

OPTIMIZING POLYMER CONSUMPTION IN SLUDGE DEWATERING APPLICATIONS

P.M. Crawford* and B.E. Jank**

*ZENON Water Systems Inc., 845 Harrington Court
Burlington, Ontario L7N 3P3, Canada

** Environment Canada, Wastewater Technology Centre
P.O. Box 5050, Burlington, Ontario L7R 4A6, Canada

ABSTRACT

As we move into the 1990's, upgrading of existing wastewater treatment plants is becoming a very important consideration. Although upgrading can take many forms, one of the most economic is to optimize the performance of the existing equipment and structures. In the realm of sludge dewatering, also an increasingly important topic, an area which has received little attention in the past is the control of the sludge conditioning process prior to dewatering. In conjunction with the Wastewater Technology Centre in Burlington, Canada, ZENON Water Systems Inc. has developed the Sludge Conditioning Controller (SCC) to fulfill this need in the wastewater marketplace. A description of both the hardware and software aspects of the SCC are presented. In addition, typical operating performance of the microprocessor-based system is shown. Experience with full scale systems has revealed that the benefits associated with the SCC far exceed the original objective of saving polymer. The others include automation of the dewatering device operation, increased capacity and more uniform performance of the of the dewatering machine.

KEYWORDS

Sludge dewatering; sludge conditioning; polymer; polyelectrolyte; belt press; centrifuge; belt thickener; dissolved air flotation; filter press; microprocessor control.

INTRODUCTION

Organic polymers have become the primary choice of conditioning agent for sludge dewatering operations. Until now, however, there has been no simple technique of automatically controlling the addition of polymer to the sludge to allow the optimal performance of the dewatering machine. Several devices have appeared in the marketplace in the past, but none to date have been the ultimate solution to the problem. Some rely on an indirect measurement of sludge conditioning by analyzing filtrate quality but are still subject to severe solids fouling. Another is capable of measuring the state of conditioning of the sludge on a labor intensive manual basis but does not provide closed loop feedback control of the polymer feed pump. Yet another is applicable only to belt presses, and even then, only to certain designs. ZENON has overcome all of these deficiencies with the new Sludge Conditioning Controller (SCC).

The SCC is a unique, on-line, real-time sludge monitoring and polymer flow rate controller developed in conjunction with Environment Canada's Wastewater Technology Centre (WTC). The relationship between the rheological characteristics of conditioned sludge and optimal polymer dosage was discovered by the WTC in the early 1970's (Campbell *et al.*, 1982, 1983). At that time, however, process control hardware technology was not sufficiently advanced to allow production of a cost effective controller. The proliferation of inexpensive microcomputers in the early 1980's, however, allowed development of the concept to the feasibility stage (Campbell *et al.*, 1985).

In 1984, ZENON began a federal government funded project to develop the SCC from the prototype stage to a commercial device. The initial part of that work was a market study. Based on the conclusions of that study, that there was a strong North American municipal market for polymer control technology, ZENON proceeded to the next phase of the project: development of rugged and inexpensive system for controlling polymer (Campbell *et al.*, 1986). After this work was completed in late 1986, the first field trial installation of the SCC was made at Guelph, Ontario on a 2.0 metre belt press. During this initial operation, the performance of the SCC was compared with historical manual operating data. Based on about four months of operating data, the reduction in polymer consumption was about 24% (Campbell *et al.*, in press).

During this first field experience, several significant improvements in ruggedness, reliability and accuracy were made. All of these changes were incorporated into the production version of the SCC which was launched into the marketplace in early 1987. ZENON is now actively marketing the SCC on a worldwide basis to both municipal and industrial plants.

THEORY

The ZENON Sludge Conditioning Controller uses proprietary process technology, in combination with ZENON's own advanced microprocessor control technology. The SCC determines the state of sludge conditioning directly by measuring the intrinsic rheological characteristics of both the conditioned and unconditioned sludge.

Rheology is the study of shear stress and shear strain behaviour of fluids. Most homogenous materials develop shear stress in proportional to the flow rate or shear strain imposed on them. This kind of behaviour is called Newtonian.

