BENEFITS FOR A BEET HANDLING SYSTEM BY POLYMER ASSISTED MUD REMOVAL IN A FLUME CLARIFIER

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Introduction

Every beet sugar factory has a beet handling system. The operation of the beet handling system provides transportation of the beets into the factory, removal of foreign debris such as rocks, foliage, mud, as well as to wash the beets prior to processing. Ninety plus percent of all beet sugar factories have a beet handling system consisting of a flume and washing process. The cost associated with a beet handling system is greater than five million dollars, thus the importance of keeping equipment in good working condition. The removal of solids from the recirculating water in a wet beet handling system will provide maintenance savings, improve environmental process in the flume and enhance overall operations. It is known that polymers have been in use for a long time in flume clarifiers. Some of the factories with a flume clarifier use polymer, but most do not. It is important to know what additional benefits and costs are associated besides getting cleaner water. Laboratory testing showed that a low charged anionic, medium molecular weight polyacrylamide was the most suitable flocculant for this application.

Flume Systems

Flume systems will vary in size and amount of makeup water. Most try to avoid the addition of water not emanating from the plant because of cost. Makeup water can come from local ponds; wash down waters, CO_2 wash systems, floor washings, condenser water spills and additions of house hot water. Generally the flume is a repository for waters from the sugar process.

At Imperial Sugar, Brawley, CA, their flume averaged recirculation flow is 6000 gpm with no set rate for water makeup. At Western Sugar, Fort Morgan, CO, the average recirculation flow is about 5000 gpm, with a 1000 to 2000 gpm make up if needed. At American Crystal Sugar factories, a typical flow in the flume could average between 5000 to 9000 gpm with an average make up water estimated between 300,000 to 400,000 gpd.

Objective

The objective in this study is to determine if there is any value added benefits in a water beet handling system by the use of polymers, both cationic coagulants and/or anionic flocculants. An evaluation of how the dirt and organic solid removal from a beet handling system could offer benefits in less abrasion and maintenance costs, reduction of biological contamination and improved performance. The primary subject of this study is Western Sugar's Fort Morgan facility. A short trial on the flume clarifier was performed to evaluate the solids removal from the system. Coupons to monitor abrasion during testing were evaluated to confirm if the solids removal from the water was significant to the abrasion of the system.

Background Information

A research of all beet factories in the United States was done in order to know whether they routinely use polymer for their flume clarifier. Out of 28 working factories, 6 factories are currently using polymer in the flume process; however, 21 factories could use polymer technology in the flume clarifier. This list is included as well as testing performed at different factories on flume clarifiers as reference of previous work.

Sugar Beet companies in the USA

1. Amalgamated Sugar factory locations:
   - Nampa, ID (11,800 TPD)
   - Nyssa, OR (9,000 TPD)
   - Paul / Mini Casa, ID (12,000 TPD)
   - Twin Falls, ID (6,200 TPD)

Twin Falls and Nampa have flume clarifiers but they do not use polymer. Nyssa uses polymer and has a Putsch filter system in the flume. Paul has a dry handling system.

2. American Crystal Sugar factory locations:
   - Crookston, MN (5,400 TPD)
   - Drayton, ND (6,000 TPD)
   - East Grand Forks, MN (9,000 TPD)
   - Hillsboro, ND (7,700 TPD)
   - Moorhead, MN (5,400 TPD)

All the factories have a flume clarifier. The only factories currently using flocculant in the flume clarifier are East Grand Forks and Hillsboro. Moorhead factory has two mud presses utilizing an anionic flocculant. East Grand Forks is in the process of commercializing a new mud press this campaign.

3. Imperial Sugar factory locations:
   - Brawley, CA (8,500 TPD)
   - Caro, MI (3,600 TPD)
   - Carrollton, MI (3,300 TPD)
   - Croswell, MI (3,800 TPD)
   - Mendota, CA (4,000 TPD)
   - Sebewaing, MI (5,500 TPD)
   - Sydney, MT (6,500 TPD)
   - Torrington, WY (5,500 TPD)
   - Worland, WY (3,500 TPD)

Caro, Carrolton, Croswell, Mendota and Sebewaing do not have a flume clarifier, thus they do not use flocculant. Brawley, Torrington, Sydney and Worland have a flume clarifier but do not use flocculant.

