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Magnetic Water Conditioning for Control of Scaling and Biogrowth

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Abstract Research and practical tests indicate that incoming city water may be conditioned by exposure to a magnetic field, altering the crystallization habit of calcium, so as to inhibit scaling of boiler systems, pipes, valves, and processing equipment. This will result in improved efficiencies and increased life of these components. Paper and film surface scratches resulting from calcium deposits will be virtually eliminated. The magnetic water conditioning has also demonstrated inhibiting effects on biogrowth, and if proved practical. may permit significant reduction or elimination of the use of biocides and reduce maintenance requirements related to biogrowth control. This system will contribute to the reliability of the processing systems in terms of increased heat energy transfer, reduced equipment wear, reduced product damage, and reduced maintenance requirements. Secondary benefits to the reduction of calcium scaling and biological growth also includes higher boiler efficiency and more efficient silver recovery.

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Introduction

The reliability of processing equipment and systems has become a critical factor in today's service and quality oriented photofinishing industry. Maintaining at least a 90% processing reliability, meeting our service time goals and achieving optimum print quality are no longer just the goals of good business, but are prerequisites of a successful photofinishing operation.

Over the years, we have gained considerable control over the chemical processes and material transport systems. Assuming that the chemical replenishers are manufactured properly, and the chemicals correctly mixed and used, the chemical activities of most processes are predictably in control. Assuming also, that transport mechanisms are maintained and preventative programs are practiced, the transport systems also have a high degree of reliability and predictability. On the other hand, many process problems are associated with our wash water systems. These problems consume a disproportionate amount of time and resources, and cause significant damage in terms of product quality, service downtime, and material and labor costs.

The two most common and obvious problems encountered are calcium scaling and biological growth. Calcium scaling of processor rollers contributes greatly to the number of scratches seen in processed film and paper. Biological growth fouls wash water lines, drains, filters, silver recovery equipment, and chemical recycling equipment. In severe cases biological growth may interfere with normal processing and can ruin processed images.

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The objective of our studies was to determine if the harmful physical attributes of calcium scale and the growth of biological organisms could be influenced by altering the fluid environment so as to achieve some degree of control over their detrimental effects. Controlling the fluid environment in our project was accomplished by subjecting the incoming fresh water supply to a strong magnetic field in a controlled and quantifiable manner. In an effort to determine the true effect of the system on biological growth, no biocides or any of the other standard biological growth control methods were used. However, such measures are functional and are considered necessary in a system where there are specific requirements for biogrowth control such as in the ***in situ*** (ion exchange) silver recovery systems.[1]

Identifying the Objectives

Previous technical reports and trade advertising had indicated that the application of a magnetic force to water demonstrated a negative effect on biogrowth, but in practice the results were unpredictable and inconsistent. Though it would be beyond the scope of this study to determine the mechanisms of all the reactions involved, it was feasible to study the behavior of calcium carbonate crystallization and measure biological growth with accuracy. Further, it might be possible to draw some conclusions regarding the relationship of these two effects.

Absolute control of biogrowth for any sustained period of time is not practically possible, even with the use of biocides. Their growth rate is dependent upon too many uncontrollable variables. Algae, bacteria, fungi, protozoa, and rotifers are found in most processing solutions. They come from the environment and the water supply. Algae comes from the water supply, but usually cannot thrive in the processing systems due to a lack of illumination. However, bacteria and fungi grow well in the processing environment, especially in the washwater. The slime-forming bacteria is responsible for the slippery slime deposits found in the wash tanks. The biomass formed is very tenacious, gelatinous capsules which continue to increase in bulk and tends to protect the bacteria against chemical and physical agents. Protozoa comes in with the water supply and usually feed on bacteria and fungi.[2]

The growth of micro-organisms in the wash water is dependent upon the chemical composition, temperature, and pH of the tank solutions. The initial slime layer which performs an important role in supporting sustained biological growth, is primarily responsible for further bacterial colonization and the rapid, exponential growth of the biomass. Growth can thus be expected to be minimized if the slime layer is removed in a timely manner or inhibited in its early formative stages.[2] Our technical objective of monitoring the effects of magnetically treated water on biological growth focused on the crystallization characteristics of calcium carbonate. The significantly different behavioral characteristics of the crystalline forms seemed to influence the structural stability of the biomass, and consequently the slime and biogrowth were not allowed to achieve explosive levels of growth.

