THE IMPORTANCE OF RAW WATER QUALITY IN THE CONTROL OF FOUNTAIN SOLUTION CHEMISTRY

by John MacPhee*

Abstract: This paper addresses a basic variable of the lithographic process, the quality of the raw water which is used to prepare fountain solution. Experimental data is presented which shows the effect of this variable on three attributes of typical acid and alkaline fountain solutions: pH, water takeup by ink, and corrosivity. The implications that these findings have on the control of fountain solution chemistry and press performance are set forth as the main conclusions of this work. Other conclusions consist of criteria for judging when treatment of raw water is advisable and recommended methods of treatment. A review of the fundamentals of fountain solution chemistry is also included, along with the standard methods for characterizing raw water quality. In addition, the corrosivity of pure or high quality water is explained in terms of modern corrosion theory.

INTRODUCTION

The studies reported on in this paper had, as their original intent, two objectives. The first was to determine if the variability of water supplies in the United States would pose any problems in the use of a closed loop conductivity control system (Hara, 1987), developed and successfully used in Japan for maintaining fountain chemistry on newspaper presses. (This was not of concern in Japan because the water supplies are soft.) The second objective was to develop basic information on the interaction between raw water quality and fountain solution chemistry, so as to become better equipped to advise printers on fountain solution handling systems and the related question of the need for water treating equipment.

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Guided by these original objectives, the study was initiated with a review of the fundamentals of raw water impurities and fountain solution chemistry. The material collected in this first phase is presented in the immediately succeeding section, entitled Background Information. This groundwork identified three possible areas of concern which were next investigated in a series of experiments: the effect of raw water quality on fountain solution pH, ink water takeup, and corrosivity. Separate sections are devoted to presenting the data so obtained. A literature search and inquiries were made on possibly adverse affects of poor raw water quality on printing and these results are summarized in a section immediately preceding the last section on conclusions.

BACKGROUND INFORMATION

Characterization of Raw Water

The term raw water is used herein to denote the water that is received by an operating entity (such as a printing plant or private home) from the water supply system. In the case of printing plants, the supply system can range from rivers or private wells to municipal water companies. Thus raw water quality can and does vary tremendously from one printing plant to the next. Because of this it is important to identify the various types of impurities which may be found in water, and this is done in Figure 1, based on a review of several texts (Camp and Meserve, 1974, American Water Works Association, 1971; and Smethurst, 1979). A variety of techniques are used to analyze the impurity content of raw water and the reader is referred to the American Society for Testing Materials for information on recommended procedures. Table I lists some typical test results obtained by a licensed public health laboratory and a municipal water company laboratory from three water samples, two of which were extremely hard. The measurement of turbidity reflects the presence of coarse susupended or undissolved solids; color, the presence of colloids; while the conductivity measurement and the five entries below it provide certain details about dissolved solids. The ABS entry reflects the presence of a frequently encountered liquid impurity (detergents), and coliform count provides a measure of bacteria present. Although not reported, all samples most likely contained dissolved oxygen (at the saturation level of 7ppm) and some dissolved carbon dioxide. The pH readings for all are slightly above 7.0 which is common for natural waters and reflect the presence of a salt of a weak acid and a strong base - in this case calcium bicarbonate.

