PROCEEDINGS OF THE SECOND AUSTRALIAN COAL PREPARATION CONFERENCE

ROCKHAMPTON, 1983

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COMPLETE ON-LINE AUTOMATIC CONTROL OF THICKENER CIRCUITS

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ABSTRACT

A quantitative semi-empirical model of sedimentation was presented at the Second Australian Coal Preparation Conference. This model has been used as the basis for a complete on-line automatic control system for thickener circuits called AUTOFLOC.

The AUTOFLOC system has been successfully trialled at three Hunter Valley Coal Preparation Plants using Hi-Rate thickeners.

The AUTOFLOC system provides for control of flocculant dose rates, underflow pumping, thickener rake torque, thickener bed level and cationic polymer dose rates in those instances where poor thickener overflow clarity requires the use of cationics. These parameters are controlled in the following way:

i) Flocculant dose rates are varied on a feed forward basis so as to achieve a constant settling rate, in accordance with the sedimentation model; provision exists for feedback adjustment in response to the measurement of bed level.

ii) Underflow pumping is varied on a feed forward basis so as to ensure that solids are removed from the thickener at the same rate at which they enter, thereby preserving thickener mass balance; provision exists for feedback adjustment in response to the measurement of rake torque and/or bed level.

iii) Thickener rake torque and bed level are normally maintained within acceptable limits by ensuring that both constant settling rates and thickener mass balance are preserved. However when this is not the case, provision exists for feedback adjustment to the underflow pumping rate so as to control both rake torque and bed level; in addition, provision exists for feedback adjustment to flocculant dose rates so as to control bed level.

iv) Cationic dose rates, when required, are varied on a feedback basis so as to control thickener overflow clarity.

The mathematical techniques used in developing the sedimentation model have been modified and extended to provide the basis for a complete on-line flotation control system which is currently being trialled.

INTRODUCTION

Because of the importance of particulate suspensions in industrial processes, the properties of sedimentary slurries have been widely investigated. The more significant references are listed here (1-9).

However, there does not appear to be any reference in the literature to the quantitative effect of variations in the particle size distribution or in flocculant dose rate. Consequently no model existed which could be used as a sound theoretical basis for a feed forward flocculant control system.

The author of the present paper conceived a quantitative semi-empirical model of sedimentation which described the settling velocity (V) of a slurry in terms of only three variables, namely flocculant dose rate (D), slurry solids concentration (C) and a particle size distribution parameter (S). The model was developed in terms of these parameters because it was believed that such a formulation would provide the basis for a simple but reliable, site-specific, automatic feed forward flocculant control system. This model was presented at the Second Australian Coal Preparation Conference (10).

This paper reports that a simple, reliable automatic feed forward flocculation control system has been developed from the above model. This control system is currently being marketed by Catoleum under the name AUTOFLOC. The flocculant control system has been successfully tried and proven at three Hunter Valley Coal Preparation Plants using Hi-Rate thickeners - Warkworth, Hunter Valley and Wambo.

The AUTOFLOC control system has been extended to achieve complete control of thickener operation - by including control of thickener underflow pumping, thickener rake torque and bed level.

This extended control system has been proven under actual operating conditions at Hunter Valley Coal Preparation Plant.

The control system has been extended further to provide feedback control of cationic polymer dose rates in those instances where poor thickener overflow clarity requires the use of cationics. This system has not yet been tested under plant conditions, but difficulties are not anticipated.

The present paper describes certain aspects of the total control system, together with other results of interest that have been developed from the paper presented at the Second Australian Coal Preparation Conference (10).

OUTLINE OF THE CONTROL SYSTEM

This section outlines the philosophy, the features and the instrumentation requirements of the AUTOFLOC control system.

Other sections deal with the mathematical basis for certain aspects of the control system, practical aspects of the control system and other areas of interest.

Control System Philosophy

Because of the low residence times and fast response, Hi-Rate thickeners are much more difficult to control than conventional thickeners. Consequently the following comments are restricted to Hi-Rate thickeners on the grounds that the corresponding problems in conventional thickeners are much easier to solve.

