A UNIQUE METHOD TO CONTROL SETTLING OF FIRST CARBONATION JUICE

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INTRODUCTION

Operational control of the separation of clear juice from first carbonation lime sludge varies widely from shift to shift and from factory to factory. Traditionally, control has relied on a simple timed settleability test and visual observation of overflow clear juice. Lime addition and alkalinity adjustments are set to achieve optimum removal of non-sugars. Addition of an organic flocculant is typically used to compensate for short hydraulic retention in the thickener vessel or to achieve rapid recovery in an upset condition.

Nalco field work has developed customized Statistical Process Control-based software tied to a sensitive optical sensor that continuously optimizes polymer feed and alerts operating personnel when juice clarity cannot be controlled by polymer addition. This enables operators to optimize alkalinity, lime addition, flows and temperature to achieve consistent clear juice quality.

BACKGROUND

Sugar beet factories that utilize an organic flocculant in their juice clarification system typically control treatment dosage manually, relying on the visual observations and past experience level of an operator. Flocculant is added to bridge calcium carbonate and magnesium hydroxide particles and help them settle faster in a thickener vessel. Faster settling helps to alleviate hydraulic overload conditions but does not necessarily lead to an improvement in juice clarity. In fact, it is Nalco's experience that overfeed of organic flocculant typically results in a more turbid juice. The natural tendency is to feed polymer at a rate to control upset situations. This means that the polymer is typically being overfed at least 75% of the time. This "chemical crutch" also has a tendency to cover-up more serious operational problems relating to the control of lime addition, alkalinity, flows and temperatures in the carbonation process.

Factories that do not utilize an organic flocculant on a continuous basis typically do not wish to establish this chemical crutch mentality–relying instead on well-trained operators and well-established operating procedures to alleviate juice clarity problems.

Nalco field work has indicated that these factories too may benefit from a well-controlled continuous polymer program to improve thin juice quality by reducing the amount of calcium carbonate and/or magnesium hydroxide particles not readily noted with the naked eye in the clear juice.

OPTICUS® SYSTEM

The Nalco Opticus W7000 System is a microprocessor-based controller designed to control and optimize chemical treatment dosage in a variety of clarification and sludge thickening processes. It features an auto-tuning, proportional-integral-derivative controller. In its simplest feed-back form, it accepts a 4-20 mA input signal from the clarification process–typically clarifier overflow juice suspended solids–and controls that parameter by supplying a varying 4-20 mA signal to the flocculant feed pump. Nalco has also utilized the optional feed-forward input of thickener influent flow rate to allow the controller to respond more quickly to process changes.

The Opticus W7000 System consists of the controller, transmitter, and clear juice suspended solids optical sensor. The controller and transmitter are enclosed in 316 stainless steel, dustproof/waterproof cabinets--making them suitable for installation in the beet sugar factory. The optical sensor consists of a 2-in. stainless steel, flow-through unit that is installed in a representative slip stream flow of clear juice. The clear juice sample should be foam free and contain as few entrained bubbles as possible. The clear juice sample flow typically requires less than 1 gpm past the flooded sensor. The sensor is the only wetted component and tolerates the temperatures associated with the clear juice with no problem.

FEED-BACK CONTROL

The basic principle of the Opticus W7000 System is to change the feed rate of the flocculant by measuring and controlling the suspended solids in the clear juice. Upon start-up, the system automatically generates a dosage response curve (Figure 1) and stores it in memory. This response curve is periodically automatically updated and the latest version is stored in memory. The operator selects the clear juice suspended solids setpoint to achieve optimum clear juice quality and mud thickness. If the setpoint is within the responsive dosage range of the curve (Figure 1), an auto-tuned proportional-integral control occurs. If the set point is too low, the Opticus System will increase dosage until it can no longer find correlation with lower levels of suspended solids. It will then reduce the dosage until the clear juice suspended solids begin to increase. The Opticus System will now control around the knee of the new dosage curve.

The highly sensitive optical probes have proven to be able to detect even the slightest change in juice clarity. The scale-forming nature of the clear juice requires that Opticus be cleaned regularly. Nalco has been successful at minimizing maintenance by utilizing a wash option that automatically washes the optical sensor with fresh water for 10 seconds every five minutes. Nalco also has instituted a simple acid wash of the optical sensor by an instrument technician every two weeks to maintain performance.