4. Minn-Dak Farmers Coop, Wahpeton ND (7,500 TPD). They have a clarifier. They add the polymer to the mud before the press.

5. Monitor Sugar, Bay City MI (8,000 TPD). The factory has a flume clarifier but no flocculant is used.

6. Pacific Northwest Sugar Co., Moses Lake, WA (6,000 TPD). The factory has a clarifier but do not use polymer.

7. Southern Minnesota Beet Sugar, Renville, MN (11,000 TPD). This factory has a flume clarifier and uses flocculant.

8. Western Sugar factory locations:
   - Fort Morgan, CO (5,800 TPD)
   - Scottsbluff, NE (5,500 TPD)
   - Bayard, NE (2,900 TPD)
   - Greeley, CO (4,000 TPD)
   - Billings, MT (4,600 TPD)
   - Lovell, WY (3,050 TPD)

All the factories have a flume clarifier. The only factory using flocculant in the flume clarifier is Fort Morgan.

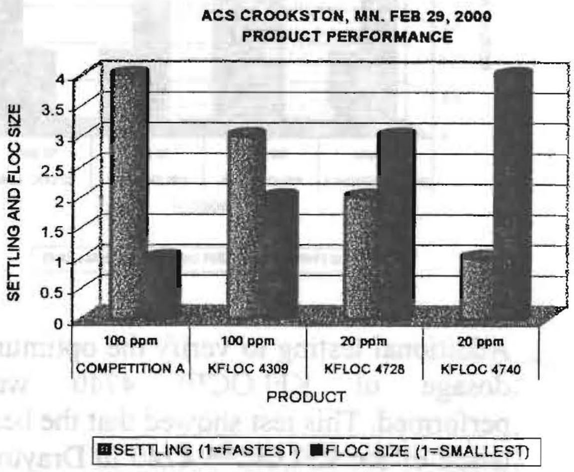
Historical Testing

Testing with polymers was conducted in several locations at different companies.

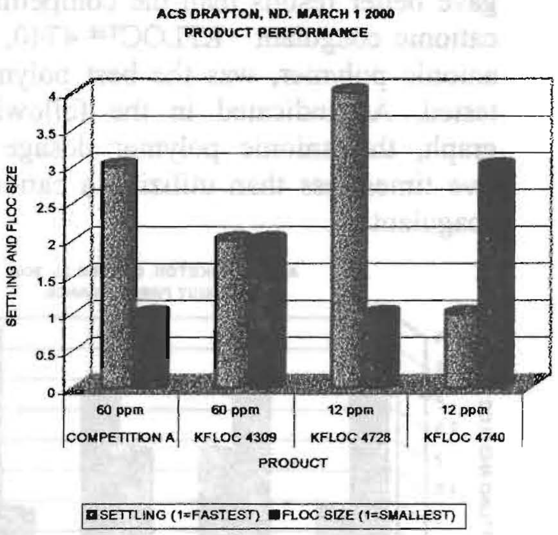
The places where testing on flume water was performed were American Crystal Sugar, all five locations, Southern Minnesota Beet Sugar, Western Sugar factories in Fort Morgan, CO and Bayard, NE, and Imperial Sugar, Woodland CA. When a factory location was not using a polymer, we tested a current competitive polymer along with our KFLOC™ for performance assessment. Some factories were using a competitive polymer and our KFLOC™ was tested against them for performance assessment. The competitive products and KFLOC™ polymers are compared below.

American Crystal Sugar
Polymer applications looked successful. However, the specific type of flocculant to be used in the clarifier for the recycle water was specific for individual plant processing conditions. Thus polymer jar testing took place at Crookston, Drayton, East Grand Forks, Hillsboro and Moorhead factories. All the factories had a better performance with the use of an anionic polymer except Hillsboro. Hillsboro did not present a good corollary to neither anionic nor cationic, but did see a benefit by feeding a cationic coagulant followed by an anionic flocculant. The solution for cationic polymers was prepared at 1% concentration and the solution for the anionic polymers was prepared at 0.2%. Following is a description by factory of the testing performed.