The basic assumption of the control system is that by

(i) achieving constant settling rates at all times (which means that the variation in floc formation has been minimised)

(ii) removing solids from the thickener at the same rate that they enter

conditions within the thickener will be kept close to steady-state, thereby minimising or totally eliminating problems with rake torque and/or bed level.

Actual performance at Hunter Valley Coal Preparation Plant indicated that

(i) problems with rake torque were completely eliminated,

(ii) bed level fluctuations were minimised but not eliminated.

It should be noted, however, that the gap to the inner ring (where bed level fluctuations were greatest) was larger than design specifications. Appropriate modifications have been carried out subsequently. This may eliminate bed level fluctuations. It is important to note that satisfactory performance of the thickener circuit was achieved which enabled production rates above the design figure to be routinely achieved.

Features of the Control System

Flocculant Control: Flocculant dose rates are controlle automatically on a feed forward basis, using the semi-empiri sedimentation model. Provision is made for feedback adjustment t the calculated dose rates in the event that bed level starts to ge out of control, although the primary means of controlling bed leve is by adjusting the rate of underflow pumping.

Thickener Control: The rate of underflow pumping can be altered so a to provide control of

i) mass balance in the thickener; that is, remove solids v: the underflow at the same rate at which they enter v: the feed

ii) thickener rake torque

iii) thickener bed level.

Mass balance can be controlled automatically on a feed forwa basis provided that the following information is available

i) the flow rate and solids content of the thickener feed,

ii) the density of the solids in the underflow and the densi of the underflow slurry,

iii) the underflow pump characteristics; that is, flow r versus pump speed at various slurry densities.

In most instances, maintaining both mass balance and const settling rates ensures that rake torque and bed level are control within acceptable limits. However, where required, provision exi for feedback adjustment to the calculated underflow pump speec order to control rake torque and/or bed level.

Control of Overflow Clarity: In some instances, particularly in Hunter Valley region, adequate overflow clarity cannot be achi with the use of flocculants alone. In such cases cationic poly or inorganic coagulants are necessary to improve overflow clarity

The control software has been extended to provide automatic control of thickener overflow clarity by adjusting cationic dosing rates on a feedback basis. Although this has not yet been tested under plant conditions, problems are not anticipated.

Microcomputer Facilities: Microcomputer flexibility enables the mathematical sophistication of feedforward calculations to be carried out. It also allows feedback control algorithms to be undertaken which are more effective than the usual PID feedback methods.

Plant Performance

The AUTOFLOC flocculant control system has been successfully proven at Warkworth, Hunter Valley and Wambo Coal Preparation Plants.

The thickener control system has been successfully proven at Hunter Valley Coal Preparation Plant. Wambo intends to use the thickener control system when the instrumentation pre-requisites have been completed.

The author is unaware of any case at any of the three sites where flocculant or thickener problems have been due to the inability of the control system to control.

It should be noted that at Hunter Valley Coal Preparation Plant rake torque was, at all times, maintained within acceptable limits by ensuring that the underflow pumps maintained mass balance. That is, as expected, feedback adjustment was never required. On the other hand, feedback adjustment for bed level was required at times. However it was noted subsequently that the gap to the inner ring was greater than the design specifications. It is possible that appropriate modifications will make feedback adjustment unnecessary.

Instrumentation Requirements

Flocculant/Cationic Control: Both systems require

i) light transmission probes which generate 4-20 mA input signals

ii) variable speed pumps which can be controlled via 4-20 mA output signals.

Thickener Control: It is preferable that variable speed underflow pumps be used, particularly with Hi-Rate thickeners, but fixed speed pumps can be controlled by varying the length of time that the pumps operate.

Control of thickener mass balance requires
i) variable speed underflow pumps which can be controlled via 4-20 mA output signals, or
ii) fixed speed underflow pumps which can be controlled via digital output signals.

Control of rake torque requires a measurement of rake torque which can provide a 4-20 mA input signal.

Control of bed level requires a measurement of bed level which can provide a 4-20 mA input signal. For example, this may be provided by
i) a Gem sensor
ii) a mechanically movable light sensor
iii) taps at the side of the thickener, together with a light sensor.