When solid particles are added to the fluid, as in wastewater sludges, the behaviour is different. Flow of fluid is inhibited by the particles until some minimum shear stress is applied. This kind of behaviour is called non-Newtonian. In addition the more particles there are, or the higher the solids concentration is, the higher the shear stress required to produce flow at the same rate. This relationship will be demonstrated more fully later.

When conditioning polymers are added to the sludge, the behaviour is different again. Fluid flow is again inhibited by the polymer chains until some minimum, but much higher, shear stress is applied. In addition, the shear stress declines with time to a lower value if the fluid flow is maintained constant. This kind of behaviour is called thixotropic.

Figure 1 shows schematically what the information that the SCC gathers looks like. On the graph, the torque or shear stress response of the sludge is plotted versus time. The "peak" is defined as the highest value of torque found for a given sample, while the "base" is the average of the value of the data near the end of the data collected. As shown, the "peaks" get higher in magnitude as the polymer dosage increases. The lowest curve is typical of unconditioned sludges as it has no distinct "peak" in the data.

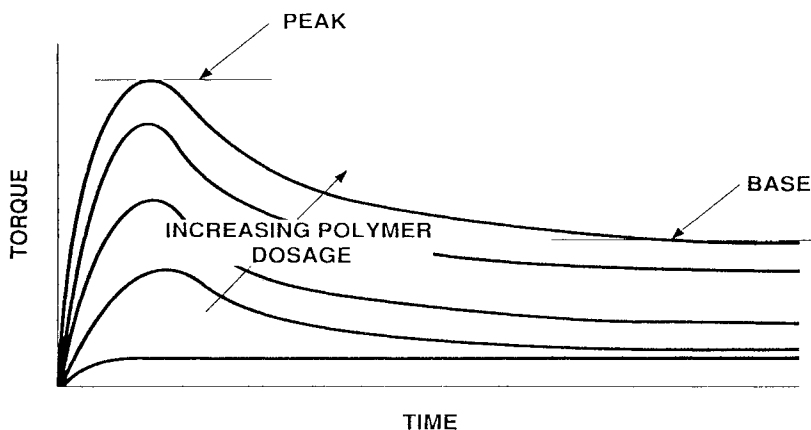


Fig. 1. Shear Response of Conditioned Sludge

The SCC uses the above kinds of information, gathered from sludge samples taken in real time, to determine the state of conditioning of the sludge. It then changes the polymer flow signal to adjust the amount of polymer added to the sludge.

HARDWARE

The hardware for an SCC consists of four main components:

- Central Control Panel
- Local Control Station
- Sample Vessel and Sensor Head
- Printer

The Central Control Panel (CCP) houses the single board computer (SBC), the sample vessel interfaces, the control signal generators, and the communications link. The SBC is the heart of the system. It controls all of the automatic sludge

sampling and data collection as well as making the control decisions on the polymer flow signal output. The sample vessel interfaces provide the necessary optical isolation between the SBC and the sampling system. The control signal generators also provide isolation between the CCP and the polymer pump controller. The communications link allows sending of the data and alarms from the SCC to a printer or computer. A single CCP has the capability of controlling the polymer flow rate for up to four dewatering devices both independently and simultaneously.

An operator interface is also provided on the front face of the CCP. It consists of a two line LCD screen and a keypad to control the operation of the SCC.

The Local Control Station contains the solenoid valves necessary for the control of both the air operated pinch valves that control sludge sampling and the rinse spray nozzles that clean the Sensor Head rotor and level probes. In addition, it also has a keypad for the manual control of all sampling system functions.

The Sample Vessel is a PVC or stainless steel container with a capacity of about 10 litres. It is piped into both the unconditioned and conditioned sludge lines and a drain via pinch valves which control the flow of sludge samples. All sludge flow in and out of the vessel is by gravity; no additional sludge pumping is required. The Sensor Head mounts on the Sample Vessel lid, which also serves as mounting for the rinse spray nozzles. The level probes, which sense when the vessel is full of sludge, and the rotor, which turns in the sludge sample, both extend through the lid into the vessel. Inside the Sensor Head is the electric motor, which turns the rotor, and the optical sensor, which measures the torque or shear stress exerted on the rotor by the sludge sample.