Experimental Conditions

It was determined that the study would be conducted at two levels, determined by the size of the photofinishing operation. A small lab would be selected for the first test so that the operational and engineering controls could be monitored and adjusted easily.

Mountain Photo (Salt Lake City, UT) provides color print finishing and some B&W services. Their water consumption requirement ranged from 3 to 15 gal/min depending on how many machines were in service. Upon achieving satisfactory and encouraging results, a larger test was established at Fotomat (Santa Clara, CA). This lab not only required water ranging up to 30 gal/min, but posed a unique engineering problem. If the results at Mountain Photo could be reproduced, it would indicate a high probability that similar results could be achieved under most conditions.

Experimental Results and Discussion

At Mountain Photo, a variable flow magnetic conditioner capable of conditioning a flow rate from 3 to 15 gal/min of water was installed on the main supply line to the processing lab. Figure 1 shows the location of the conditioner in relationship to the water system. The water is conditioned as it comes into the plant. The line then separates, part going into a cold water manifold and the rest providing feed water to the boiler. After passing through the boiler, the heated water is piped to the processing systems through a hot water supply manifold.

Prior to the installation of the conditioner, the Pako HiPak processor wash tanks were drained and washed off weekly to control biological growth. This procedure would not remove all of the growth, and the tank walls, racks, and rollers would retain a slimy film. Every two weeks, the tanks were drained and the transport racks removed, and the entire wash system was thoroughly cleansed. If these controls were not performed regularly, processor performance was affected. Biological growth would actually cause mistracking of the processor leader belts. Each cleaning process required nearly 2 hr. Once a month, chlorine bleach was used in the cleaning process. A chemical biocide was used regularly but on a limited quantity basis.

The magnetic conditioner was installed in April 1986. Since then, chlorine bleach has been used only once, in May 1986, for the purpose of cleaning out the overflow collection reservoir. The wash tanks and racks have been scrubbed only twice during the last year. The wash tanks are still drained and washed down weekly, but the biogrowth is almost completely removed by the rinsing process alone. In order to accomplish the rinsing without removing the transport racks from the machine, a water jet is used at the end of the water hose.

Prior to the installation of the magnetic water conditioner, the wash water overflow lines would become so fouled with biological growth that the tanks would risk overflow. One indication of the degree to which biogrowth activity was inhibited was apparent in these drain lines, which are now completely clear. Chemical biocides are no longer used in the processors, but are still being used in the overflow collection pans. Drains which previously plugged have not plugged since the installation of the magnetic conditioning system.

Based upon the positive indications produced during the first test, two water conditioners were installed in Fotomat, Santa Clara. This configuration of two magnetic conditioners was chosen because of engineering and cost considerations. Because of the large amount of water required at peak service, a variable flow conditioner of the required size would have cost significantly more. A single nonvariable flow rate unit would have to provide optimum magnetic conditioning over a wide range of flow rates which might affect performance efficiency. Therefore, two magnetic conditioners were used. They were installed on both cold and hot water supply lines, rather than just on the main incoming water supply line. Although the water supply to the boiler was being conditioned, the cold water supply to chemical mixing was not conditioned. This is shown in Fig. 2.