Crookston, MN: Crookston was experimenting with a competitive cationic coagulant, COMPETITON A. The optimum usage of COMPETITION A was found to be 100 ppm after several tests at different concentrations. The cationic coagulant, KFLOC™ 4309, gave better results than the competitive cationic coagulant. KFLOC™ 4740, an anionic polymer, was the best polymer tested. As indicated in the following graph, the anionic polymer dosage is five times less than utilizing a cationic coagulant.



Drayton, ND: Drayton was not using a polymer in their clarifier. Jar testing was done at Drayton comparing several KFLOC™ polymers to the cationic coagulant found at Crookston. The testing revealed that the cationic coagulant KFLOC™ 4309 gave better results than COMPETITION A. Further testing showed that KFLOC™ 4740, an anionic polymer, out performed all cationic coagulants. The results obtained in Drayton were similar to the results obtained in Crookston, keeping the relation of five times more cationic polymer dosage compared to the anionic polymer. The best performing polymer was KFLOC™ 4740, as indicated in the following graph.

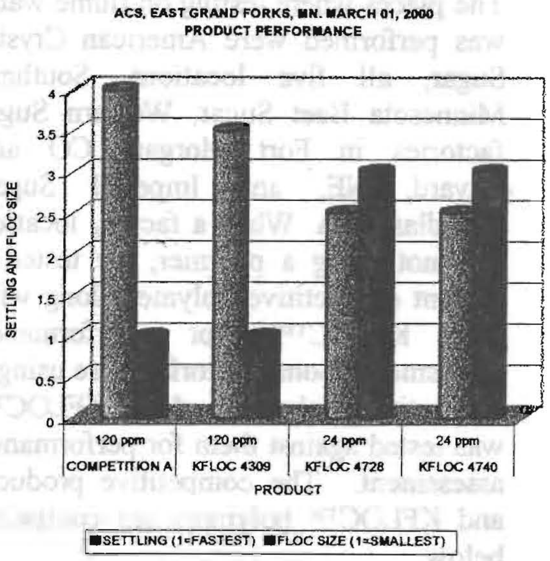


Additional testing to verify the optimum dosage of KFLOC™ 4740 was performed. This test showed that the best usage of the KFLOC™ 4740 in Drayton was 8 ppm.

East Grand Forks, MN: This factory was difficult to test. The cationic polymers did not work. Cationic coagulants formed very small flocs and there was no settling. The anionic polymers did not work as well as they did at either Crookston or Drayton. The anionic polymers settled quickly, but did not remove many solids. The usage of cationic coagulant followed by anionic polymer was also tested, but there was no appreciable differences when comparing these samples to samples with only anionic polymer.

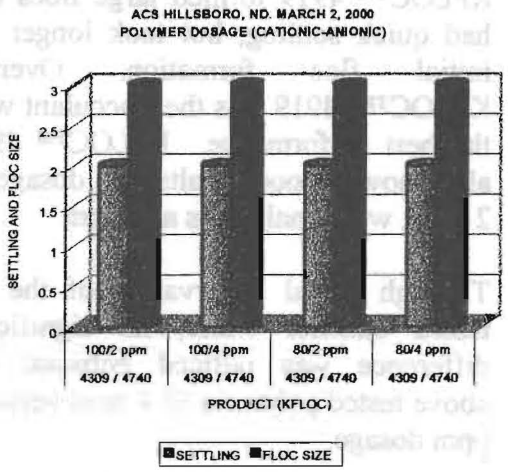
As indicated in the graph below, KFLOC™ 4740 had the fastest settling rate and the largest floc size. This polymer performed best at this location.

Additional testing should include a branched anionic versus a linear anionic. The branched flocculant should work better in biologically treated water.