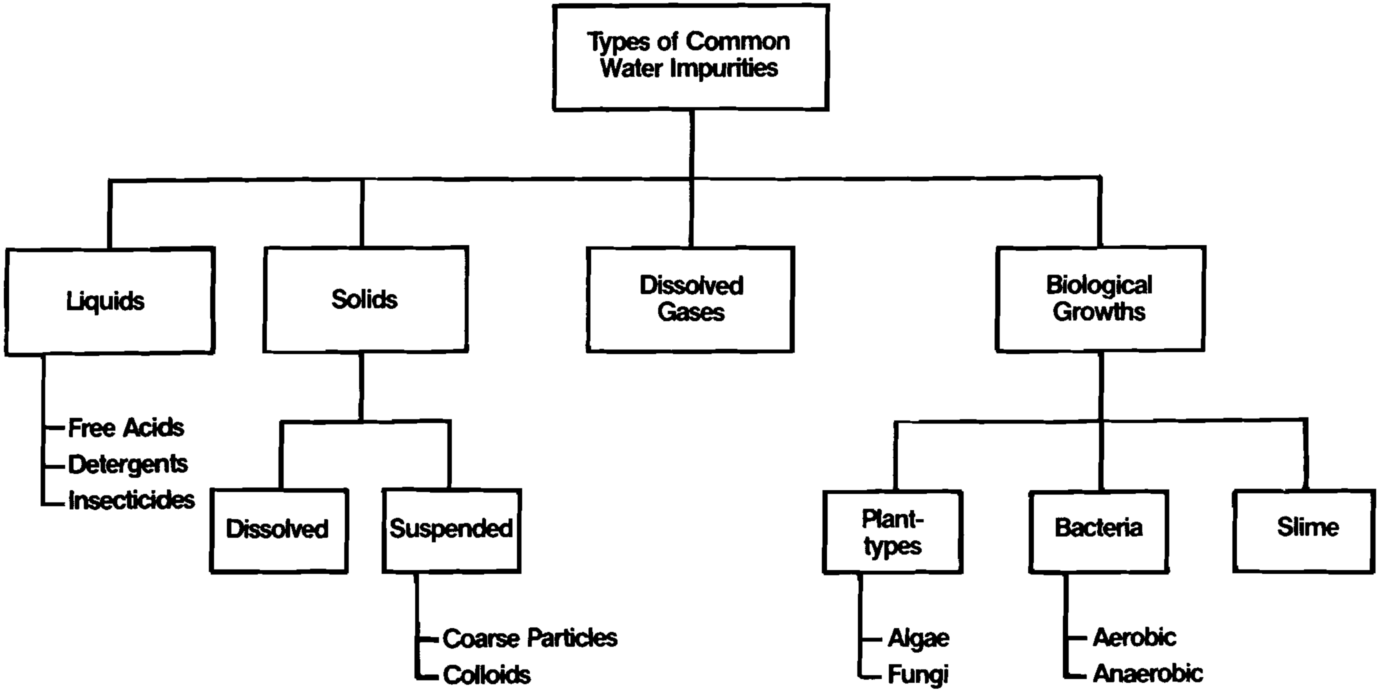

Figure 1 Classification of Impurities Found in Raw Water

Table I Some Representative Results from the Analysis of Three Raw Water Samples Carried Out by a Public Health Laboratory

	Stamford Connecticut Tap Water	Los Angeles Area Tap Water	Chicago Area Well Water
Color	2	4	4
Odor	1	1	1
Turbidity	0.6	0.67	0.72
pH	7.4	7.65	7.60
Conductivity (umhos/cm)	170	1040	1440
Total Dissolved Solids (ppm)	99	636	977
Chloride (ppm)	62	302	94
Sodium (ppm)	36	195	59
Alkalinity (ppm $CaCO_3$)	48	244	440
Total Hardness (ppm $CaCO_3$)	48	524	944
ABS	0	0.13	0.13
Coliform Colonies (per 100 ml)	none	none	> 200

Insofar as the lithographic process is concerned, the dissolved solids are of utmost importance and will be used to characterize water for printing. The reason for this is that suspended solids are generally not a problem and biological impurities usually can be controlled through good housekeeping (i.e. periodic flushing and cleaning) and/or the use of germicides or U.V. lamps. Likewise, the dissolved gases normally encountered in water are benign to printing.

The dissolved solids in water are divided into those which do not contribute to "hardness" and those that do. In general the latter comprise various salts of calcium and magnesium. They are undesirable in everyday life because the hardness they impart to water produces insoluble compounds (scale) and impedes the detergent action of soap. One might logically speculate that similar objections would arise in printing.

One very important point to note is that there are two types of hardness; temporary, produced by bicarbonate salts, and permanent, produced by sulfates and to a lesser extent the chlorides and nitrates of calcium and magnesium (Ehret, 1946). These salts are dissolved by the water in its passage over and through the soil. Although limestone (calcium carbonate) is very insoluble in water, it interacts with the carbonic acid contained in all natural waters, to produce calcium bicarbonate, which is quite soluble. The entries in Table I for total hardness are a measure of all the salts present of magnesium and calcium while alkalinity is a measure of the bicarbonate and hydroxide ions. Both are expressed in terms of that weight of calcium carbonate which is chemically equivalent. The various units of hardness used, together with the appropriate conversion factors, are given in Table II (Anonymous, 1976).

Table II Conversion Factors for Various Units Used to Measure Water Hardness

To Convert	To				
	Parts per Million	Grains per U.S. Gallon	Clark Degrees	French Degrees	German Degrees
	Multiply By				
1 part per million	1.0	0.058	0.07	0.10	0.056
1 grain per U.S. Gal.	17.1	1.000	1.20	1.71	0.958
1 Clark degree	14.3	0.829	1.00	1.43	0.080
1 French degree	10.0	0.583	0.70	1.00	0.560
1 German degree	17.9	1.044	1.24	1.78	1.000

There are no standards in the U. S. for hardness levels. However a level above 200 ppm seems to be generally accepted as the border between "medium" and "very hard". For example, Hamilton quotes a figure of 180 ppm from the U.S. Geological Survey (Hamilton, 1983) while Sonderman (Sonderman, 1967) suggests a figure of 220 ppm, which will be assumed here. Similarly, water with a hardness below 50 ppm will be taken as "soft". In the absence of laboratory facilities for analyzing hardness, paper test strips are available from suppliers of chemical supplies. In the absence of both, a conductivity meter can be used to obtain a rough (and conservative) estimate. This is based on two observations: the relationship between conductivity and total dissolved solids as reported in two differenct references (Kemmer, 1988 and Camp, 1974) is approximately 1.5 for a representative number of U.S. water sources, and the previous discussion brought out that total dissolved solids represents an upper limit on hardness. Thus the rough ratings given in Table III can be derived.

Table III Approximate Hardness Ratings for Raw Water

Range in Total Dissolved Solids (ppm)	Conductivity Range (umhos/cm)	Upper Limit on Relative Hardness
0-50	0-75	Soft
50-220	75-330	Medium
Above 220	Above 330	Hard

Chemistry of Fountain Solution Concentrates

For many many years now, U.S. printers have used commmercial proprietary formulations as the basic ingredient in fountain solution. These formulations, in liquid form, are mixed with water in concentrations generally ranging from 1-5 ounces per gallon to produce press-ready fountain solution. Most commercial printing is carried out with acid type formulations while newspaper and others who print on uncoated paper use either neutral or alkaline types. The emphasis in this section will be on acid types.

