press and the latter to the ink's emulsification capacity.

The authors found it difficult to objectively determine these two constants from the emulsification curves in the experiments reported here. Most newsinks do not reach the equilibrium state within the time frame of the emulsification test. Additionally, in this method, the shear conditions are not the same as those existing in the roller nips of a press, and hence the quality and uniformity of emulsions produced are also different.

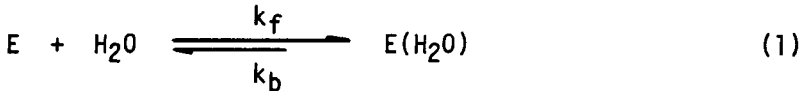
Many different roller distribution systems have also been used to study ink emulsification because the shearing action should better simulate that in a real press. Tasker and co-workers (1983) emulsified a controlled volume of ink on a Litho-Break Tester with a filled water tray. After a certain period of mixing, a very small ink sample was taken for water content measurement. The same procedure was repeated until an emulsification curve was completed. They treated emulsification as a pseudo-first-order reaction and were able to calculate two constants from the experimental data: the apparent emulsification rate constant and the ultimate water-pickup. This test method is relatively tedious and probably less reproducible because of the difficulty in obtaining a very small sample that is representative of the actual emulsion ink.

In this paper, the reaction rate theory of ink emulsification is critically reconsidered in order to gain a better insight into the physical meaning of the two parameters and to better understand the limitations of the existing test methods.

THEORETICAL CONSIDERATION OF EMULSIFICATION

Emulsification Rate Theory

Representation of the emulsification reaction was adopted from the work by Tasker et al (1983) as follows :



The net emulsification rate is given by

$$d[E(H_2O)]/dt = k_f [E] [H_2O] - k_b [E(H_2O)] \quad (2)$$

where $[E]$, $[H_2O]$, and $[E(H_2O)]$ are concentrations or quantities of emulsifier, free fountain solution, and emulsified fountain solution respectively at time t . The constants, k_f and k_b are emulsion formation and emulsion breakdown rate constants, respectively. This is a second-order reaction.

When free fountain solution is present in large excess, the change of free fountain solution concentration is negligible during the course of reaction and the quantity $[H_2O]$ can be incorporated into the emulsification rate constant. The resultant emulsion formation rate is, in most cases, so much greater than the emulsion breakdown rate that the term $k_b[E(H_2O)]$ can be neglected. With these assumptions, the emulsification becomes a pseudo-first-order reaction and Eq. (2) reduces to

$$d[E(H_2O)]/dt = k_a [E] \quad (3)$$

where k_a is the apparent emulsification rate constant. Since $[E]$ is an unknown quantity, it is impossible to solve Eq. (3). Fortunately, Eq. (3) infers that the emulsification will continue until all emulsifier is consumed in forming the water-in-ink emulsion. At this point, the emulsification curve levels off. This plateau value corresponds to the ultimate water-pickup as defined by Tasker et al (1983), and is essentially equivalent to the initial concentration of emulsifier. Accordingly, the quantity of emulsifier available for emulsion formation at time t is equivalent to the difference between ultimate water-pickup and emulsified fountain solution. Then the rate of emulsification is given by

$$dX/dt = k_a (A - X) \quad (4)$$

where X and A represent quantities of emulsified fountain solution and ultimate water-pickup at time t , respectively. Integration of Eq. (4) gives

$$\ln [A/(A-X)] = k_a t \quad (5)$$

or

$$X = A [1 - \exp(-k_a t)] \quad (6)$$

The constants A and k_a can be calculated by fitting the experimental data to Eq. (6).

Applicability Of Rate Theory

The pseudo-first-order rate theory enables us to evaluate two important parameters from the emulsification data: the ultimate water-pickup and the apparent emulsification rate constant. It is, however, limited to the condition that free fountain solution should exist in large excess. This condition is fulfilled by the approach taken by Tasker et al (1983), but it does not simulate the real printing condition. MacPhee (1979) has shown that the ink film thickness on the image area of the plate is 2 to 3 microns under normal operating conditions while the water film on the non-image area is 0.5 to 1 micron thick. The ratio of these values is, on the average, equivalent to 15 ml fountain solution to 50 gram ink, and is similar to that adopted in Surland's emulsification test. On the other hand, both ink and fountain solution are continuously fed to the plate during printing and are printed out to the substrate, whereas all laboratory emulsification tests are carried out in closed systems so that none of the ink and fountain solution is consumed during the emulsification test. Nevertheless, the measurement of apparent emulsification rate constant and ultimate water-pickup appears to be a useful tool to rank press performance of various ink/fountain solution combinations.