Benefits of the Control System

Since there are no moving parts, maintenance problems and costs are low.

The software package communicates in user-friendly language, and can be easily extended as newer advances are made.

In addition, the control system ensures that
i) flocculant/cationic usage is optimised
ii) thickener operating objectives are constantly achieved e.g. rake torque, bed level and overflow clarity
iii) plant downtime due to rake torque problems is eliminated
iv) satisfactory overflow clarity is achieved, which optimises the performance of other process units e.g. magnetite recovery and, particularly, flotation performance
v) operator involvement is minimised, which provides time for operators to optimise the performance of other unit processes.

The reduction in plant downtime can have significant cost benefits. For example, increased plant availability of 10 hours per annum for a plant producing 1000 t/h at a value of $50/tonne results in increased production of $500,000 per annum.

3. THE MATHEMATICAL BASIS OF THE CONTROL SYSTEM

There are four major components of the total control system
i) flocculant control
ii) cationic/overflow clarity control
iii) thickener mass balance control
iv) rake torque, bed level control.

As outlined in the previous section, flocculant dosing is varied on a feed forward basis so as to achieve a constant settling rate (or other suitable operating objective) while underflow pumping is varied on a feed forward basis so as to achieve thickener mass balance. In most instances, ensuring a constant settling rate and thickener mass balance will control rake torque and bed level within acceptable limits. On those occasions when this is not so, provision for feedback adjustment to the rate of underflow pumping exists. Cationic dosing is varied on a feedback basis so as to ensure that the desired thickener overflow clarity is maintained.

For reasons of space, this section will deal mainly with the flocculant control system, but will deal briefly with the cationic control system also.

The Basis For the AUTOFLOC Feedforward Flocculant Control System

It is generally agreed that the settling velocity of particulate slurries is a function of

i) the properties of the material being settled
ii) the properties of the process water
iii) the properties of the flocculant used
iv) the fluid dynamics of the slurry in the specific piece of equipment in which settling occurs.

However, in any given plant, it would be unusual for some of the above variables to vary significantly over the period of a day. For example, a given flocculant would be used, the process water chemistry should be approximately constant (if not, the problem should be examined thoroughly) and, to a lesser extent, the process hydrodynamics and, to an even lesser extent, the surface chemistry of the slurry particles should be reasonably constant.

This suggests that an adequate site-dependent description of settling can be given in terms of the slurry solids content, C the particle size distribution parameter, S, and the flocculant dose rate in g/t, D.

It has been shown (10) that a semi-empirical quantitative model relating these variables has the form

$$V = \left[-a_o + \frac{a_1}{C^n} \right] + \left[\frac{a_2 \exp(-a_3 S)}{C^n} \right] D \qquad (1)$$

where a_o, a_1, a_2, a_3 and n are empirically determined, site-specific constants.

For control purposes we wish to express the flocculant dose rate in terms of the other parameters.

$$D = \frac{(V + a_o)\ C^n - a_1}{a_2 \exp(-a_3 S)} \qquad (2)$$

At any particular plant, the settling rate objective, V, will be a constant. Thus we have

$$D_v = \exp(a_3\ S)\ [a_4\ C^n - a_5] \qquad (3)$$

where D_v = dose rate in g/t required to achieve the desired settling velocity, V

$a_4 = (V+a_o)/a_2$

$a_5 = a_1/a_2$

Under actual plant conditions, it is easier to work with dose rates expressed in units of ppm rather than g/t. This is because plant dose rate in ppm can be calculated from the flocculant dose rate in l/m, whereas a dose rate in g/t requires that, in addition the slurry solids content be known.

Since $D = d/C$

where d = flocculant dose rate in ppm
C = fractional solids content (not % solids)

we have

$$d_v = \exp(a_3\ S)[a_4\ C^{n+1} - a_5 C] \qquad (4)$$

where d_v = dose rate in ppm required to achieve the desired settling velocity, V.