The Printer serves as an output device to record the data and any alarms from the SCC for historical purposes. If it is desirable to save this information in electronic form, it can be saved to a computer disk as well as, or instead of, being printed.

The SCC hardware is entirely automatic in operation from taking batch samples of sludge to self cleaning after sample analysis to adjusting the polymer pump flow rate. The only requirement for the operator is to adjust the initial polymer dosage to get the sludge dewatering operation working the way he likes it. He then presses the "Tune" button on the Central Control Panel and the SCC takes over the control of the polymer flow rate. Although the SCC does not require any further attention the operator can, if he wishes, adjust the "Auto Setpoint" to alter the setpoint that the SCC is controlling to.

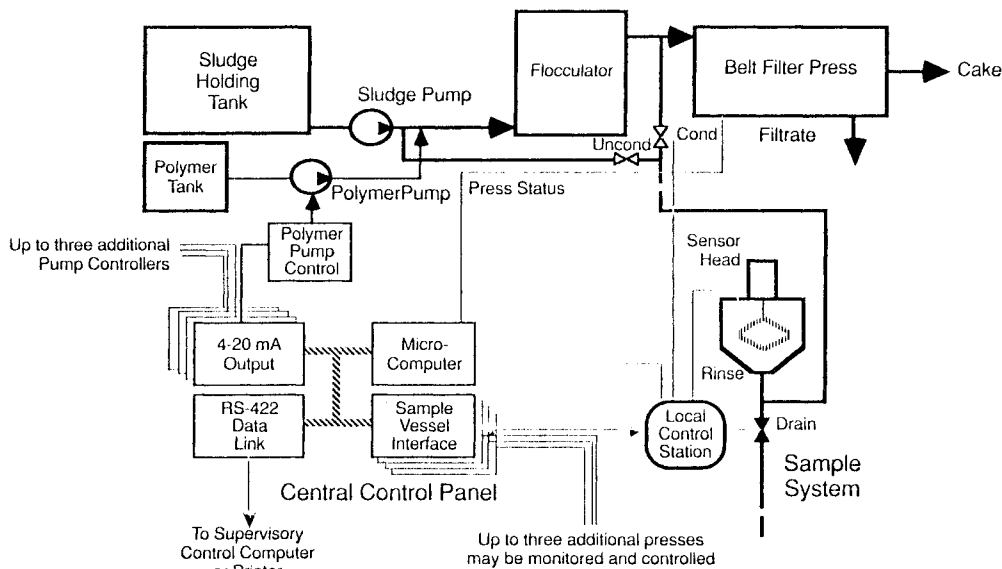


Fig. 2. SCC block diagram

Figure 2 illustrates how the SCC fits into a typical sludge dewatering flow schematic. The sludge sampling points are as shown upstream of the polymer addition point for the unconditioned sludge and just before the belt filter press for the conditioned sludge sample. The two samples are taken separately and independent data is collected from each. The data is transmitted to the CCP which makes the decision as to the change in polymer flow signal. The system therefore operates as a classic closed loop feedback control system with an additional feedforward input based on the unconditioned sludge sample.

This information is obtained by analyzing an unconditioned sludge sample. The nature of the response of the SCC Sensor Head to unconditioned sludge is very different to that of conditioned sludge. Referring again to Figure 3, the curve for the "0" % initial polymer flow rate is the typical response with no high "Peak" value, simply a constant low level torque value. The average value of the last two seconds of data is defined as the base value. By testing, we have found a relationship between the "Base" value of the unconditioned sludge and the solids concentration. They are related such that decreases in solids concentration will cause decreases in the unconditioned "Base" value. This is shown graphically in Figure 4. Therefore, the "Tune Peak" value can be adjusted in relation to the unconditioned "Base" value to ensure that the polymer flow signal is always adjusted in the correct direction regardless of what happens to the solids concentration of the sludge.