A. The Role of Fountain Solution in Lithography. Three of the more important conditions which must be satisfied in order for the lithographic printing process to succeed are as follows:

1. The ink and fountain solution must be formulated such that the ink will have a capacity to take up some (but not too much) water.
2. The image surfaces of the plate must have greater adhesion for ink (compared to fountain solution), when placed in the presence of ink and fountain solution.
3. The non-image surfaces of the plate must have greater adhesion for fountain solution (compared to ink), when placed in the presence of ink and fountain solution.

Condition #1 reflects the fact that ink and water must be compatible if they are to work together to achieve top performance. Thus one essential measure of a given fountain solution is the degree to which it can be emulsified into the ink. Condition #2 can be paraphrased as the image surfaces or areas of the plate must love ink more than water, whereas Condition #3 states that the converse must be true for the non-image surfaces.

The key element in the above is Condition #3 because most materials used for plates are somewhat ambivalent about ink and water. In other words most solid materials have a strong liking for greasy fluids (like ink) and therefore have a hard time making up their mind whether they should love water more than ink, when both are present. For this reason, Condition #3 is the most difficult to achieve in practice. Generally, to get around this problem, the non-image surface is produced during platemaking by depositing a thin layer of a desensitizing agent (like gum arabic) onto the metal surface of the plate. Although most modern plates will run for a while using only water as the fountain solution, the desensitizing agent applied during platemaking gradually wears away during printing and failure will occur if ingredients are not included in the fountain solution to maintain or replenish the desensitizing agent. This then can be taken as the primary role of fountain solution concentrates.

B. Acid Type Fountain Solutions. Until the early 1970's, all fountain solutions were of the acid type and generally contained two basic ingredients: a weak acid and a water soluble gum. Starting with Senefelder (Senefelder,1818), lithographers have discovered that the particular compounds which perform best are phosphoric acid and gum arabic. Either one of these, used by itself, functions reasonably well to maintain desensitization but the combination works even better. The generally accepted explanation for this is that the gum is acidified by the phosphoric acid and the resultant arabic acid is more strongly bonded to the non-image areas of the plate (Ostrander, 1986). Although phosphoric acid and gum arabic continue in popularity, there are reasons why other compounds are sometimes used instead. For example, phosphate ions were discovered to poison the catalysts used in some systems to reduce the emission to the environment of the volatile organic compounds released in web heatset dryers. As a result, citric acid is currently used in many concentrates formulated for use on web heatset presses. As for the gum component, some suppliers prefer to use synthetic gums because of better consistency in quality. (Gum arabic is a natural compound and therefore the quality and purity of the raw material varies with seasonal conditions.)

In addition to the basic ingredients of gum and acid, other compounds are added to acid type fountain solutions. These generally include a nitrate salt to condition the plate metal (Hartsuch, 1961, and Bruno, 1987) and other salts to buffer the solution. Additional ingredients may include germicides and the like to control biological growths, corrosion inhibitors, and surfactants to improve spreading and/or to achieve a given water takeup by the ink.

Fountain solution concentrates include buffering agents to stabilize the pH of the final fountain solution mix. The degree to which buffering is effective in counteracting variations in concentration is illustrated in Figure 2. Later on, more will be said about this effectiveness viz-o-viz changes in raw water alkalinity.

C. Alkaline Type Fountain Solutions. Alkaline type fountain solutions came to the fore in the early 1970's, for use on newspaper presses, where they are the popular choice today in the U.S. and Japan. (In contrast, acid type fountain solutions are generally used by Canadian and European newspaper printers.) It is the author's recollection that the original impetus behind alkaline types was the reduction of biological growths and of roller stripping, both of which were problems on early offset newspaper presses. It has also been claimed that alkaline solutions eliminate the need to gum plates during a stop, but an investigation by the author (MacPhee, 1987) failed to substantiate this.

It is not possible to discuss in detail the makeup of alkaline fountain solutions because so little about them has appeared in the open literature. One singular reference (Blom, Wilhelmi, and Bratley, 1978) states that many contain phosphate salts. Some formulations may also include gum but the efficacy of gums in high pH solutions is questionable.

D. Neutral Type Fountain Solutions. As the name suggests, this class is designed to produce a near-neutral (7.0) pH fountain solution. Except for patents, the literature is also sparse on the ingredients of this fountain solution type. One patent (Canale and Papazian, 1983) indicates that phosphate salts are an ingredient here as well. A novel two-part near-neutral fountain solution was developed in the 1970's (Lipovac, 1978) which did not contain any phosphate ions, but did employ gum arabic. So far as is known, this latter formulation has not gained acceptance in the industry.