OPERATING RESULTS

Nalco has six Opticus Systems in operation in five beet sugar processing factories in the Midwest. Initial data indicates significant reductions (40-

70%) in flocculant consumption in factories that relied on the flocculant to increase hydraulic throughput in conventional thickener systems. Nalco has achieved reductions (15-55%) in flocculant usage in factories using another thickener system. One factory that utilizes a different thickener system has not been able to substantially reduce flocculant dosage without adversely effecting lime mud thickness and deteriorating lime mud dewatering on vacuum drum filters.

Nalco field experience with Opticus Systems has demonstrated a strong correlation between control of lime addition and alkalinity to the relative clarity of first carbonation juice. Since raw juice is typically 82-87% water, Nalco decided to explore the similarities of the beet sugar carbonation process and the hot lime softening water conditioning process. With better control of lime and and by adding carbon dioxide, the typical factory can reduce lime mud handling costs, reduce the potential for evaporator scaling and produce a better quality thin juice (Figures 3-8).

Nalco has observed that high pH juice may contain less non-sugars, but is typically higher in lime salts due to the calcium carbonate converting to soluble calcium hydroxide above a pH of 10.2. This high pH juice may still be within the alkalinity specifications set for the process, but it is the wrong alkalinity species for optimum limesalts removal. This change in the ratio of hydroxide to carbonate alkalinity increases the solubility of the calcium ions and hinders settling characteristics of the juice.

Suspended solids that leave the clarifier with the clear juice and are observed by Opticus' optical sensor are typically expected to be removed on the second carbonation filters. This is not necessarily true, however, since a substantial portion of these suspended solids are calcium carbonate crystals. As these crystals pass through carbon dioxide gas blowers, carbonate is converted to bicarbonate and the crystals dissolve–allowing the calcium to pass through the filters. This situation increases the lime salts in the thin juice which increases the potential for scaling in the juice heaters and the evaporators.

In the beet sugar factory, it is a widely accepted fact that the primary function of the first carbonation process is to remove the non-sugars from the raw juice. The addition of lime raises the pH of the raw juice to a level that forces calcium to precipitate as the carbonate salt and magnesium to precipitate in its hydroxide form. Organic and suspended inorganic non-sugars then are removed by adsorption on the insoluble hardness salts.