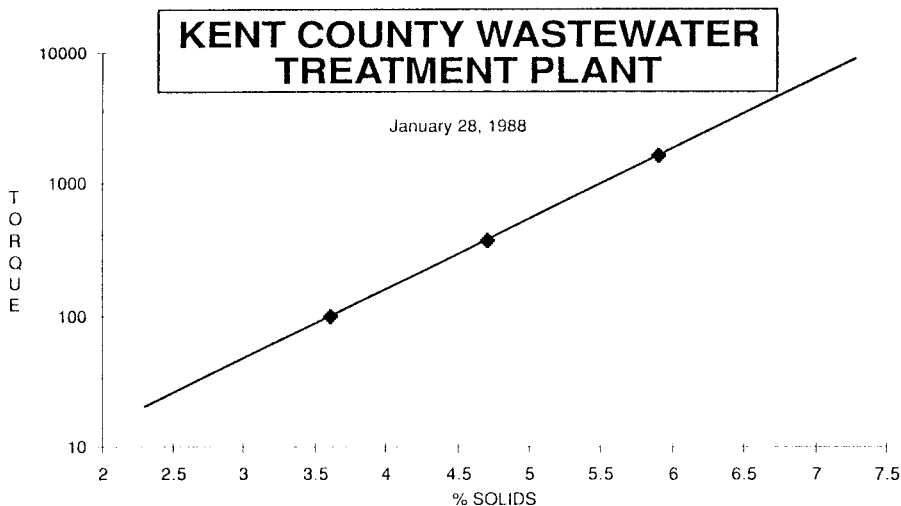


Fig. 4. Typical torque versus solids concentration results

For most sludges, up to a certain polymer dosage, the relationship between the conditioned sludge "Peak" value and polymer flow rate is direct, that is increasing the polymer flow rate with all other conditions held constant results in an increase in conditioned sludge "Peak" value. Usually at some relatively high dosage in the overdose range, however, the relationship changes so that further increases in polymer flow rate cause the conditioned sludge "Peak" value to decrease. The general nature of this more complete relationship is depicted in Figure 5. It is apparent that, using the control logic outlined above, once the polymer flow rate exceeded the maximum value on the Figure 5 curve, the system would be out of control. First the "Peak" drops, and the algorithm responds by increasing the polymer flow rate. Then the "Peak" drops again and polymer flow rate increases again. This process will continue until the maximum available polymer flow rate is reached. To prevent this unstable situation from occurring, the algorithm is continually testing for the relationship noted above in which increases in polymer flow rate result in "Peak" values that are further away from the adjusted "Tune Peak". When this condition is recognized, the algorithm continues to control but now in the opposite sense, that is if the "Peak" is too low, the polymer flow rate is decreased, a change which should result in an increase in the "Peak" for the next sample. This direction of control action continues until a decrease in polymer yields a decrease in "Peak". At this point the "Peak" / Polymer relationship is considered to have returned to the normal state, and control continues in the original direction.

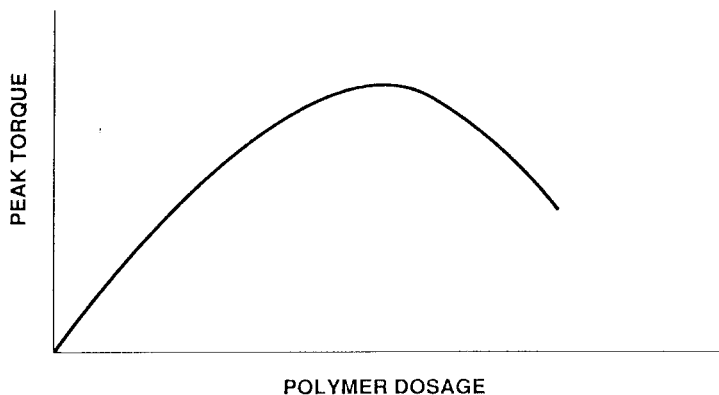


Fig. 5. Typical peak torque versus polymer dosage relationship

SOFTWARE

The most vital part of any computer controlled system is the software. For the SCC, the software controls all aspects of the operation including flushing of sample lines, filling of the sample vessel, changing of operational parameters, data collection, data analysis, data output, and the control algorithm.