The basis for many flocculant control systems is the belief that the quantity of flocculant which must be added to achieve a desired settling rate is proportional to the quantity of solids present in the slurry. In other words, it is believed that adequate control can be achieved by varying the flocculant dose rate in accordance with

$$d_v = k\ C \quad (5a)$$

or

$$D_v = k \quad (5b)$$

It can easily be seen that there is a major difference between the two models.

The proportional or ratio model makes no allowance for variation in the slurry solids particle size distribution, while the semi-empiric model predicts that the dose rate required will increase exponentially with increases in the particle size distribution parameter. A detailed examination of A.I.S. raw coal thickener feed has shown conclusively that variation in the particle size distribution does have a dramatic effect on the flocculant dose rates required to achieve a given settling rate (10). This can be seen from Fig 1, where approx 25 g/t is required to achieve a settling rate of 10 m/h with slurries containing 35-38% of -53 microns material (with solids content approximately 12%) whereas less than 10 g/t is required to achieve the same settling rate when only 26-28% of the solids present are -53 microns (with solids content also 12%).

Furthermore, the proportional model predicts that flocculant dose rate, D, is independent of C, whereas the semi-empiric model predicts that the flocculant dose rate depends on C^n. From Fig 1, noting that dose rates are given in g/t, it can be seen that D is not constant, as is required by the proportional model, but does in fact increase with C, as required by the semi-empiric model.

It is instructive to compare the magnitude of the effect of changes in solids content versus changes in particle size distribution. It can be seen either from equation 4 or Figure 1 that the influence of the particle size distribution is more important than the solids content. This has not been generally recognised in the coal industry, or elsewhere, although it could be argued that it is somewhat obvious. For example, Stokes Law predicts that a spherical particle of 100 microns diameter will have a settling velocity 25 times as large as that of a 20 microns diameter spherical particle. Furthermore, in interface settling (10), virtually all particles settle at the same rate. On the other hand it seems difficult to avoid the assumption that the actual settling rates for interface settling is largely determined by the "natural", or unflocculated, settling rate of the smallest particles.

Confirmation of the validity of the semi-empiric model is given from a practical viewpoint as well. For example, control of Hi-Rate thickeners has been notoriously difficult because of their very small residence times. This can lead to loss of thickener control in such a short period of time as 15-30 minutes. However, by using the semi-empirical model as its basis, three Hunter Valley Hi-Rate thickeners have been successfully controlled for long periods of time without, to the author's knowledge, a single instance of loss of control due to the control system. If the quantitative predictions of the model were significantly in error, then it is reasonable to assume that these errors would have manifested themselves in the rapid loss of control of the Hi-Rate thickeners.