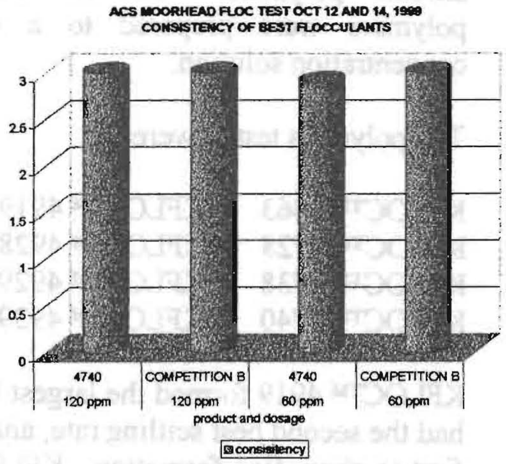
Hillsboro, ND: The dosage of COMPETITION A was 120 ppm. The best working cationic polymers were KFLOC™ 4312 and KFLOC™ 4309. The cationic polymers worked better than the anionics (using six times more than the anionic), settling faster.

By using a cationic coagulant and an anionic flocculant, the flocs formed nicely and settled quickly. The best paired products and dosages were with KFLOC™ 4309 and KFLOC™ 4740 at 80 and 2 ppm respectively. The usage of 2 ppm of anionic with cationic, reduces the use of the cationic by 40 ppm (a 66% reduction). Graphs showing the performance of a cationic polymer KFLOC™ 4309 with KFLOC™ 4740 at different concentrations follow below.



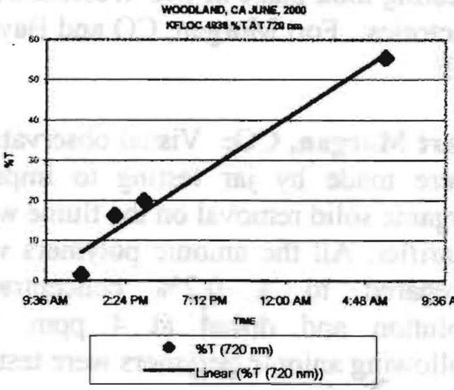
Moorhead, MN: Testing at this factory was at the mud press. Moorhead was utilizing a competitive anionic at 120 ppm (COMPETITION B). KABO's KFLOC™ 4740 performed equally well at 120 ppm. During testing, the KFLOC™ 4740 dosage was reduced 50%, to 60 ppm, and this dosage was found to perform comparably to COMPETITION B, dosed at 60 ppm.

The floc formation with COMPETITION B and KFLOC™ 4740 was at the same time and both flocs looked good.



Imperial Sugar Woodland, CA: Jar testing on the flume clarifier water at 10 ppm was performed with 24 cationic polymers and eight anionic polymers. The best cationic polymer was KFLOC™ 4223. However the anionic polymers out performed the cationic polymers. The best jar testing performance of the anionic polymers tested were KFLOC™ 4625, KFLOC™ 4645 and KFLOC™ 4939.

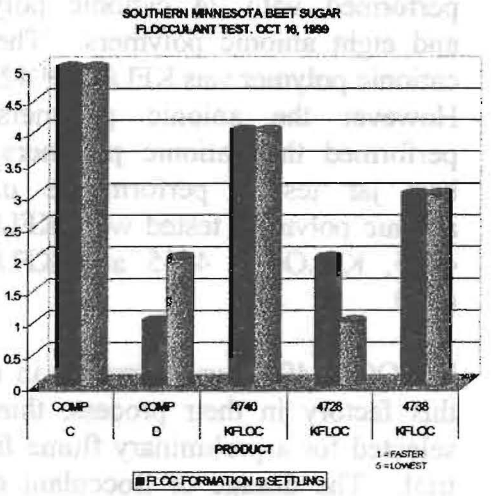
KFLOC™ 4939 was currently in use at this factory in their process, thus was selected for a preliminary flume factory trial. The dosage of flocculant during the trial was set at 0.5 ppm and the flocculant was prepared in a 0.2% solution. The only parameter monitored during this test to check removal of solids from the water was %T at a wavelength of 720nm. The results obtained are shown on the next graph.



Good results were obtained in this test. The transmittance was increased from 1.5% to 55.5%, an increment of 54%.

Southern Minnesota Beet Sugar Renville, MN: KFLOC™ 4728, KFLOC™ 4738, and KFLOC™ 4740 were tested against two competitors. KFLOC™ 4728 showed faster settling and the floc consistency was better than

KFLOC™ 4738 and KFLOC™ 4740. KFLOC™ 4728 produced the best settling.