Thus, although Surland's emulsification test method only partially fulfills the requirements for pseudo-first-order rate theory, it is easier to perform than the roller distribution methods and is, therefore, used in this study.

EXPERIMENTAL APPROACH

Two black newsinks (A and B) were used in this study in conjunction with two commercial fountain solutions (FS1 and FS2). Fountain solution FS1 is an alkaline solution and FS2 a neutral solution. The fountain solution concentrate was diluted with deionized water to the concentration specified by the suppliers and to five and ten times the standard amount for the study of concentration effect. The conductivity and pH of these diluted solutions are summarized in Table I. Two specially formulated fountain solutions (FS3 and FS4) were also used and diluted to the standard concentration. Fountain solutions FS3 and FS4 are similar to FS1 but contain five and ten times the concentration of wetting agent, respectively. Table I also includes their conductivity and pH values.

All emulsification tests were carried out at room temperature with a Duke Tester following the procedure suggested by Surland (1980) with one exception. Each excess fountain solution quantity was retained and reused in the subsequent step. Except when otherwise mentioned, 15 ml fountain solution was added at each step for mixing with an initial 50 grams of ink. The quantity of emulsified fountain solution was determined gravimetrically.

TABLE I. CONDUCTIVITY AND PH VALUES OF FOUNTAIN SOLUTIONS.

FOUNTAIN SOLUTION	CONCENTRATION (oz/gallon)	pH	CONDUCTIVITY (μ mho/cm)
FS1	1.5	11.0	2000
FS1	7.5	12.0	7850
FS1	15.0	12.4	12960
FS2	1.5	6.9	1100
FS2	7.5	6.8	4950
FS2	15.0	6.8	6850
FS3	1.5	11.4	2050
FS4	1.5	11.6	2200

EMULSIFICATION TEST RESULTS

Many newsinks picked up all of the 15 ml fountain solution during each of the first few minutes of mixing.

In these cases, more than 15 ml fountain solution was added to assure a constant surplus of unemulsified fountain solution. Confusing results were obtained. In some cases, the ink picked up more fountain solution. In other cases, less fountain solution was emulsified. Therefore, the effect of fountain solution quantity present during mixing needed to be studied first.

Effect Of Fountain Solution Quantity

Figures 1 to 4 illustrate the emulsification behavior of Inks A and B with FS1 and FS2 when 15, 30, 50, or 70 ml fountain solution of standard concentration was added during each mixing period to an initial 50 grams of ink. Ink A always picked up more FS1 when more fountain solution was added for mixing (Figure 1). Ink B initially tended to emulsify more FS1 as the amount present was increased, but the ultimate water-pickup tended to correspondingly decrease (Figure 2). The apparent emulsification rate constants and ultimate water-pickups summarized in Table II were obtained by fitting the experimental data to Eq. (6).

TABLE II. ULTIMATE WATER-PICKUP AND APPARENT EMULSIFICATION RATE CONSTANT OF INKS A AND B WITH FS1.

INK	FOUNTAIN SOLUTION QUANTITY (ml)	k_a (per min)	A (g/100g Ink)
A	15	0.199	207.4
A	30	0.340	221.3
A	50	0.523	241.5
A	70	0.603	252.3
B	15	0.142	279.2
B	30	0.339	178.5
B	50	0.421	160.0
B	70	0.226	174.2

Great difficulty was encountered during the tests of both Inks A and B with FS2. A portion of the ink mass was torn loose and relatively severe bleeding was observed, especially when more fountain solution was present during mixing. With great care to separate the floating ink mass from unemulsified fountain solution, it was found that the

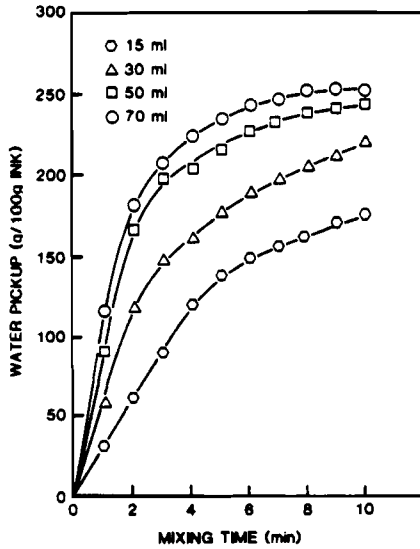


FIGURE 1. Emulsification results of Ink A with FS1 as a function of fountain solution quantity.