Initial analysis of the effects of conditioning indicated that the cold water unit was performing as expected. However, even though the hot water side was being conditioned, it was

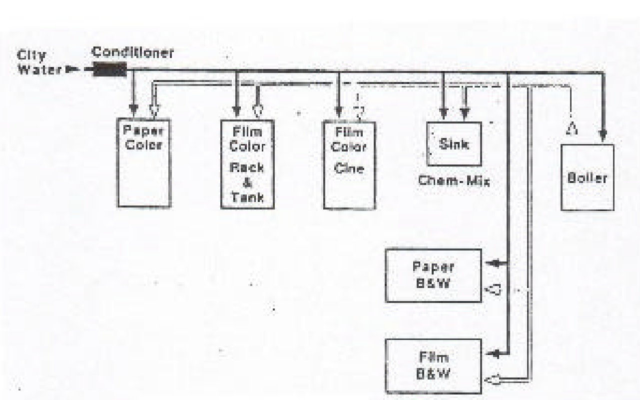

Figure 1. The water supply system at Mountain Photo

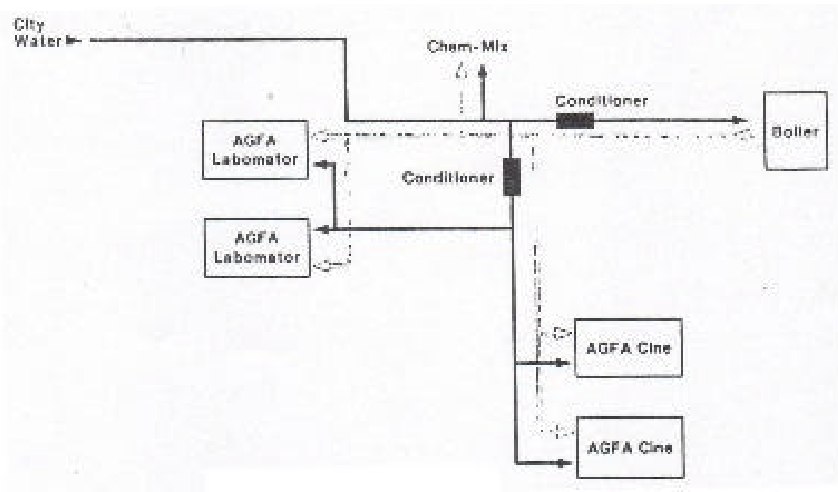

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Figure 2. The water supply system at Fotomat Santa Clara.

not producing results at the expected level. A modification was made on the magnetic conditioning unit to increase flow velocity through the magnetic flux. This change yielded the desired results. The velocity at which the fluid passes .through the magnetic flux, and the strength of the field was determined to be critical to producing predictable crystallization characteristics. Attainment of the desired crystalline habit was determined by microscopic observations.

When calcium carbonate crystals are formed from unconditioned water, they are typically composed of hard, cubic crystals and dendrites. When calcium carbonate crystals are formed from magnetically conditioned water, they have a "snowflake" appearance. The crystals are planar and very thin, and characterized by a nucleating center. The crystals in conditioned water also appear to form on nucleating centers suspended in solution, whereas crystals in unconditioned water tend to form on surfaces.

During the initial stages of the evaluation, a chemical biocide was used to control biological activity in the paper process. wash tanks during "downtime" intervals. These downtime intervals are periods of time in which processor wash tanks are held stagnant. In this condition, the water is extremely susceptible to biological growth. After the conditioning of tempered water was deemed to be satisfactory, the dose of biocide was incrementally decreased to determine if the growth inhibiting effects of conditioned water had comparable control characteristics. Even though control of the biological growth was a primary objective, as was previously stated, it could not be monitored directly. However, since protozoa were present in the wash water system, and their population was influenced by the population of the slime forming bacteria upon which they feed, a microscopic procedure to measure relative population densities of protozoa was used to monitor biogrowth potentials.

The gradual elimination of the use of biocides had no operational effect on paper processing nor maintenance requirements. Microscopic analysis of water samples did not indicate increases in biological activity. The inhibiting effects of biocide and conditioned water were observed to produce similar population levels of micro-organisms.