COMPETITION C flocculant worked well, but took longer to form floc and settle. COMPETITION D flocculant worked almost as good as KFLOC™ 4728.

Western Sugar
Testing took place at two Western Sugar factories: Fort Morgan, CO and Bayard, NE.

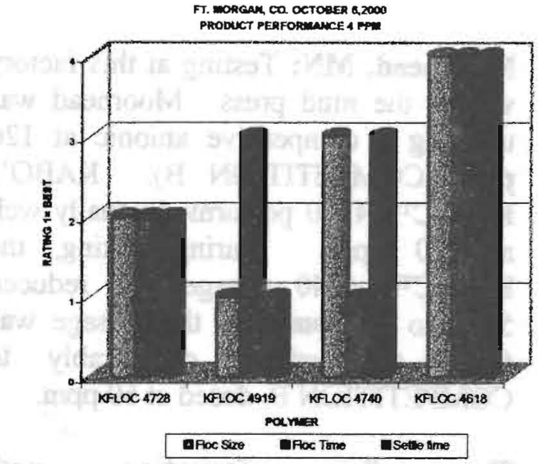
Fort Morgan, CO: Visual observations were made by jar testing to improve organic solid removal on the flume water clarifier. All the anionic polymers were prepared to a 0.2% concentration solution and dosed at 4 ppm. The following anionic polymers were tested:

KFLOC™ 4618	KFLOC™ 4929
KFLOC™ 4728	KFLOC™ 4937
KFLOC™ 4738	KFLOC™ 4939
KFLOC™ 4919	KFLOC™ 4940
KFLOC™ 4927	KFLOC™ 4978
KFLOC™ 4928	

Several cationic polymers and combinations of anionic and cationic polymers were also tested.

KFLOC™ 4919 formed large flocs and had quick settling, but took longer for initial floc formation. Overall, KFLOC™ 4919 was the flocculant with the best performance. KFLOC™ 4919 also showed good results at a dosage of 2 ppm, with small flocs at 1 ppm.

Through visual observation of the jar tested clarifier water, no significant difference was noticed between the above tested polymers @ 4 ppm versus 2 ppm dosage.

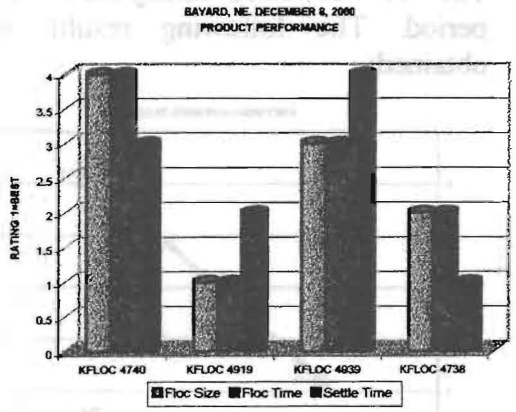


Bayard, NE: From our work at Imperial Sugar, Woodland and Fort Morgan, jar testing was performed with anionic polymers. All the anionic polymers were prepared to a 0.2% concentration solution.

The polymers tested were:

KFLOC™ 4463	KFLOC™ 4919
KFLOC™ 4728	KFLOC™ 4928
KFLOC™ 4738	KFLOC™ 4929
KFLOC™ 4740	KFLOC™ 4939

KFLOC™ 4919 formed the largest flocs, had the second best settling rate, and was first to show floc formation. KFLOC™ 4919 also showed good results at a usage of 2 ppm, with small flocs at 1 ppm. No difference was noticed between the above tested polymers at a higher dosage of 4 ppm. Clarity was equal among the above tested polymers, but KFLOC™ 4919 showed no surface floc formation (floaters) verses the other flocs tested.