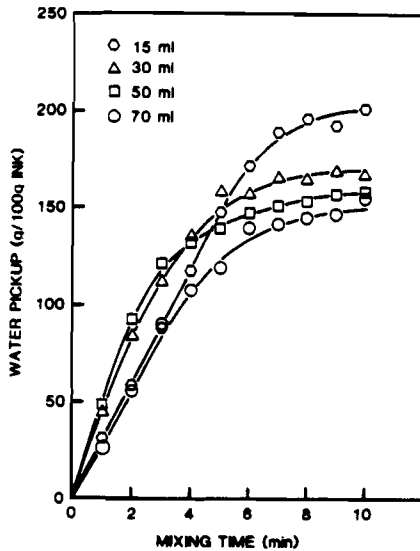


FIGURE 2. Emulsification results of Ink B with FS1 as a function of fountain solution quantity.

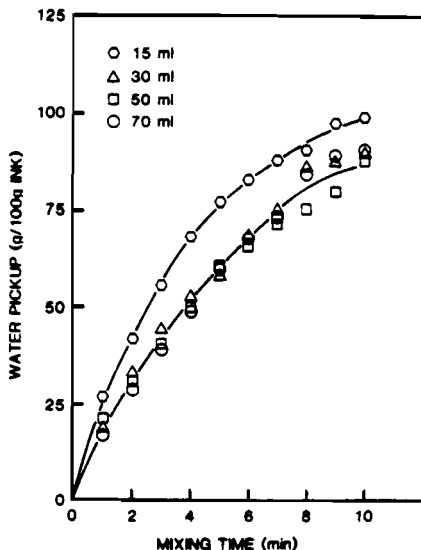


FIGURE 3. Emulsification results of Ink A with FS2 as a function of fountain solution quantity.

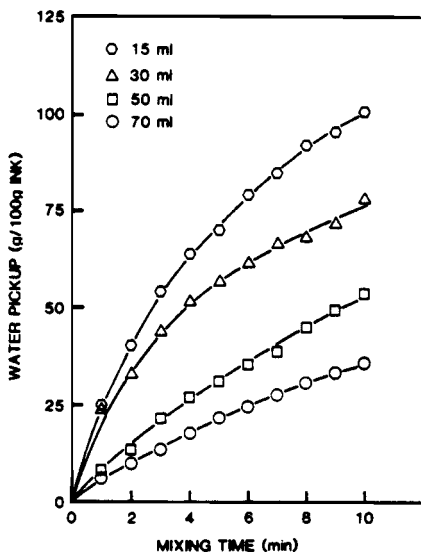


FIGURE 4. Emulsification results of Ink B with FS2 as a function of fountain solution quantity.

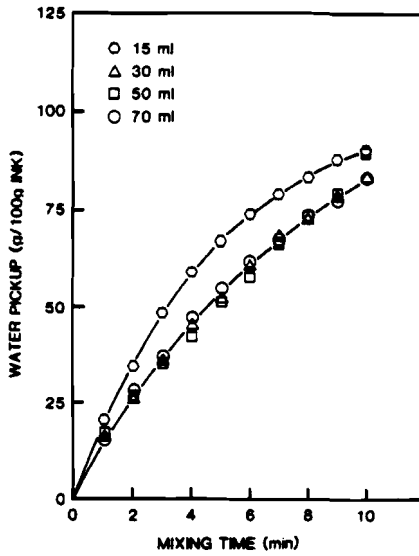


FIGURE 5. Emulsification results of Ink A with deionized water as a function of deionized water quantity.

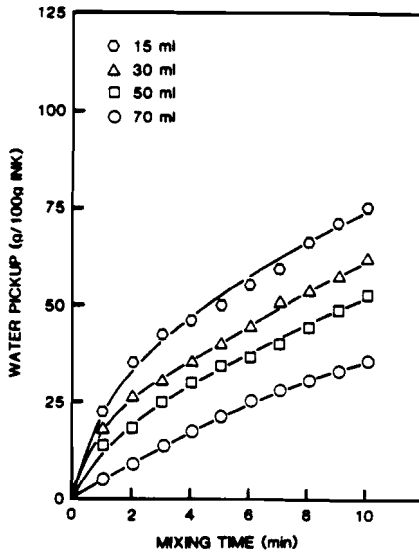


FIGURE 6. Emulsification results of Ink B with deionized water as a function of deionized water quantity.

emulsification curves of Ink A with FS2 were nearly independent of the fountain solution quantity (Figure 3). The emulsification curve of Ink B with FS2 was systematically lowered by increasing fountain solution quantity (Figure 4).