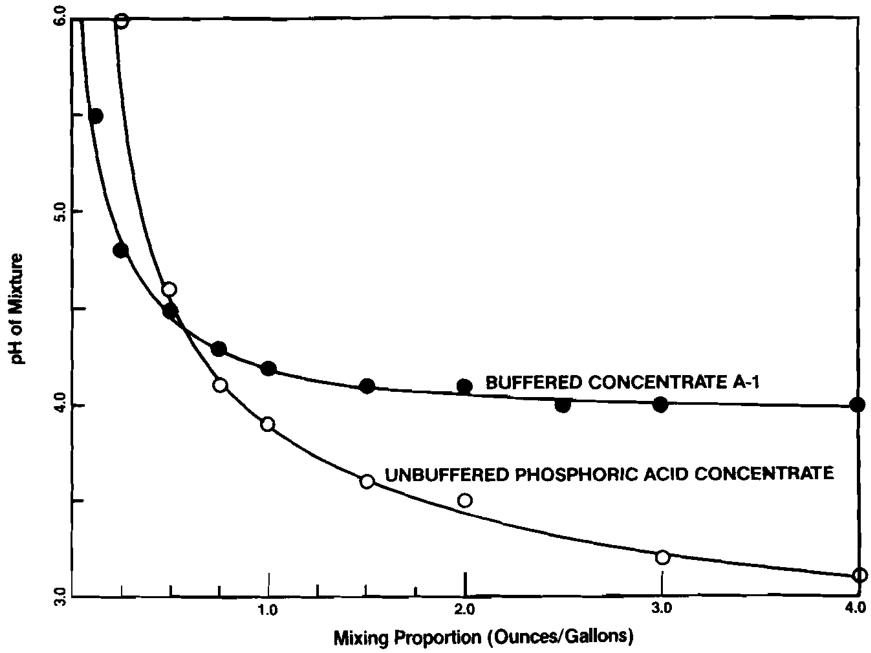

Figure 2 Effect of Buffering on Shape of Curve of pH versus Concentration. Buffered concentrate is commercial formulation A-1 listed in Table III. Unbuffered mix only contained phosphoric acid.

EFFECT OF RAW WATER QUALITY ON FOUNTAIN SOLUTION pH

Lithography is a chemical process. For this reason fountain solution pH is an important parameter and should be maintained at the level which is optimum for the particular ink and fountain solution selected. For example, with acid type fountain solutions, too low a pH may lead to ink drying problems (with sheetfed inks) and premature plate wear, while too high a pH causes a weaker bonding of the gum to the non-image areas. Although the use of buffering agents in modern fountain solutions has helped to reduce pH disturbances, the experience of several printers suggested that variations in raw water quality might be the cause of pH variations seen by them. Accordingly, the experiments reported on here were designed.

The concept employed was to prepare samples of varying water hardness. A fixed amount of a given concentrate was added to each sample and the pH and conductivity of the resultant

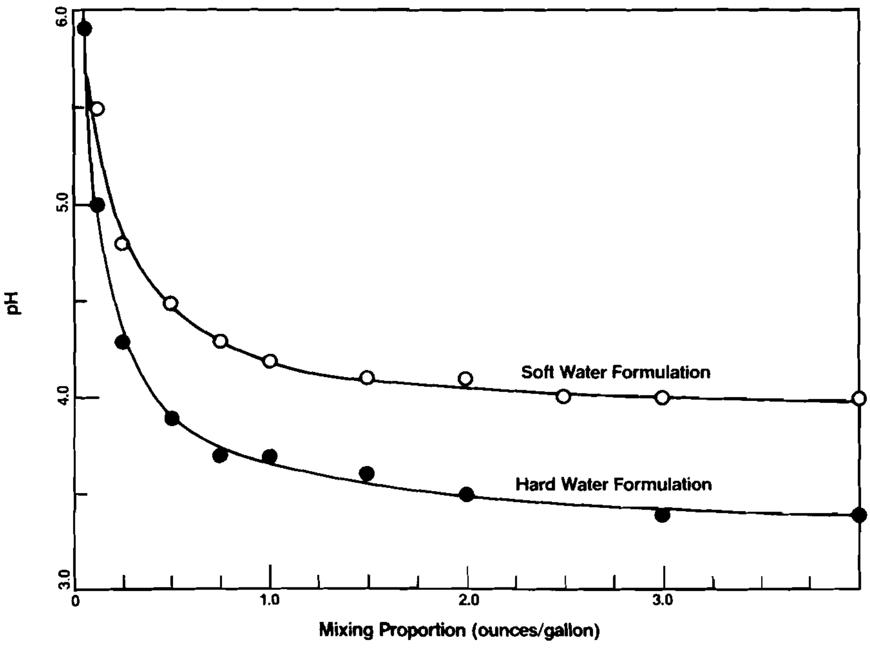

Figure 3 Fountain Solution pH vs Concentration for Two Different Concentration Formulations Mixed in Stamford Tap Water

Table IV List of Commercial Concentrates Tested

ID Number	Type	Formulation	Recommended Mixing Ratio (ounces/gal)	pH of Concentrate	Treated Water Mix*		Chicago Water Mix*	
					pH	Conductivity	pH	Conductivity
A-1	Acid	For soft water	1-2	3.6	3.9	1400	5.8	2400
A-2	Acid	For hard water	1-2	3.0	3.4	1475	5.2	2325
B	Alkaline	-	1-2	12.1	11.2	1910	8.5	2200
C	Neutral	-	2	6.5	6.7	900	6.6	1880
D	Acid	-	3-6	3.0	3.4	1720	5.0	2450
E	Acid	-	1-2	1.9	3.1	920	5.9	1600
F	Acid	-	1-3	2.7	3.1	2050	5.8	2800
G	Acid	For medium water	1 ½ -2	1.9	3.5	1700	5.9	2780
H	Acid	For hard water	1 ½ -3	2.4	3.0	1400	3.9	2100
I	Acid	Phosphate free	3-4	3.3	4.3	2200	6.1	3000
J	Acid	Phosphate free	2 ½	4.2	4.6	1300	5.5	1900