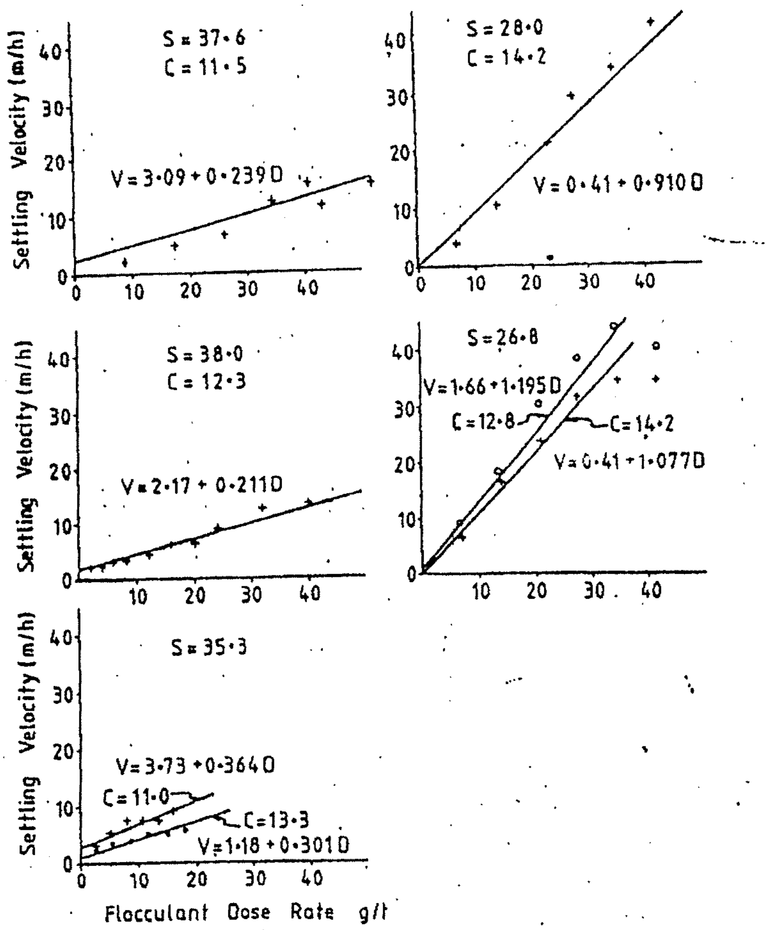

FIGURE 1 - THEORETICAL CURVE AND EXPERIMENTAL DATA
A.I.S THICKENER FEED

The Use of Light Transmission/Scattering Probes

The theoretical model depends on <u>both</u> solids content and a particle size distribution parameter. But there is no simple convenient way of monitoring both on-line.

However the problem can be viewed in another way.

The surface area of slurry solids is dependent on the solids content and the particle size distribution. A parameter that is related to the surface area of slurry solids can be measured by means of light transmission/scattering methods using radiation of a suitable wavelength.

By examining the mathematical properties of the relationship describing the correlation between transmitted/scattered light intensity, T, and the slurry % solids and particle size distribution parameter, it has been possible to arrive at a correlation between d_v and T which is described by a mathematical form which is an invariant.

We are therefore left with the problem of determining the value of the "constants" which specify a definite function within the family of functions which have the given form. Under actual operating conditions the value of the "constants" will depend on variations in particle surface chemistry, process hydrodynamics and other process variations (such as pump wear etc.) as well as variations in the particle size distribution.

A simple calibration procedure has been devised which determines the values of the constants. This enables a single, specific function to be selected from the infinite number of functions belonging to that family of curves which describes the plant behaviour on that particular day.

This is indicated schematically in Figure 2.

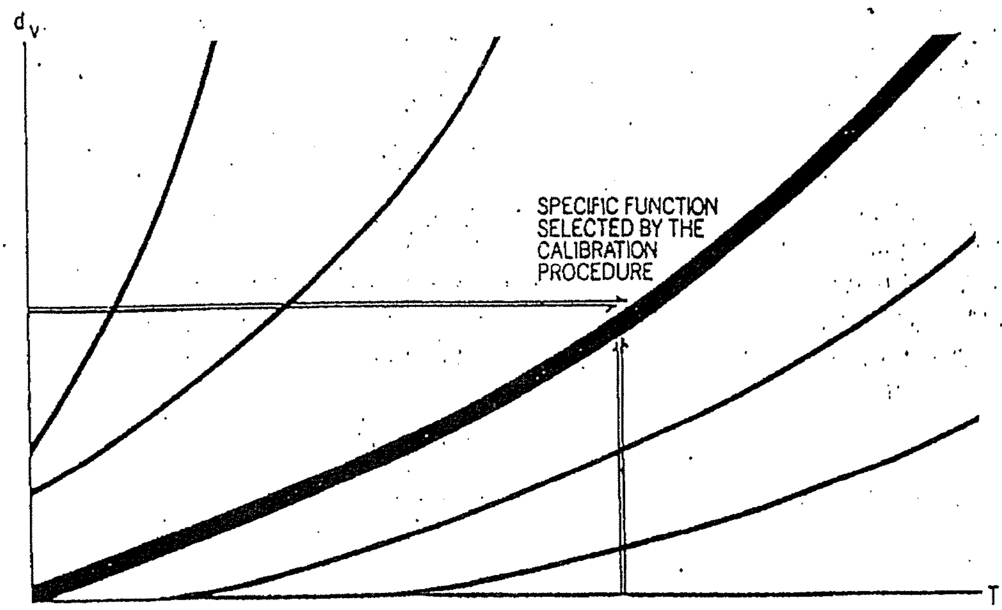

FIGURE 2 FAMILY OF CURVES FOR d_v VERSUS T

The Cationic Control System

The feedback control algorithm devised for the addition of cationic polymers is based on simple but well-defined physical principles.