One of the objectives of this large scale test was to see if rack maintenance requirements could be reduced as they were at Mountain Photo. Previous practice of weekly rack cleaning in ultrasonic equipment and cleansing of wash tanks with chlorine bleach was discontinued. Again, the machine condition did not deteriorate. Regular maintenance of the processor wash racks and tanks was reduced to rinsing the equipment down with a water jet without removing the racks from the tanks. The racks were pulled only for inspection and servicing.

After about two months in this operating mode, a detailed inspection was made of the system. There were indications of biological activity, but not of the normal magnitude or severity. Timely rinsing of the racks and tanks were able to dislodge any accumulations of biological growth without labor intensive scrubbing. With unconditioned water, the slime is very tenacious and difficult to remove. With conditioned water, the calcium is transformed into micron level crystalline particulates and deposited as a microthin layer. Most of the calcium carbonate is in a colloidal suspension and passes through the system. The biogrowth cannot effectively "anchor" under these conditions and is easily dislodged with a stream of water. Although a thin layer of calcium carbonate remains after rinsing, it can be removed by hand wiping, if desired.

Inspection of the wash rollers did not indicate any calcium deposits which are primary sources of scratches. Scratches are caused by the usual hard, scale deposits, whereas the micron size crystals cannot cause scratches for two reasons. First the crystals are too small to cause scratches and have the consistency of fine talc powder. Secondly, they are not fixed to the roller surfaces and are easily dislodged under the slightest pressure. Inspection of developer racks did reveal calcium deposits on the rollers. Because installation of the water conditioners by-passed the cold water supply to chemical mixing, the chemical replenisher solutions were mixed using unconditioned water. The evaluation presented in this paper will not deal with scaling potentials in chemical tanks, but it is likely that calcium scaling may not be experienced in chemistry mixed with conditioned water. Calcium scale deposits on process rollers were reduced significantly or eliminated at Mountain Photo. This aspect was not specifically addressed at Mountain Photo, however, because the water supply there is considerably softer, and any lack of calcium scaling in the developer chemistry may have been related to the chelating activity of the chemistry as well as from mixing developer replenisher solution from conditioned water.

Calcium scale deposits on the rollers, alone, do not cause emulsion scratches. Scale deposits in an otherwise clean machine will simply cut the emulsion by indentation. The cut will probably “heal over” during the drying process. Scratches are caused when the emulsion slides over the hard, stationary particles. This condition is usually experienced when slime builds up on the rollers, lubricating the surface, reducing friction, and thereby causing the roller not to turn. This allows the sensitive photographic emulsion to slide over the stationary roller, producing a scratch.

A secondary benefit realized by the use of magnetic water conditioning was the elimination of calcium scaling in heat exchangers and other water system components. Though this study did not measure the energy transfer efficiencies, heat transfer studies have been well documented.

Summary

Within defined bands of water flow volumes, the water can be magnetically conditioned with acceptable levels of reliability. Water conditioning status can be observed by monitoring the growth patterns of calcium crystal formations. These observations will predict, with a high degree of accuracy, the level at which the desired effects can be produced repeatedly. When conditioning has been effected, calcium scaling does not occur.

Since magnetic conditioning of the water is not biocidal dependent, control of biogrowth is achieved by affecting the growth rate and colonization capabilities of the slime producing bacteria. By interfering with the ability of the bacteria to form slime on the tank walls and equipment surfaces, they can be easily dislodged and flushed from the system.

It is critical for the systems to be completely free of established bacterial colonies before the magnetically conditioned fluid environment can produce the desired effect of inhibiting the growth of bacterial colonies. Thereafter, by periodically rinsing the tank with a water jet to remove the slime that does develop, the bacterial population can be effectively controlled.

In a lab similar to Fotomat's Santa Clara operation, depending upon the extent to which maintenance is practiced, the reduction in biocide use is approximately $2000/yr. Machine downtime for maintenance is also reduced by about 6 hr/wk, and the labor required to clean and service the tanks and racks is estimated to be reduced by $1800/yr.

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