* Mixing ratio was average of recommended value.

fountain solution was measured. A total of eleven different concentrates, listed in Table IV, were tested. These included nine acid types and one each of a neutral and alkaline type. The first two concentrates listed in Table IV are examples of formulations tailored by a supplier for use with waters of different hardnesses. The shape of the pH vs concentration curves for these two samples, from the same manufacturer, are given in Figure 3.

The water samples were prepared by mixing different proportions of treated water (10 umhos/cm) with extremely hard water from the two different sources given in Table I. Figure 4 shows two typical curves obtained, using concentrate A-2 in Table IV.

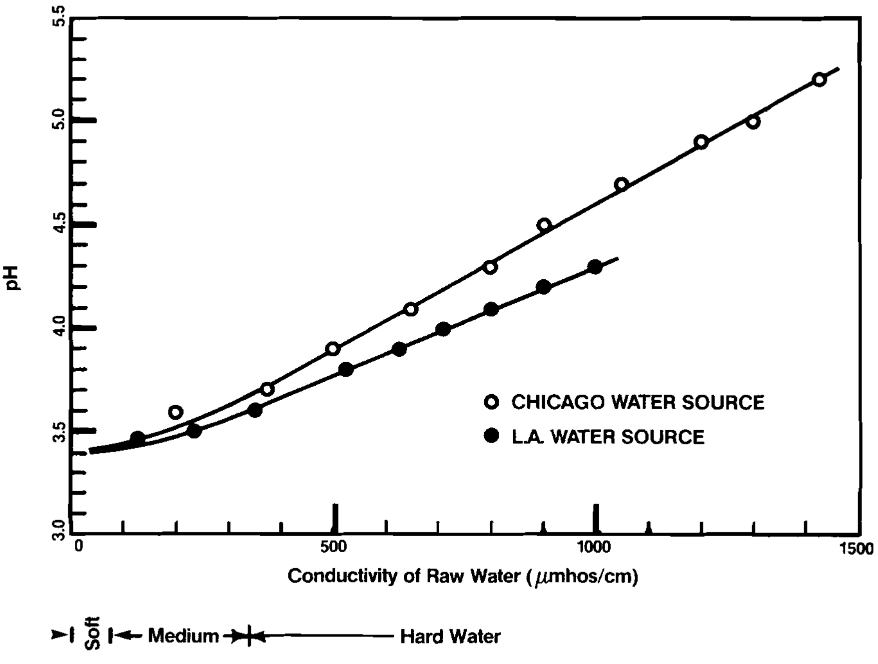

Figure 4 Effect of Raw Water Quality on the pH of a Fountain Solution Containing 1.5 ounces per gallon of an Acid Type Concentrate Formulated for Hard Water

The change in pH from treated water to extremely hard water is significant: +0.9 in the case of Los Angeles area water and +1.8 in the case of Chicago area water. The ratio of these changes is approximately equal to the ratio of hardnesses given in Table I.

This fact supports the theory that the pH change is a result of the partial neutralization of the acid component, by the bicarbonate ions in the hard water. Printers of course produce the same effect when they add bicarbonate of soda to a fountain solution that is "too hot", i.e. has too low a pH.

The corresponding result for the alkaline concentrate, listed in Table IV, is given in Figure 5. Here the effect is greater and more linear, although the hardness results in a decrease in pH of 2.7. In this case the pH change is attributed to a dilution of the phosphate ions, which comes about from the formation of calcium and magnesium phosphates, which precipitate.