Similar tests were also carried out with deionized water alone. The experimental data are presented in Figure 5 for Ink A and in Figure 6 for Ink B. Although the emulsification behaviors of these two inks with deionized water are similar to those with the neutral fountain solution, no experimental difficulty was encountered during the tests. Floation of ink mass on the fountain solution surface was absent.

Effect Of Fountain Solution Concentration

The emulsification curves obtained using the standard procedure are given as a function of fountain solution concentration in Figures 7 to 10 for various ink/fountain solution combinations. The first few data points were omitted from the figures because the entire fountain solution was absorbed. In all cases, the maximum emulsification was observed with the fountain solution at five times the standard concentration.

Effect Of Wetting Agent Concentration

Figures 11 and 12 detail the effect of wetting agent concentration on the emulsification behavior of Inks A and B, respectively. Ink A emulsified more fountain solution with increasing wetting agent concentration, while the reverse was observed with Ink B.

DISCUSSION

Significance Of The Results

Surland (1983) observed that when more fountain solution is added for mixing, the mixing efficiency is reduced and hence less fountain solution is emulsified. This effect is seen for the emulsification behavior of Ink B with FS2 (Figure 4) and with deionized water (Figures 6). However, when FS1 was used with both Inks A and B, adding more fountain solution for mixing did not necessarily result in less fountain solution being emulsified (Figures 1 and 2). The reduced mixing efficiency concept does not apply in all cases.

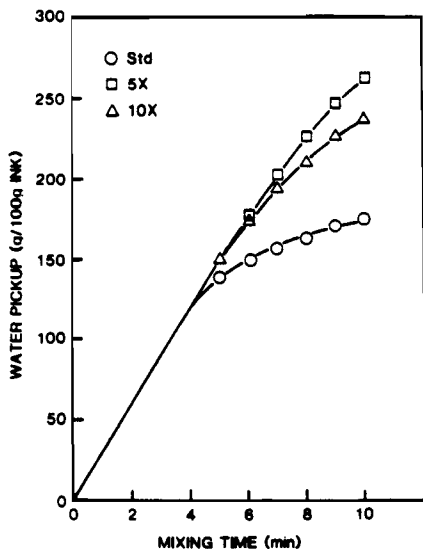


FIGURE 7. Emulsification results of Ink A with FS1 as a function of fountain solution concentration.

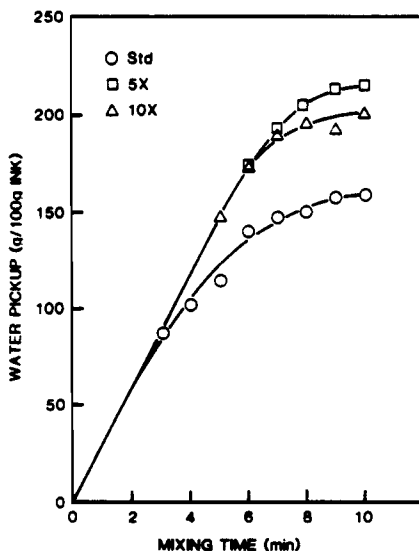


FIGURE 8. Emulsification results of Ink B with FS1 as a function of fountain solution concentration.

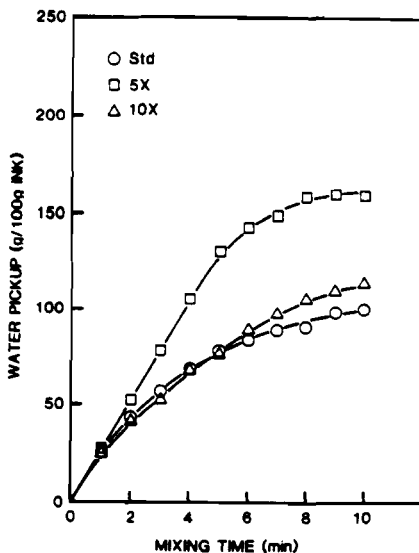


FIGURE 9. Emulsification results of Ink A with FS2 as a function of fountain solution concentration.