All parameters which control how the system will behave at a specific site can be changed using the built-in keypad operator interface. The values of these parameters are presented on the two line LCD screen and can be viewed only, but not changed, unless the appropriate password is entered. Some of the parameters need to be established only during the commissioning of the system and not adjusted again. Examples of these are the flushing and filling time parameters for the unconditioned and conditioned sludge samples as well as the drain and rinsing times. Operational parameters such as controller gain, solids sensitivity, setpoint deadband, maximum polymer change, minimum and maximum polymer flow, and sample cycles per tune can be changed by the operator to customize the response of the system to the specific needs of the plant.

The data output consists of a summary for each sample cycle of the information collected during the calibration check in air, analysis of both the unconditioned and conditioned sludge samples, the present "Tune" and "Auto Setpoint" values and the most recent polymer flow rate signal. Each set of data is preceded by the date and time for reference purposes. The data is transmitted in ASCII format and serial form on an RS422, RS232C compatible data link.

The main objective of the control algorithm is to maintain constant sludge conditioning with varying solids and dewaterability. To achieve this objective the SCC compares the present state of conditioning with the reference point of known satisfactory conditioning obtained during the tuning cycle. If the present state of conditioning is either satisfactory or better than satisfactory, then the algorithm directs the polymer flow signal to be reduced. If, on the other hand, the present state of conditioning is not satisfactory, then the algorithm directs the polymer flow signal to be increased.

The SCC determines the present state of conditioning by analyzing the sample of conditioned sludge and finding the "Peak" value of the torque vs time data. This "Peak" value is directly related to the state of conditioning of the sludge. This relation is shown graphically in Figure 3, which represents demonstration data obtained with the SCC Sensor Head at the City of Detroit Wastewater Treatment Plant. As the polymer flow rate is reduced from 100% of the initial to 60%, the "Peak" values also decrease. This information shows that SCC Sensor Head is sensitive to changes in the polymer flow. From experience, we also know that the "Peak" value represents a particular state of conditioning. Therefore, once the belt press operation has been optimized with a particular sludge characteristic and a polymer flow rate, determined by the operator to be neither too high nor too low, then the "Peak" value obtained on conditioned sludge represents the ideal state of conditioning or the "Tune Peak". If, on subsequent samples of conditioned sludge, the "Peak" value is either above the "Tune Peak", or within the "Setpoint Deadband" range above or below the "Tune Peak", then the polymer flow rate signal will be reduced. Conversely, if the "Peak" value is below the "Tune Peak" and outside of the "Setpoint Deadband", then the polymer flow rate signal will be increased.