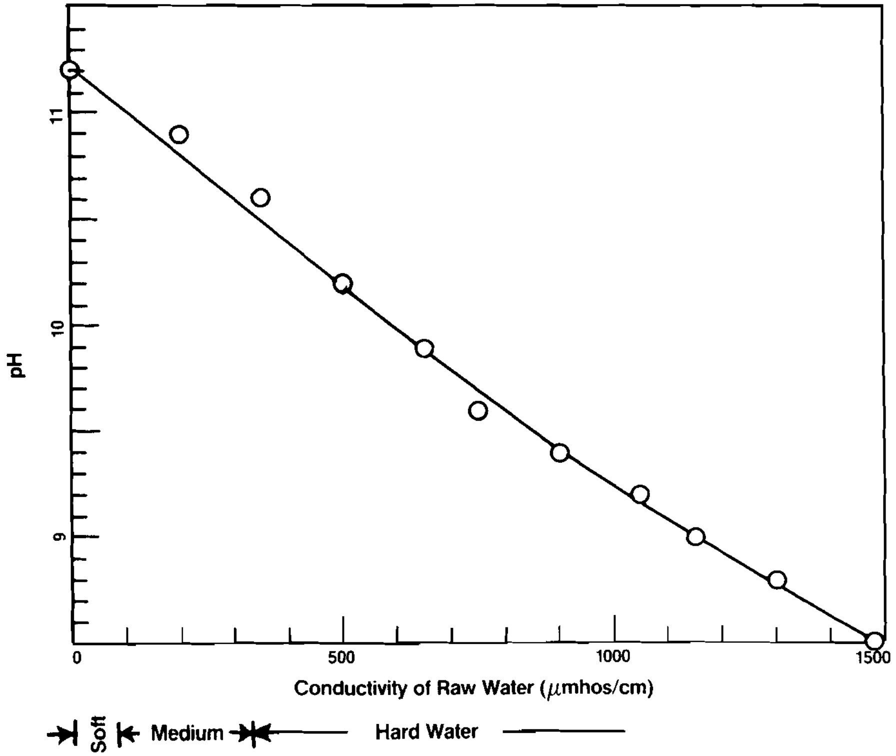

Figure 5 Effect of Raw Water Quality on the pH of a Fountain Solution Containing 1.5 ounces per gallon of an Alkaline Type Concentrate

The results for all of the concentrates tested are given in bar chart form in Figure 6. The only fountain solution which did not respond in pH to water hardness is the neutral type. However, because this type also appears to be phosphate based, it may well be diluted by the formation of insoluble phosphates.

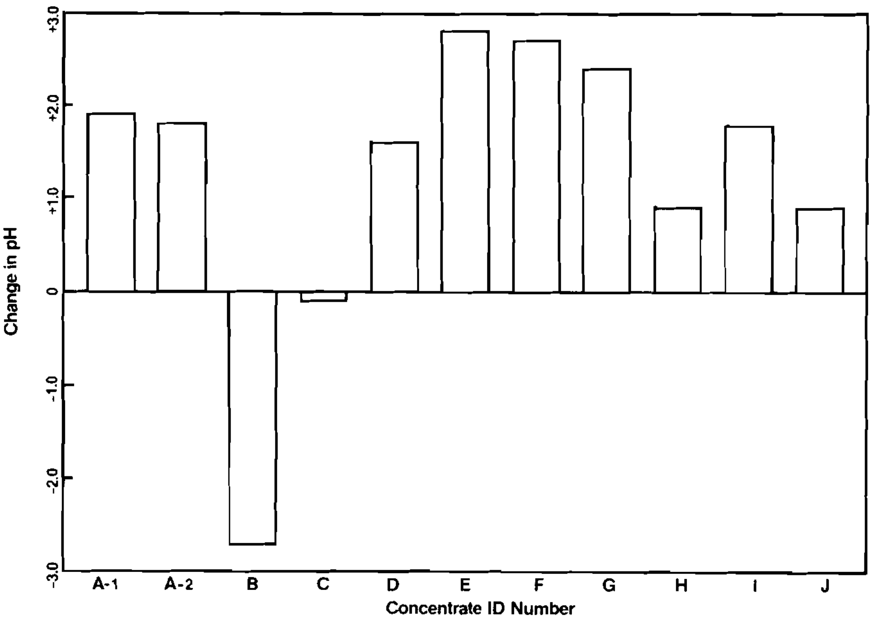

Figure 6 Bar Chart Showing Change Produced in Fountain Solution pH When Switching from Treated Water to Very Hard Water (1425 umhos/cm)

EFFECT OF WATER QUALITY ON WATER PICKUP BY INK

In addition to its role of maintaining densensitization of the non-image areas of the plate, fountain solution must emulsify into the ink to some degree. Surland has pointed out (Surland, 1980) that the degree to which this occurs is very important because if not enough fountain solution is emulsified or taken up by the ink, water marking or snowflaking will occur; while too much takeup leads to scumming problems. For this reason it was decided to run tests to determine if water takeup is a function of water quality. This was done using Surland's method and the Duke Tester. Two series of tests were run: the first using a black sheetfed ink in daily use at GATF, and the second using a black news ink obtained from a newspaper printer.

In the first series four different waters ranging in conductivity from 10 to 1440 umhos/cm were tested. No discernible difference was noted in the water takeup curves. The measurements for the softest and hardest waters were repeated with two ounces per gallon of an acid type fountain solution concentrate added. This resulted in a ten percent reduction in water takeup for the soft water mix and a ten percent increase for the hard water mix. Water takeup after ten minutes, in grams of solution per 100 grams of ink is given in Table V for this first test series.

Table V Results of Water Takeup Measurements Using a Production Sheetfed Ink

Water Characteristics		Type of Fountain Solution Concentrate	
Source	Conductivity	None	Acid
Treated	10	104	93
Danbury	520	102	Not Measured
Los Angeles	1040	104	
Chicago	1440	104	114

In the second series of tests involving a news ink two different waters (distilled and very hard) and three different type fountain solutions (acid, alkaline, and neutral) were explored. Here the results were quite different: water takeup increased 50-70 percent when the very hard water was substituted for distilled water. Surprisingly, the water takeup differences between acid, neutral and alkaline fountain solutions were much less. The amounts of water takeup, after ten minutes, obtained in this second series are given in Table VI, in grams of solution per 100 grams of ink. As in the first series, the curves all had the same general shape.