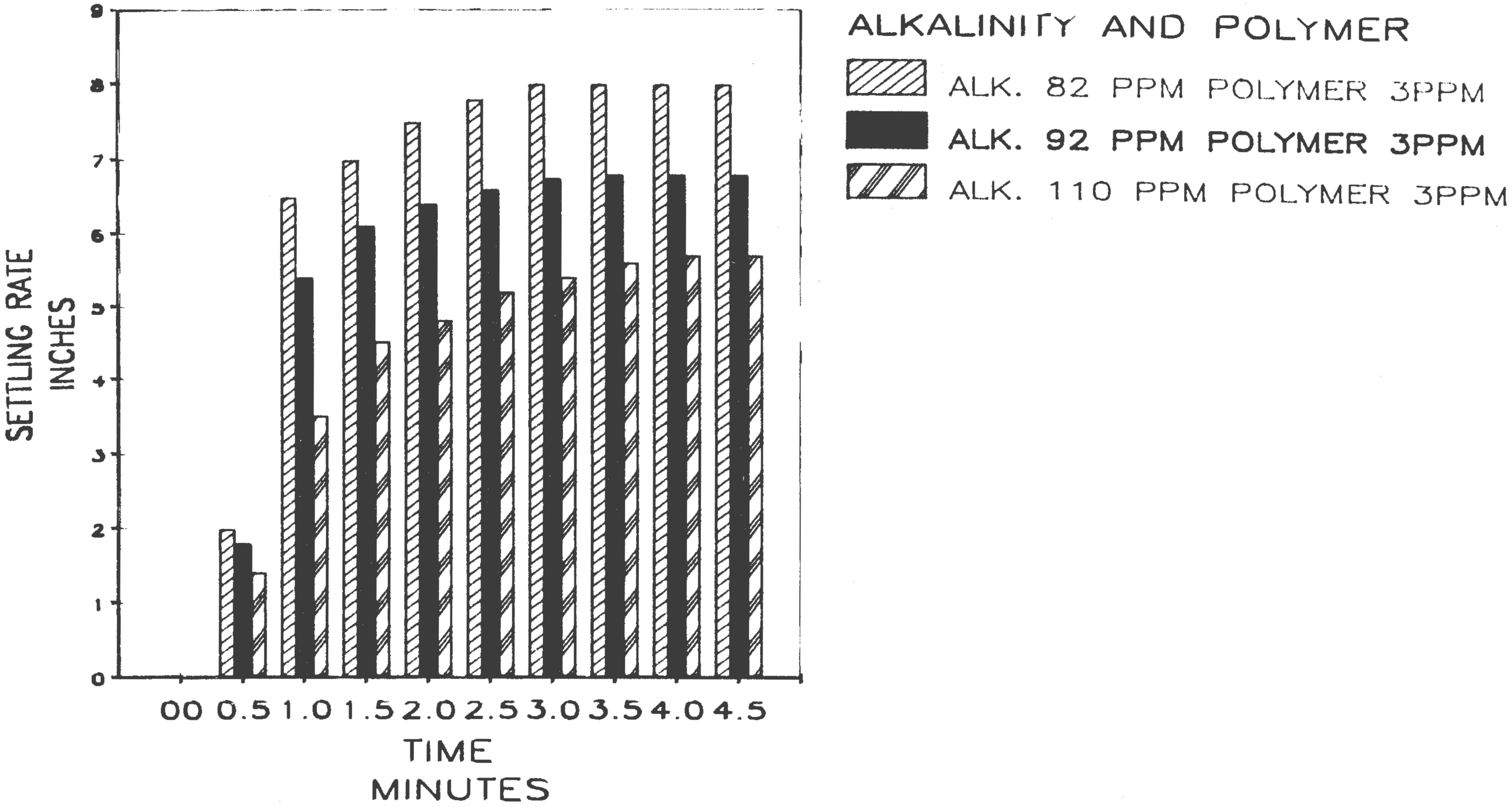
For these hardness (lime) salts to precipitate, the proper alkalinity species must be present in the raw juice. This is a function of the pH of the juice. Figure 2 shows the relative concentration of the various alkalinity species at different pH. The conversion of bicarbonate to carbonate continues until pH 10.2 when all the bicarbonate is converted. As more carbonate is produced and the pH approaches 10.2 more calcium can precipitate. Above pH 10.2, free hydroxide persists and can precipitate with magnesium. Calcium does not precipitate as calcium carbonate below pH 8.2 and magnesium is not removed in appreciable amounts below pH 10.2.

Problems arise in first carbonation due to the historical practice of adding as much lime as the carbon dioxide capacity will allow. This is done to provide as many particles of calcium carbonate as possible for the organics and suspended particles to adsorb on. Control is based on maintaining an alkalinity range that can be changed by adjusting either milk of lime feed or carbon dioxide gas feed. While it is true the alkalinity may be within specification its species may not be optimum for lime salts removal or settling.

Nalco is currently working with its customers to improve the testing and control procedures for specific alkalinity species and to reduce the amount of lime used in the carbonation process. In addition to the apparent cost reductions from using less flocculant, the aforementioned factories also have been able to benefit from a more consistent quality of clear juice--resulting in reduced scale formation in juice heaters and evaporators, reduced maintenance and replacement costs, and improved energy efficiencies.