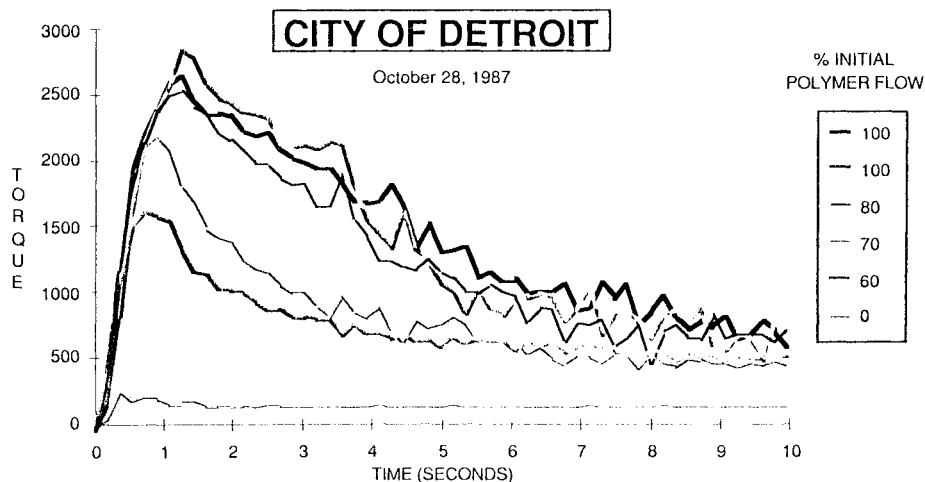


Fig. 3. Typical SCC demonstration results

The preceding description assumes that there is a change only in polymer demand of the sludge and not in the solids concentration of the sludge. If the solids concentration changes, we again know from experience that the "Peak" value of the conditioned sludge will also change. They are related such that a decrease in solids concentration will cause a decrease in "Peak" value even for the same state of conditioning. But using the previous approach, a decreasing or lower "Peak" value would result in an increase in polymer flow rate. If the solids are decreasing, however, the polymer flow rate should be decreased not increased. Therefore, additional information is required to determine whether the decrease in "Peak" value is due to increased polymer demand or decreased solids concentration.

The software supplied with the SCC is complete and the SCC will perform its task of polymer flow rate optimization without the addition of any other hardware or software. New versions of software with improved capability and ease of use are continually being prepared and released after complete field performance testing.

PERFORMANCE

The application of SCC technology is very broad with respect to both the dewatering device and the material to be dewatered. In addition to all belt press designs, the SCC can control polymer addition on belt thickeners, dissolved air flotation units, centrifuges, filter presses, and vacuum filters. Although developed initially for municipal wastewater sludges, the measurement technique is equally applicable to coal refuse slurries, chemical plant organic sludges, foundry inorganic sludges, and pulp and paper sludges to name a few. In short, any dewatering or thickening operation which uses a flocculating agent for conditioning prior to treatment can benefit from the use of the SCC.

In municipal plant operation, the range of solids concentrations on which the SCC has worked successfully is from about 0.3% for waste activated sludges up to about 7% for anaerobically digested sludges. In the industrial applications, the lower limit is comparable and, while there is no theoretical limitation for the Sensor Head, the practical limitation of being able to get the sludge samples to flow into the vessel govern the upper limit. Fortunately this limitation is usually shared with the dewatering device, so that if the sludge will flow to the machine, it will flow into the SCC. As an example, in coal refuse applications, solids concentrations up to about 40-45 % have been routinely sampled.

Over a dozen SCC systems are presently in the field in eight countries around the world. Typical operating data showing the changes in polymer flow rate signal with time is presented in Figures 6, 7, and 8. The savings indicated are specific to the time interval of operation but are representative of normal operation. The average polymer savings range from about 15 to 40 % depending to some degree on the amount of overdosing experienced during manual operation.