Fort Morgan Testing

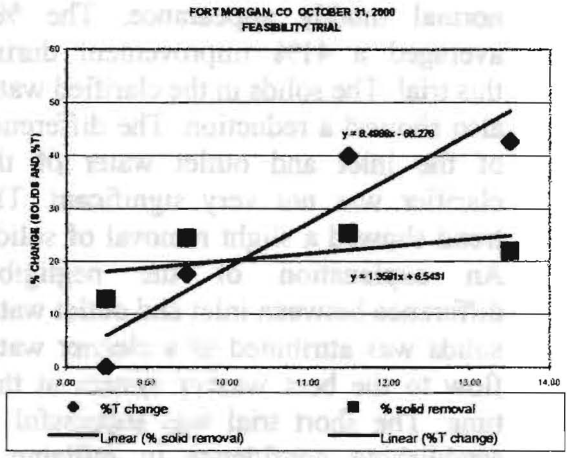
Testing at Fort Morgan was developed in 4 stages: jar testing as it has been already described, a feasibility trial to corroborate flocculant performance, short plant trial of two days, and a long plant trial of 15 days.

Trial Dosages

Previous damage to the clarifier rake had been experienced during a flocculant test on the clarifier. Due to this concern, the polymer dosage was gradually increased with initial testing at 0.5 ppm, then at 0.8 ppm and finally at 1.5 ppm. Significant improvement was observed with the low polymer dosing, and would offer the best economics.

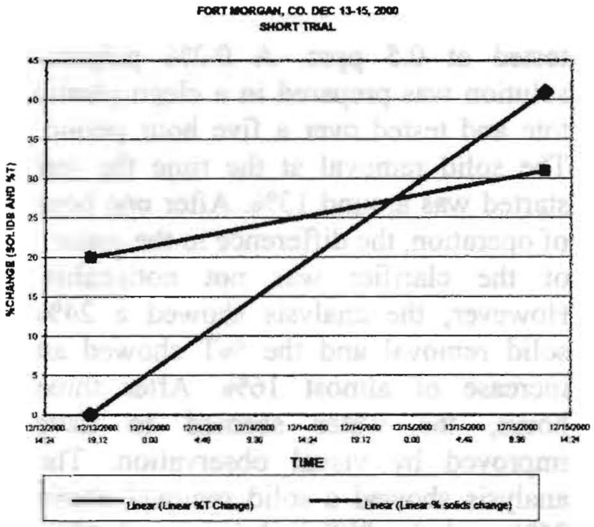
Feasibility Trial

The objective of this trial was to corroborate the data obtained from the jar testing showing KFLOC™ 4919 as the best flocculant to use. The use of 2 ppm of flocculant was the recommended usage based on the jar testing. Due to clarifier concerns, this short trial was tested at 0.5 ppm. A 0.2% polymer solution was prepared in a clean plastic tote and tested over a five hour period. The solid removal at the time the test started was around 13%. After one hour of operation, the difference in the water of the clarifier was not noticeable. However, the analysis showed a 24% solid removal and the %T showed an increase of almost 16%. After three hours, the water seemed to have improved by visual observation. The analysis showed a solid removal above 25% and the %T had increased 42%. The tote with solution finished a little bit before the five hours. The overall solids removal was 22% for the five-hour test. The following graph shows the trend of the %T on clarified water and solid removal over the testing period.



Short Plant Trial

After the positive results obtained in the feasibility trial, a two-day trial was performed. During this trial, the usage of flocculant was 0.8 ppm. The results are shown in the following graph.

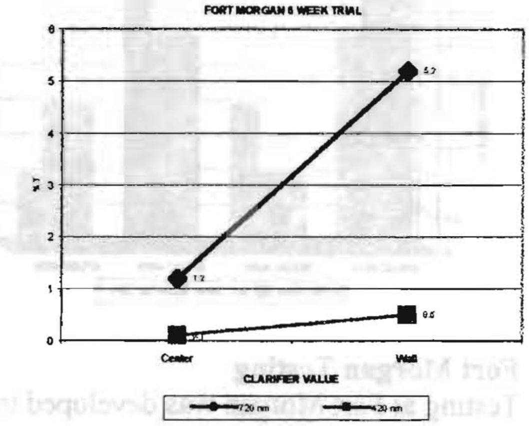


Even with the fluctuations of the system and problems with polymer feeding to the clarifier, there is a trend observed during this trial. At some intervals, the clarifier showed water somewhat clear with a green color to it instead of the normal muddy appearance. The %T averaged a 41% improvement during this trial. The solids in the clarified water also showed a reduction. The difference of the inlet and outlet water of the clarifier was not very significant. The trend showed a slight removal of solids. An explanation of the negligible difference between inlet and outlet water solids was attributed to a cleaner water flow to the beet washer system at that time. The short trial was successful in establishing confidence in utilizing a flocculant without damage to the clarifier rake system.