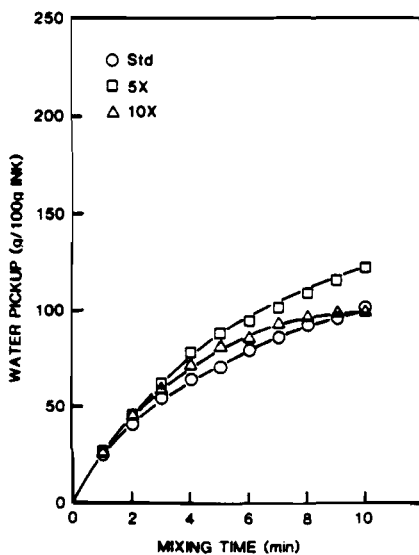


FIGURE 10. Emulsification results of Ink B with FS2 as a function of fountain solution concentration.

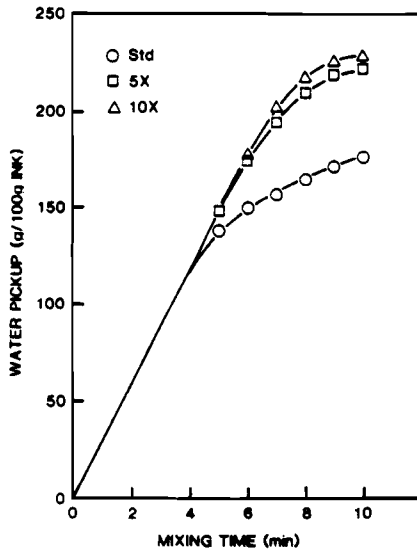


FIGURE 11. Emulsification results of Ink A with the alkaline fountain solution as a function of wetting agent concentration.

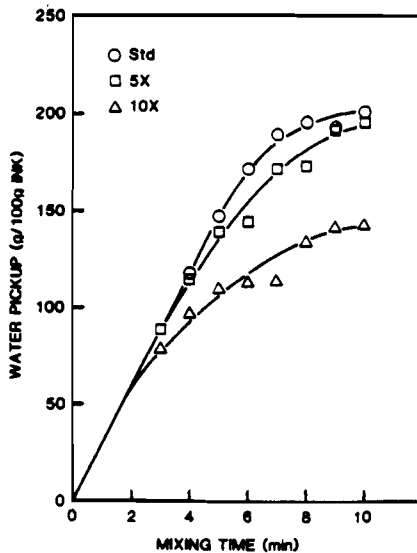


FIGURE 12. Emulsification results of Ink B with the alkaline fountain solution as a function of wetting agent concentration.

The amount of emulsified fountain solution is expected to increase with increasing fountain solution quantity, according to Eq. (2). This effect is only seen for the case of Ink A with FSI (Figure 1).

Eq. (3) also infers that if the emulsifier participating in emulsion formation comes solely from the ink, the emulsification of fountain solution by the ink should be independent of the type of fountain solution used. Figures 1 to 4, however, show that an ink definitely exhibits different emulsification curves with different fountain solutions and vice versa. Both the apparent emulsification rate constants and the ultimate water-pickups were affected by the nature of fountain solution and by the quantity used in the emulsification test (Table II).

No ink floatation was observed when deionized water was emulsified into either Ink A or B but was seen with the neutral fountain solution, even though they exhibited similar emulsification behaviors.

All of these results indicate that ink emulsification cannot be fully explained by the reaction rate theory. The physico-chemical nature of emulsifiers (or more generally surface active materials) and their quantities present in both ink and fountain solution must be affecting the emulsification behavior.

HLB Theory For Emulsion Systems

An emulsion system comprises three phases : oil, water, and emulsifier. Depending on the physico-chemical nature of the emulsifier, an oil-in-water (O/W) or a water-in-oil (W/O) emulsion can be formed. In general, O/W emulsions are produced by emulsifiers that are more soluble in the water than in the oil, whereas W/O emulsions are produced by emulsifiers that are more soluble in the oil than in the water (Rosen, 1978). A brochure published by the ICI Americas Inc. (1984) presents a systematic study of the physico-chemical nature of emulsifiers and its application to emulsifier selection for obtaining the desired emulsions, known as HLB theory.

In this theory, each emulsifier is assigned a numerical value (HLB number) ranging from 0 to 20, depending on the relative size and strength of the hydrophilic and the

lipophilic groups of the emulsifier. An emulsifier with a HLB number below 9.0 is lipophilic in character and one with a HLB number above 11.0 is hydrophilic. Those in the range of 9.0 to 11.0 are intermediate. Each oil is characterized by two "required" HLB numbers, a low value for making a W/O emulsion and a high value for making an O/W emulsion. When the HLB number of emulsifier is equal to the required HLB number of the oil, the emulsion is most stable. For a multicomponent oil phase, the required HLB number is the sum of the products of the weight fraction times the required HLB number of each component. The HLB number of an emulsifier blend can be calculated in the same manner.