Table VI Results of Water Takeup Measurements Using a Production Black News Ink

Fountain Solution		Distilled Water	Chicago Area Water
Type	oz./gal.		
None	-	50	86
Acid	2	46	Not measured
Neutral	2	54	Not measured
Alkaline	1.5	58	84

EFFECT OF RAW WATER QUALITY ON THE CORROSIVITY OF FOUNTAIN SOLUTION

From time to time, there have been instances where press components have corroded badly as a result of being splashed or wetted with fountain solution. In spite of this, no information has been published on the part played by fountain solution concentrates in this problem. Likewise, no information was available on the extent to which the presence, or complete absence, of dissolved solid impurities would affect the corrosion rate of fountain solution. This latter point was of concern in deciding whether or not to use treated or pure water to make fountain solution, in view of the established fact that ultrapure water can be highly corrosive under certain conditions. To investigate these questions, the corrosion rates of two steel alloys were measured in different waters and fountain solutions.

The technique employed for measuring corrosion rate is known as the polarization resistance method. In this method, two electrodes of the material to be investigated are immersed in the corroding fluid and a small DC voltage is applied across them (Marsh, 1968). The polarity of the voltage is reversed and the corrosion rate is determined from the magnitude of the potentials and measured currents. The advantage of this method is that a measure of corrosion rate can be obtained in a matter of hours.

The data reported on here was obtained using a Model 9030 Corrater, which is an instrument designed for measuring corrosion rates and which is manufactured by Rohrback Cosasco Systems of Sante Fe, California. In all, three materials were tested: 1018 steel, 4130 alloy steel, and copper, 110 ETP Commercial Pure. The test rig consisted of a two liter reservoir exposed to the atmosphere and which contained a small immersion pump. The pump was connected to a line containing a tee for mounting the test probe, which held the electrodes. Fluid was circulated through the line and back into the reservoir at a velocity of approximately 14 feet per minute past the electrodes. After each test, the electrodes were removed and mechanically cleaned of scale.

Table VII presents some typical results obtained. Although not enough tests were run to generate confidence in the absolute corrosion rates measured, these results do show the relative effects of the different waters and of the chemicals used in the various type fountain solutions.

Table VII Results of Corrosion Rate Measurements in mils/year

Environment		Material		
Water Source	Type of Concentrate	Mild Steel	4130 Steel	Copper
Treated	None	0.5	0.3	0.2
	Acid	480	*	*
Stamford	None	2.4	*	*
	Acid	555	540	1.8
	Alkaline	0	*	*
	Neutral	19	4	*
Chicago	None	12	23	*
	Alkaline	2	8	*

* Not measured

EFFECT OF RAW WATER ON PRINTING QUALITY

A survey of printers, manufacturers of fountain solution concentrates, and published literature disclosed that while little quantitative data exists, there is information suggesting that extremely hard water has an adverse effect on printing.

One printer interviewed by the author reported a decrease in ink feedback in his contact type dampeners and less tinting on brush dampened presses when he switched from hard to treated water. The earliest published report found by the author (Mitchell, 1969) reported less problems when using treated water, but no specific improvements were mentioned. An article appearing in a periodical published by a leading press manufacturer (Anonymous, 1980) states that long-term observations in print shops have shown that difficulties can arise in offset if the water hardness is above roughly 270 ppm CaCO3. The difficulties alluded to were unwanted deposits on ink and dampening rollers and filling in of halftones on the plate. In a lecture given at IFRA (Schmitt, 1987) Dr. Dieter Schmitt of E. Merck, a manufacturer of fountain solution additives recommended that printers avoid both very soft and very hard waters. He stated that very soft (less than 50 ppm CaCO3) water can aggravate ink buildup on dampening rollers, while very hard water (more than about 325 ppm CaCO3) can increase emulsification and also will promote roller stripping and the buildup of deposits on ink rollers. Cuzner also reported that water in ink emulsification as measured by Surland's method, increased when hard water was used (Cuzner, 1985).

A survey by the author of half a dozen U.S. manufacturers of fountain solution concentrates resulted in a consensus that raw water variability poses the greatest problem. All were confident that they could provide satisfactory formulations for a given water quality but readily agreed that printing problems would result if there were wide swings in the quality or hardness of incoming water. The majority of those surveyed were also in agreement that the preferred water quality was in the range of 50-200 ppm total dissolved solids.

In addition to actual experience, theoretical considerations lead to the conclusion that water containing large amounts of dissolved solids will create printing problems in the long-term. The basis for this is the finding that most of the water used in the lithographic process is evaporated in the inker (MacPhee, 1985). Thus, the dissolved solids contained in the water will be left behind in the inking system where they can form unwanted deposits on press rollers and cylinders. To gain some idea of the magnitude of these potential deposits, consider one half of a 38 inch wide web press unit running at 1500 feet per minute. Assume a consumption rate of 2.7 gallons per hour, four thousand hours per year of running time, and a water quality of 500 ppm total solids. Under these conditions, potentially over three and one half pounds of solids could be deposited each month. This is roughly equal to the solids contained in and left behind by a typical fountain solution concentrate.