Long Plant Trial

From the positive results of the short two-day trial, Fort Morgan made an investment in purchasing a dry powder feed system equipped with make down tank. KABO purchased a higher capacity pump that would allow for greater dosage variability between 1 to 5 ppm. A 0.2% feed solution was maintained. KFLOC™ 4919 was fed at an average dosage of 1.5 ppm until the end of the process campaign, 47 days. During the last weeks, beets can be difficult to process, causing dirty water in the flume system.

The %T was tested during the six-week period. The following results were obtained:



Towards the end of this campaign, the green color in the clarifier was somewhat prevalent; however, the extended use of an anionic polymer, KFLOC™ 4919, showed an improvement in %T between the wall and center of clarifier at either 720 nm or 420 nm.

Coupons were placed at two locations: 1) Water coming over the clarifier walls and 2) Water coming from the plant just before entering the clarifier. The coupons were fitted to a long rod secured to scaffolding. An average of 5000 gpm flow was maintained. The ware on the coupon at the inlet of the clarifier was twice that of the coupon in the clean water.

Using KFLOC™ 4919 to treat the flume water clearly indicated the significant potential of extending the life of the flume equipment and reducing the costs of its maintenance and repairs.

Over All Observations

The Imperial Holly factory continued to use KFLOC™ 4939 in the flume clarifier until the plant closed its doors. The dosing was at 0.2% (0.5 ppm) solution and the flume water was clear. There were no specific test parameters being monitored on the flume water; however, the use of KFLOC™ 4939 helped to reduce effluent odors and improve mud settling.

Western Sugar, Fort Morgan initially began treatment, dosing 0.2% KFLOC™ 4919 polymer solution from 0.5 ppm to 2 ppm, while monitoring the clarifier brix on the mud and torque tension on the rakes. The flume water was improved so dramatically that a mud density system monitor was being installed to help monitor the clarifier flow, rake torque and mud removal rate to the ponds. In early discussion, they also felt that this system could be integrated with the polymer feeder to keep the mud removal rate at a constant level.

Economics

The polymer consumption costs equate to approximately $9.00 per 1000 gallon per minute of water treated at 0.5 ppm dosage. This flow of 1000 gpm treatment cost is based on six pounds per day usage. An average chemical cost of $1.50 per pound equates to $9.00 chemical cost per 24-hour period.

An estimated cost for the Woodland, CA factory trial with an average flow of 4000 gpm in the clarifier would average $36.00 per day in chemical costs. The estimated cost for the Fort Morgan factory trial at an average flow of 5000 gpm in the clarifier would be $45.00 per day in chemical costs.

Dry polymer feed systems are expensive and can cost between $15,000 to $30,000 or higher depending on the equipment, automation, and tank capacity of the system. Comparatively, liquid feed systems are relatively inexpensive; between $4,000 and $7,000, however, there is a trade off on the polymer type selected.

An average chemical cost of different polymer types would be as follows:

%Active	Type	Price/LB
50	EPI-Polyamine	<$1.00
28	Anionic Emulsion	<$1.00
100	Anionic Powders	<$1.60

Conclusion

From the initial testing at Western Sugar's Fort Morgan factory, the flume clarifier water showed improvement starting at dosages of around 0.5ppm with average water flow of 5000 gpm.

For the cost of using 30 pounds per day, KFLOC™ 4919 greatly improved flume water quality and clarity and increased mud removal. The increased mud removal would reduce wear and maintenance on flume processing equipment and allow for the pumping of more collected solids from the clarifier to ponds.

Overall, an initial investment of less than $10.00 per day would offset the major costs on repairs and replacement parts for the flume beet handling system, enhance mud settling rate, give cleaner water from clarifier, and overall improved operation by using cleaner water.