An emulsion system may exhibit different stability depending on the chemical structure of the emulsifiers, but the required HLB numbers of the oil phase corresponding to the most stable emulsions do not change. This principle has been applied with success in the colloid industry to formulate emulsions with desired properties.

Application Of HLB Theory To Ink Emulsification

The identity and quantity of surface active materials in the inks and fountain solutions used in the experiments reported here are not known to the investigators. However, this does not preclude a qualitative explanation of the experimental results. When more fountain solution is added to a constant quantity of ink during mixing, the HLB number of the emulsifier blend (from ink and fountain solution) shifts to a higher value and the stability of the water-in-ink emulsion changes accordingly, because the HLB number of the wetting agent in the fountain solution is greater than that of surface active materials present in the ink. Water-in-ink and ink-in-water emulsions are referred to as W/O and O/W emulsions in this paper for convenience.

In the experimental set of Ink A with FS1 (Figure 1), the ink always emulsified more fountain solution when more fountain solution was added for mixing. It follows from this result that the HLB number of this particular emulsifier blend increases toward the required HLB number, producing a more stable emulsion. Higher stability corresponds thermodynamically to more reaction product, and hence more fountain solution is emulsified. In addition to this effect, when more fountain solution is present during mixing, the ink will more rapidly emulsify fountain

solution, according to Eq. (2). The combined effects result in emulsification curves of the type shown in Figure 1.

When more FS1 was added to Ink B, this ink initially emulsified more fountain solution, except for the anomaly with the 70 ml addition. The ultimate water-pickup, however, decreased correspondingly. The explanation for this behavior is that the HLB number of the emulsifier blend shifts away from the required HLB number of the oil phase with the increase in fountain solution quantity. The stability of the emulsion and hence the amount of emulsified fountain solution decreases accordingly. The initial increased amount of emulsified fountain solution is due to the effect of fountain solution quantity, according to Eq. (2). These opposing effects account for the emulsification behavior of the type shown in Figure 2. Similar arguments apply to the other two sets of data (Figures 3 and 4).

Each ink and fountain solution combination may exhibit different emulsion stability curves because of different emulsifier blends. Figure 13 summarizes these widely varying emulsification behaviors in a single stability curve for simplicity. Inks A and B do not form stable W/O emulsions with FS2, but may have a greater tendency toward forming O/W emulsions. This behavior infers that the wetting agent of the neutral fountain solution has a higher HLB number than that of the alkaline fountain solution. This high HLB number would favor forming O/W emulsions and probably accounts for the severe bleeding encountered with these two sets during emulsification tests.

The next logical step to further verify the foregoing theory was to vary the concentration of wetting agent, keeping the fountain solution quantity constant. This approach is equivalent to varying the HLB number of the emulsifier blend in the emulsion system (as the variation in fountain solution quantity does) but eliminates the complicating effect of variable fountain solution quantity on the emulsification rate as well as maintains consistent mixing efficiency. One way of doing this is to dilute a fountain solution concentrate to different levels. The results given in Figures 7 to 10 show that the emulsification curves do not follow the same patterns as those shown in Figures 1 to 4. This may be due to the variation in electrolyte concentration, which increases proportion-