FIGURE 4

1st CARBONATION JUICE SLUDGE SETTLING PROPERTIES EFFECTS OF VARIATION IN ALKALINITY AND POLYMER DOSAGE



TEMPERATURE OF ALL SAMPLES = 85 C

FIGURE 4

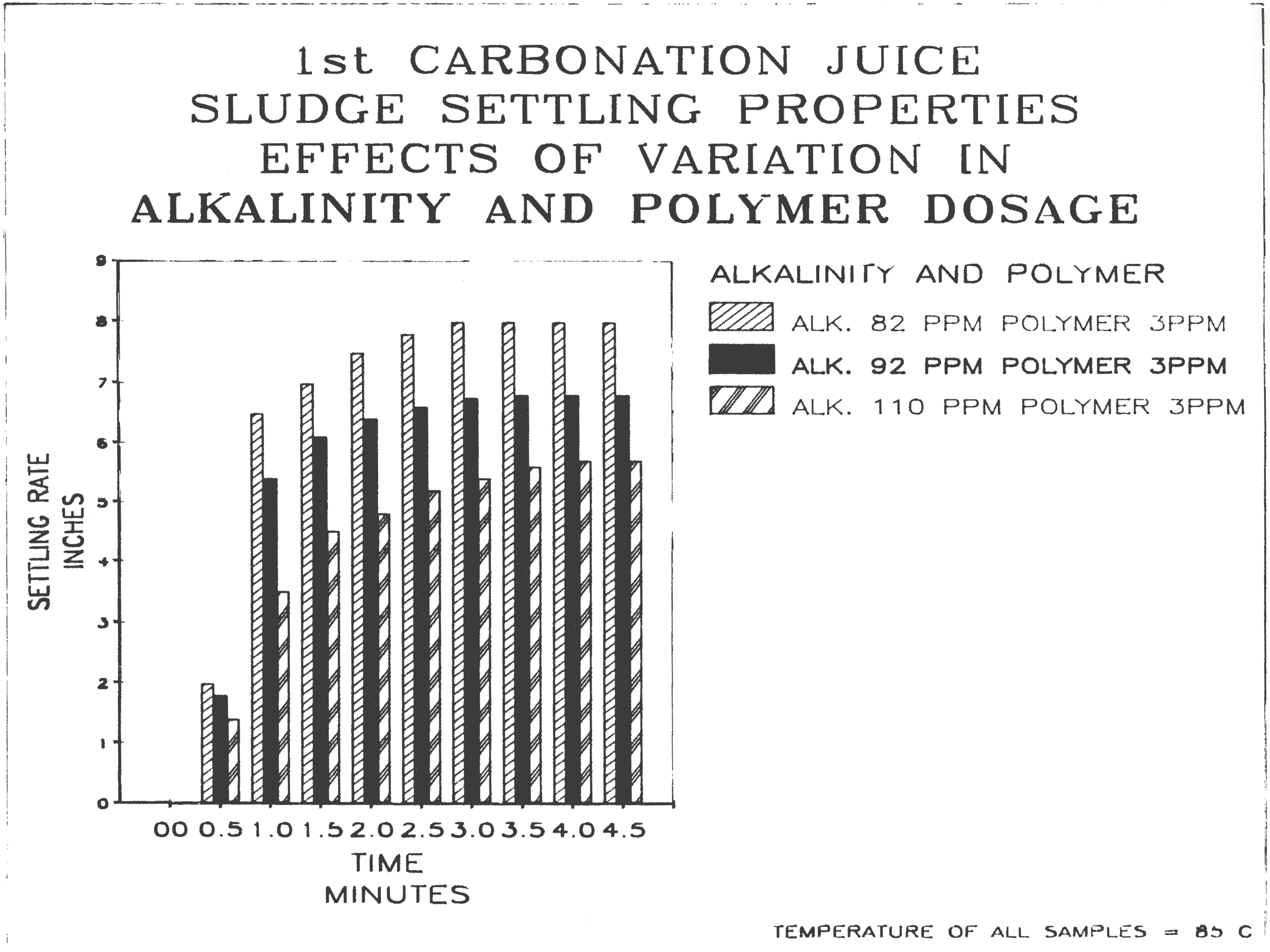
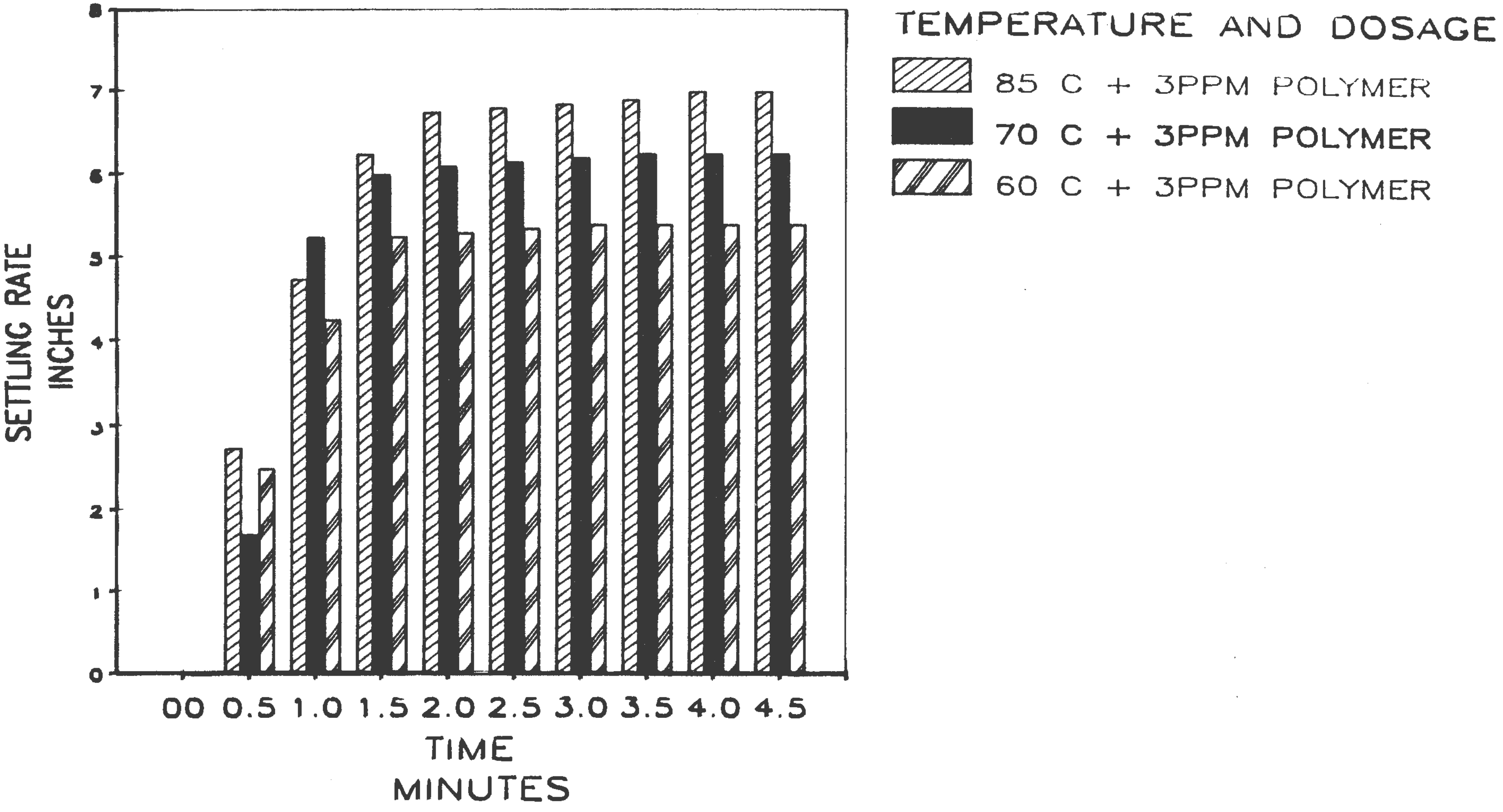