DISCUSSION AND CONCLUSIONS

Based on the data and information collected during the course of the work reported on in this paper, there are a number of pertinent conclusions which can be drawn regarding the importance of raw water quality to fountain solution chemistry. First and foremost is the conclusion that, in order to control fountain solution chemistry, it is essential that the quality of the raw water used, in terms of total dissolved solids, be maintained at a reasonably constant level. The recommended limits on variability are plus minus 50 ppm total solids which is equivalent to a conductivity variation of no more than plus minus 80 umhos/cm. This finding is independent of the type of concentrate used and the method employed to control fountain solution chemistry; thus closed-loop conductivity control is feasible, so long as there is constancy in raw water quality. The logical steps behind this main conclusion are set forth below in terms of a presentation and discussion of the many other conclusions which were reached.

1. There is no question that the impurities found in U.S. water supplies enter into the chemistry of fountain solution. The clearest evidence that this is true is the fact that most manufacturers of fountain solution concentrates make two or more formulations, each of which is designed for a given range of water quality.

2. The water impurities usually of concern to printers are dissolved solids, especially those that produce hardness, that is the salts of calcium and magnesium. In general, these impurities are of concern in the short-term because they affect fountain solution pH and in the long-term because they can be left behind as unwanted deposits on press rollers and cylinders. Other types of impurities in raw water are generally not a problem either because they are easily controlled (such as by filtering or periodic flushing and cleaning) or because they are benign.

3. Constancy of water quality is important because most commercial fountain solution concentrates of both the acid

and alkaline types are formulated to produce a given pH when mixed with water of an assumed hardness level. Tests reported on in this paper show that if the hardness level of raw water deviates significantly from a given level (due for example to switching sources) the pH of the fountain solution will change by an amount large enough to cause a printing problem. More specifically, these tests indicated that a variation in water hardness of 50 ppm CaCO3 produced, on average, a pH change of about 0.1. in the nine acid type fountain solutions examined. For the given water used, this amounted to a change in raw water conductivity of about 80 umhos/cm. In the case of the one alkaline formulation tested the change in pH was 50 percent higher while it was nil for the one neutral mix.

4. Constancy of water quality is also important in that the level of dissolved solids affects the water takeup characteristics of some, but not all, inks. This provides a second reason for the recommended limits on raw water variability.

5. Suppliers of fountain solution concentrates can and do prepare formulations for use with very hard water, and which result in satisfactory printing performance. However, because the bulk of the fountain solution which is consumed is evaporated in the inker, the high solids content of very hard waters can lead to long-term problems due to the accumulation of these solids on press rollers and cylinders. (In the paper the potential rate of accumulation of such deposits was calculated to be over three and one half pounds per month per inker in a high speed web press.) For this reason it is recommended that the level of hardness be limited in water employed in printing. The recommended limit, based on available information is 200 ppm total solids. This is equivalent to an upper limit of 300 umhos/cm in the conductance of raw water.

6. No conclusions could be reached on whether some lower limit should be observed on the level of dissolved solids. One reference was found in which it was recommended that a lower limit of 50 ppm CaCO3 in hardness be adopted to reduce ink buildup on dampening rollers. Also it is known that a common European practice in treating water is to blend the treated water stream with raw water to produce a feed which has a constant finite level of dissolved solids. However, to date no coraboration for the need for such a limit has been obtained in the U.S..

7. The corrosion rates measured, especially the lower values, should not be looked upon as absolute measures of what can be

expected on press. This is because the test setup was designed to include a fixed fluid velocity so as to provide reasonably consistent results. However, actual corrosion rates on press can be expected to be higher because splashed fountain solution will corrode under stagnant conditions which will be aggravated further by alternate wetting and drying. Thus, at best the corrosion data obtained only provides a measure of trends.

8. The limited corrosion tests carried out indicate that acid type fountain solutions can be extremely corrosive to steel alloys. It was also found that the corrosivity is caused by the chemicals contained in the concentrate, rather than the impurities in the raw water. For this reason there is no cause to place limits on raw water quality, based on corrosion considerations.

9. The corrosion rates measured in treated water, obtained from a printer, were very modest, and in fact were less than the rates measured in harder waters. These results fly in the face of the known fact that ultrapure water can be quite corrosive to both steel and copper. A possible explanation for this anomaly is that the treated water tested was not pure enough (a resistivity of 0.1 megohm-cm) to be excessively corrosive. This is based on the two phenomena that are invoked by corrosion engineers to theorize why ultrapure water is corrosive. The first theory is that natural waters produce a passivating or protective film, as a result of their alkalinity and the dissolved solids they contain. Treated waters are generally acidic which, coupled with a relatively complete absence of solids, therefore leads to high corrosion rates, if a dissolved gas like oxygen is present. A second theory is centered on the fact that the half-cell potential of the corrodant is inversly proportional to the log of the ion concentration in the corroding fluid (the Nernst equation). Thus the half-cell potential, which is the force which drives corrosion, becomes extremely large when water is made ultrapure. Here again, an oxidizing agent in the form of a dissolved gas must be present for corrosion to occur. In any case the actual corrosivity of the grade of treated waters used in printing does not appear to pose a problem.

10. No exhaustive study was made of the various methods available for producing treated water. However, the results obtained in this study would indicate that all of the methods currently in use (such as mixed bed deionizers and reverse osmosis) are acceptable and that therefore, the choice should be based on economic considerations.

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