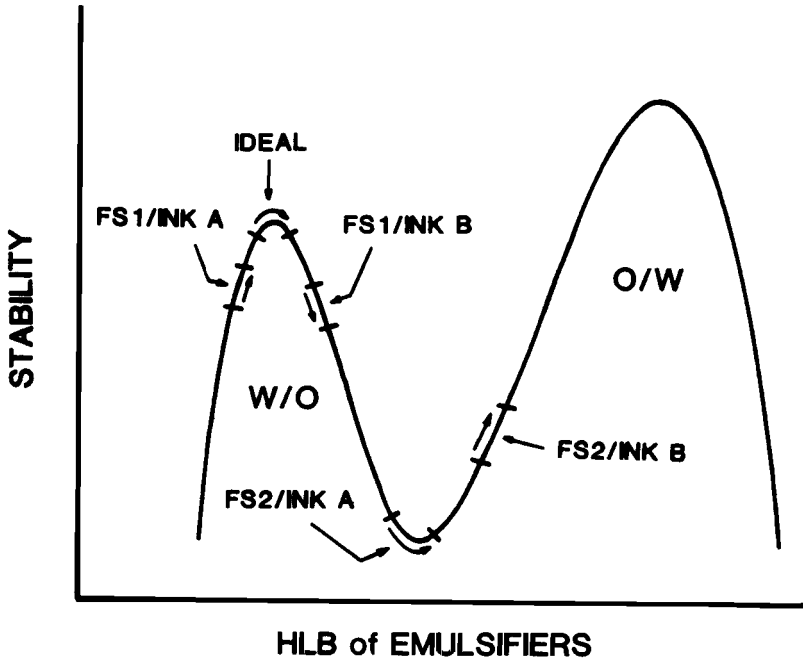


Figure 13. Correspondence of the emulsification results shown in Figures 1 to 4 with an emulsion stability curve. Arrows indicate the increasing fountain solution quantity present during each mixing stage, which is equivalent to the increasing input ratio of fountain solution to ink on a conventional lithographic press. Emulsion stability of the proposed ideal ink/fountain solution combination is almost independent of the ink/fountain solution input ratio. Hence, this combination is expected to have a wider ink-water balance latitude than the others.

ally with increasing fountain solution concentration. Electrolyte concentration is known to affect the emulsion stability as well as the "effective" HLB number of emulsifiers (Shinoda and Friberg, 1986). This effect is beyond the scope of this paper and will not be discussed here.

The complicating effect of electrolyte concentration is eliminated by increasing only the wetting agent itself, using specially formulated fountain solutions. The experimental results are shown in Figure 11 for Ink A and in Figure 12 for Ink B. Ink A always emulsified more fountain solution when it contained more wetting agent, and the reverse was observed with Ink B. These data are consistent with the HLB theory.

Application Of HLB Theory To Ink-Water Balance

On a conventional lithographic press, ink feed is regulated with ink keys according to the image format so that the amount of ink transferred to the plate varies from one location to another across the press. Conversely, the fountain solution is uniformly fed to the plate. As a consequence, the ratio of ink to fountain solution present in the form roller/plate cylinder nips, and hence the HLB number of the emulsifier blend, varies across the width of the press. Accordingly, there is a range of HLB numbers instead of a single value during conventional printing. The stability of the W/O emulsion and therefore the emulsifying ability of the ink also varies from one location to another.

When the ink and fountain solution are selected so that the HLB number of their emulsifier blend appears in a range corresponding to maximum stability, slight changes in the ink or fountain solution input do not seriously affect the emulsion stability, and the result is a wide ink-water balance latitude. If the HLB number of the emulsifier blend in the selected system deviates from the optimum value, small adjustments of ink keys or dampening setting will result in significant changes in the emulsion stability. These ink/fountain solution combinations will have a narrow ink-water balance latitude. These predictions are also explained schematically in Figure 13 in terms of an emulsion stability curve.

Many difficulties were encountered when the newspaper industry started to print with treated oil newsinks. These inks are formulated with refined mineral oils in

which aromatic compounds are reduced. The required HLB value for a W/O emulsion is 4 for both aromatic and paraffinic mineral oils (Becher, 1965), while it is 12 for aromatics and 10 for paraffins to form O/W emulsions. This small but significant difference implies that the emulsion stability for a treated oil ink is more sensitive to changes in ink or fountain solution input than that for an untreated oil ink, as shown schematically in Figure 14. An untreated oil ink may produce a reasonably stable