1st CARBONATION JUICE
SLUDGE SETTLING PROPERTIES
EFFECTS OF VARIATION IN
ALKALINITY AND POLYMER DOSAGE
ALKALINITY AND POLYMER
ALK. 82 PPM POLYMER 3PPM
ALK. 92 PPM POLYMER 3PPM
ALK. 110 PPM POLYMER 3PPM
SETTLING RATE
INCHES
0
1
2
3
4
5
6
7
8
9
00
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
TIME
MINUTES
TEMPERATURE OF ALL SAMPLES = 85 C

FIGURE F

1st CARBONATION JUICE SLUDGE SETTLING PROPERTIES EFFECTS OF VARIATION IN TEMPERATURE AND POLYMER DOSAGE



ALKALINITY OF ALL SAMPLES = 82PPM (CaO)

FIGURE 7

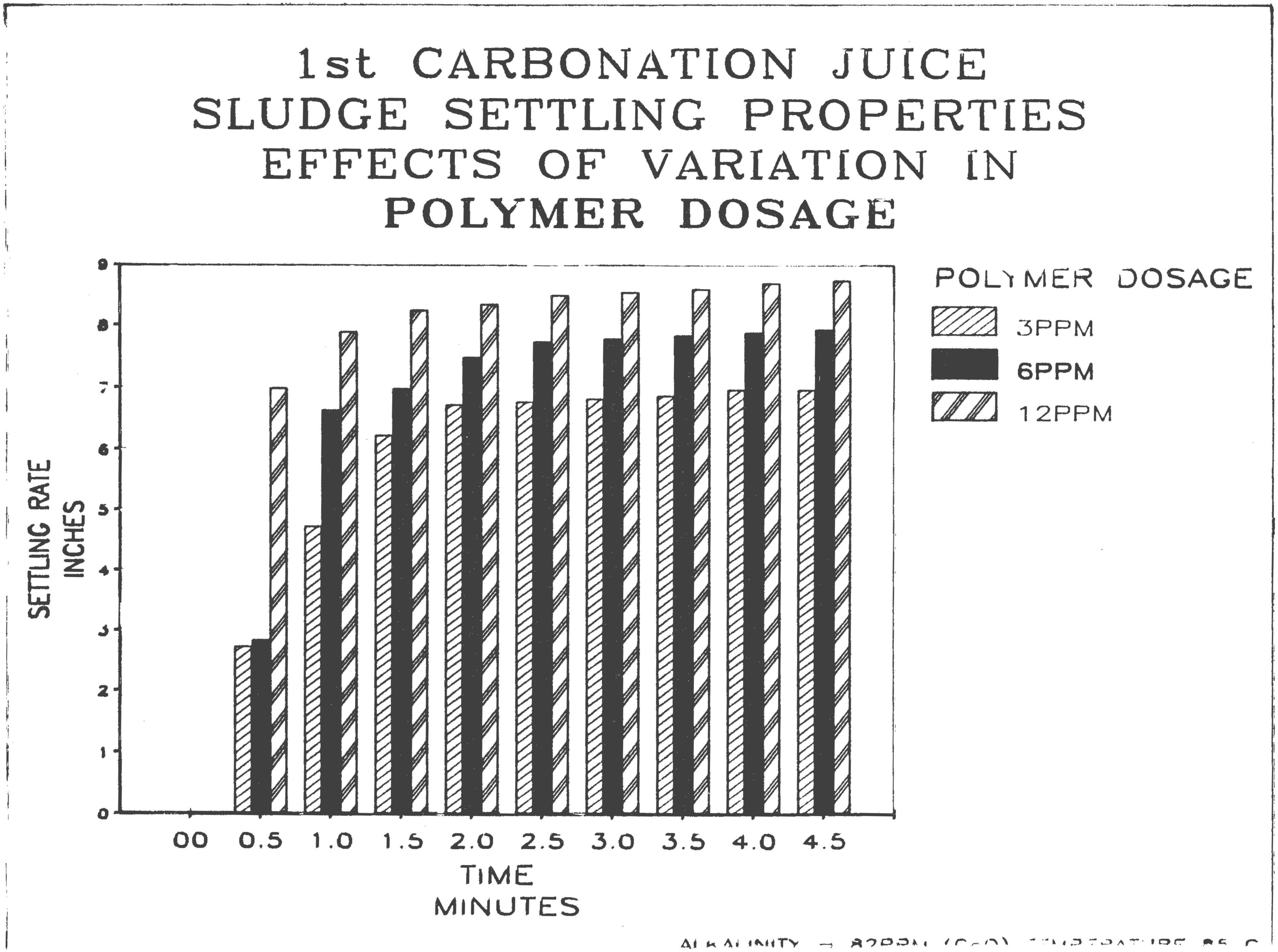
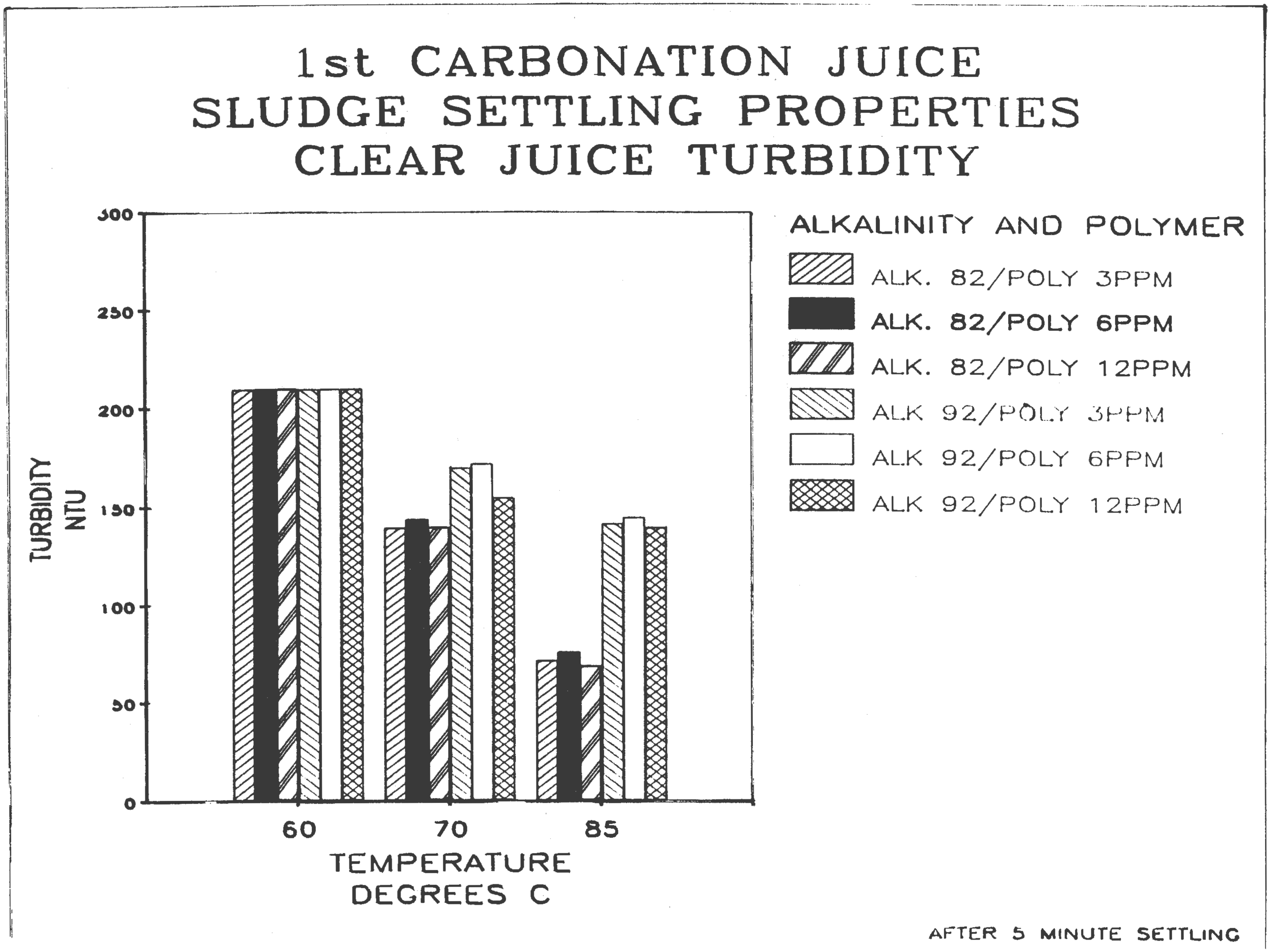

1st CARBONATION JUICE
SLUDGE SETTLING PROPERTIES
EFFECTS OF VARIATION IN
POLYMER DOSAGE
SETTLING RATE
INCHES
0
1
2
3
4
5
6
7
8
9
00
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
TIME
MINUTES
POLYMER DOSAGE
3PPM
6PPM
12PPM
ALKALINITY = 82PPM (CaO) TEMPERATURE 85 C

FIGURE 8


1st CARBONATION JUICE
SLUDGE SETTLING PROPERTIES
CLEAR JUICE TURBIDITY
TURBIDITY
NTU
300
250
200
150
100
50
0
60
70
85
TEMPERATURE
DEGREES C
ALKALINITY AND POLYMER
ALK. 82/POLY 3PPM
ALK. 82/POLY 6PPM
ALK. 82/POLY 12PPM
ALK 92/POLY 3PPM
ALK 92/POLY 6PPM
ALK 92/POLY 12PPM
AFTER 5 MINUTE SETTLING