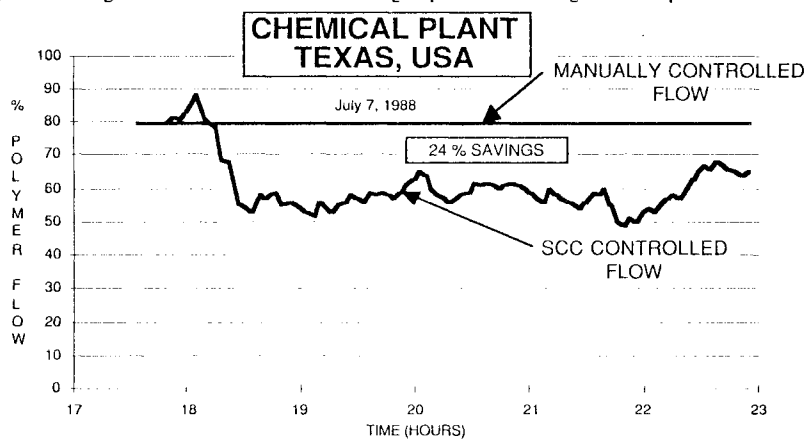


Fig. 6. Typical operating results on chemical bio-waste sludge

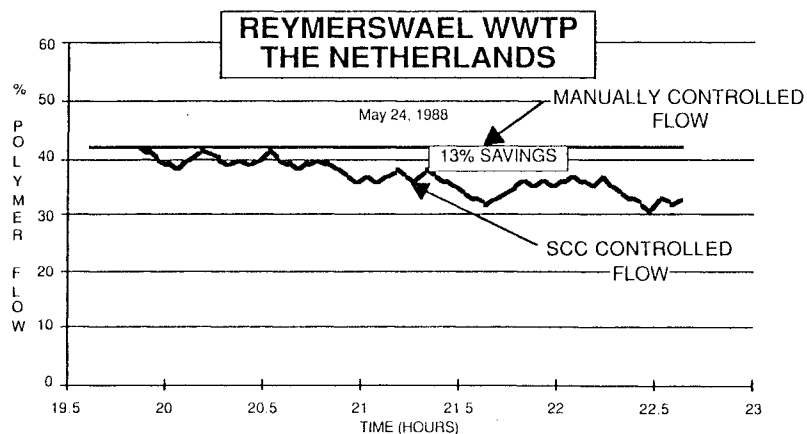


Fig. 7. Typical operating results on municipal digested sludge

Based solely on polymer savings, the payback period for the SCC ranges from about 4 months to 4 years, with an average of about 1.5 years, depending mainly on the pre-SCC polymer consumption.

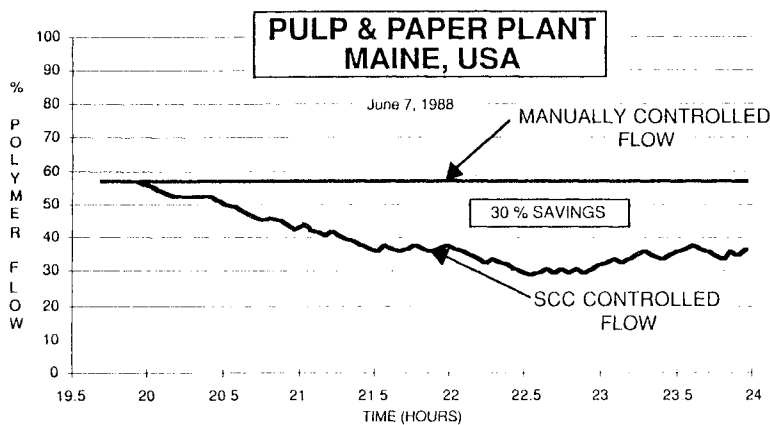


Fig. 8. Typical operating results on pulp and paper sludge

There are also additional benefits which accrue with the installation of an SCC. The operator will gain the freedom to concentrate on maximizing the solids throughput on the dewatering device. Typically these machines are mass flux limited. This means that if the solids concentration of the sludge decreases, the sludge flow rate can be increased to maintain the same solids loading. Normally this is very difficult for the operator, since he would have two variables to adjust, sludge flow rate and polymer flow rate. With the SCC controlling the polymer flow rate automatically, the operator can adjust the sludge flow to what ever is desirable. A future development of the SCC will be to use the solids concentration information obtained from the unconditioned sludge samples to control the sludge flow rate. By optimizing this aspect of the dewatering operation, an increase in total capacity can be obtained without resorting to the major capital investment of purchasing additional dewatering machinery.

Another benefit of using the SCC is the more precise control of cake solids that it provides because of the continuously optimized sludge conditioning. Since all forms of ultimate sludge cake disposal are cost sensitive to the cake solids concentration, this factor is very important with respect to savings and payback period.

In addition to the full scale installations, ZENON and its overseas distributors have performed demonstrations of the SCC measurement technique at over 50 different municipal and industrial plants. In all cases, the response to both conditioned and unconditioned sludge samples was as expected.

CONCLUSION

Optimization is a vital part of the advanced management approach to wastewater treatment plant operations. Shrinking capital budgets force the need to upgrade wastewater treatment plants to operate more effectively without major investment. The SCC meets these requirements with an inexpensive microcomputer-based approach designed to implement sludge conditioning process control strategies reliably and economically on a wide variety of sludges and dewatering devices. The many benefits include automation of the dewatering device operation, increased capacity and more uniform performance of the of the dewatering machine, and polymer cost savings.

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