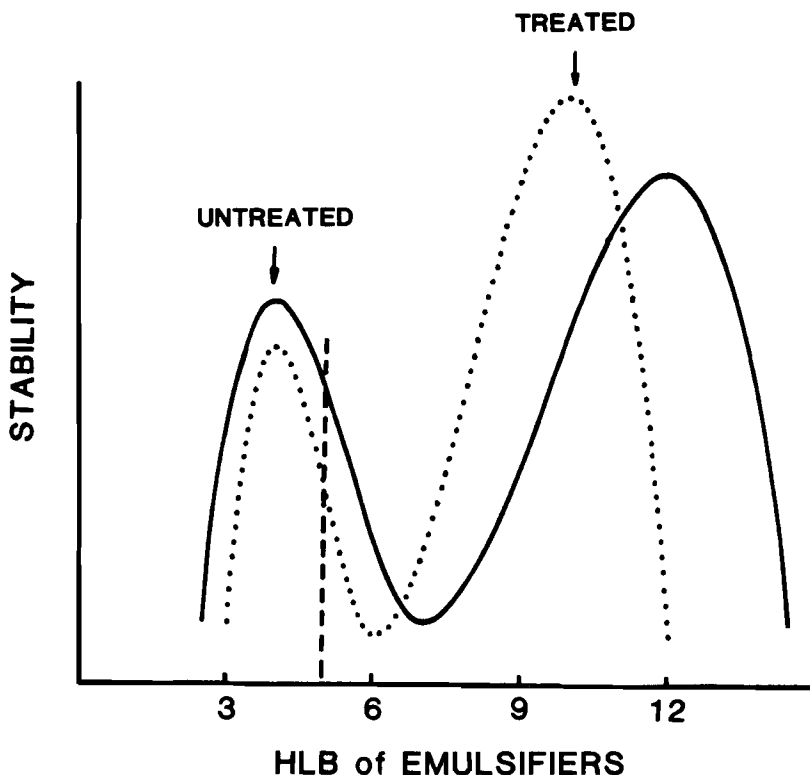


FIGURE 14. Comparison of emulsion stability of treated oil ink to that of untreated oil. Emulsion stability of a treated oil ink is more sensitive to changes in the ink/fountain solution input ratio than that of an untreated oil ink, inferring that the former has a narrower ink-water balance latitude than the latter.

W/O emulsion with a particular fountain solution and functions well on the press. The treated oil ink of similar formulation is unable to form a stable W/O emulsion, or even tends to form an O/W emulsion, and fails to print properly. It is expected that a treated oil ink will have a narrower ink-water balance latitude than the untreated oil ink.

Implications Of HLB Theory In Keyless Lithography

The development of keyless offset presses is a major research activity in the industry. A keyless press differs from the conventional in that a uniform ink film is metered to the plate regardless of the image format. The unused, excess ink which contains emulsified fountain solution is returned to an ink pan that is designed to maintain a uniform dispersion of W/O emulsion. Although the ratio of ink to fountain solution present in the form roller/plate cylinder nips remains almost constant, the keyless press prints an emulsion ink which contains more fountain solution than a conventional press does. Absence of cross press variation in ink and fountain solution inputs suggests that the HLB number of the emulsifier blend in keyless lithography should be a single value, or nearly so, at the steady state and this HLB number in keyless inking should be at the upper extreme of the range expected for a conventional lithographic process.

A marginal ink/fountain solution combination which prints acceptably on a conventional press may become a disaster on the keyless press. We had great difficulty in finding an acceptable ink/fountain solution combination for our keyless press with treated oil inks. Based on numerous tests carried out both in the field and in our laboratory (Fadner and Bain, 1987), we found that for a good ink/fountain solution combination the fountain solution content of the ink in the ink pan reaches a constant value not exceeding 30% and that the fountain solution is retained in a stable form as an emulsion at the steady state. The emulsion stability and the observed steady state condition seem to be directly related. For a poor ink/fountain solution combination, fountain solution content of the ink in the ink pan increases almost linearly without levelling off. Free fountain solution soon appears in the ink pan and the press fails to print properly.

It is expected that because of the nearly single value

of the HLB number of the emulsifier blend existing in the roller nips of a keyless press, changes in the dampening setting will result in a more predictable and less drastic changes in the emulsion stability than with conventional lithography. It seems that if both ink and fountain solution are tailor-made according to the HLB theory, we should be able to run a keyless press more predictably and more easily than a conventional press.

CONCLUDING REMARKS

The basic HLB theory satisfactorily explains widely varying emulsification behaviors and provides a promising means to explain the ink-water balance latitude appearing on both conventional and keyless lithographic printing processes.

The HLB number of an emulsifier blend and the required HLB number of the oil phase referred to in this theory are determined at 25°C and in the absence of electrolyte. Changes in temperature and the addition of electrolyte to the emulsion system may affect the actual HLB numbers, and hence the stability of the emulsion system. It has been shown that temperature significantly affects the stability of emulsion inks (Chou and Fadner, 1986).

An extended theory (Shinoda and Friberg, 1986) referred to as HLB Temperature or PIT (Phase Inversion Temperature in emulsion) takes these effects into account and, though much more complicated, may be a better way to predict the emulsion stability of the very complex ink-fountain solution systems.

Another limitation of the HLB theory is that it only predicts the thermodynamic properties, such as the stability, of an emulsion system. It does not provide a measure of kinetic properties such as the emulsification rate constant. The modification of present methods or the development of new techniques will be required for determining actual rather than apparent emulsification rate constants and ultimate water-pickups.

We intend to extend our research to include the effects of temperature and electrolyte on the emulsion stability. The development of techniques for determining the actual emulsification rate constants and ultimate water-pickups is in progress now. Hopefully, we will be able to

correlate these findings with press performance in the near future.

ACKNOWLEDGMENTS

The authors acknowledge F. Tripp and H. Soni for their assistance in carrying out the emulsification tests.

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