Suitable limits on the overflow clarity must be established by plant observation. Given these limits it makes physical sense to require the dosing pump to increase its output exponentially up to maximum capacity as the overflow clarity approaches its lower limit and to decrease its output exponentially to zero (or some small amount) as the overflow clarity approaches its upper limit. When the overflow clarity is near the set point then changes in pump output should approach zero exponentially.

If the average feed conditions change, then the nominal pump operating point is automatically adjusted in an exponential fashion.

The above changes can be specified mathematically in a unique way This can be used to advantage in trouble-shooting situations.

PRACTICAL ASPECTS OF THE AUTOFLOC FLOCCULANT CONTROL SYSTEM

Daily Calibration Procedures

The initial motivation for the semi-empiric settling model was to determine the quantitative effect of those variables which might be expected to vary over the short term. Those variables which were expected to vary over a longer period were neglected. However a plant must operate over a long period, so it is necessary that a procedure be developed which takes account of this variation.

In practice, a simple calibration procedure has been devised which takes account of any variations in the particle size distribution, particle surface chemistry, concentration of the flocculant solution, characteristics of the flocculant solution pump, process hydrodynamics and other process variations which have arisen since the previous calibration procedure.

The calibration procedure can be carried out daily, or on an as-required basis. However since the time required to calibrate is only 10 mins approx, daily calibration is recommended.

The calibration procedure is:

i) Ensure that the thickener is performing satisfactorily at one instant of time. For example, vary the flocculant dose rate so as to achieve the desired settling velocity.

ii) Record the flocculant pump speed, and the transmitted light signal at that instant.

Flocculant Pump Calibration

The control program calculates the dose rate required in ppm. However the flocculant solution pump is controlled by a 4-20 mA signal. Consequently it is necessary to calibrate the flocculant pump for l/m delivered vs % pump speed (or mA).

The daily calibration takes account of any pump wear, or variation in the concentration of the flocculant solution that has occurred since the previous calibration. Naturally, however, no account can be taken of any variations which occur between calibration periods. If poor control were to occur , then this would suggest some sudden change due to such (or other) variations. This could be easily overcome by a recalibration of the control system.

OTHER AREAS OF INTEREST

The fact that the sedimentation model could be used to make reliable quantitative predictions as to the effect of various parameters generated confidence to approach practical problems in flocculation on a proper scientific cause-effect basis, rather than avoid such problems on the basis that "what works in the laboratory doesn't work on the plant".

Indeed the view was taken that the differing performance in laboratory and plant could be used to identify those relevant factors which differ in the plant. This approach has met with success in many different areas.

For example, a particular area in which this approach was predicted to provide significant improvement was in the examination of the efficiency of flocculant/cationic dosing systems (10). At B.H.P. Newcastle Coal Preparation Plant the use of cationic polymers has been necessary since the use of salt water as process water has ceased. It was anticipated that the change to fresh water would result in significant increases in the total chemical costs. However, by implementing plant modifications suggested by laboratory test work which was carried out by Catoleum, B.H.P. have been able to reduce the annual consumption of flocculants and cationics to approximately one half of the previous flocculant usage rates, while the usage rate of cationics has been reduced to one quarter of the usage rate.

achieved with the original dosing system. Similar successes have been achieved at other plants.

As another example, many problems in flocculation are strongly influenced by the details of process-water chemistry and water quality. Wambo Coal Preparation Plant has long been renowned for its very difficult clay problems, which have required exceptionally high chemical costs to keep under control. Through the combined use of gypsum, recommended by Catoleum, and the AUTOFLOC flocculant control system, chemical costs have been reduced to approximately one-third of previous usage rates. In addition, the increased production rates now possible following the recent plant upgrading, have been handled without bottlenecks arising from problems in the thickener circuit.

In another example, the recovery of coal from the flotation circuit at Coal Cliff Coal Preparation Plant was increased by approximately 9% by means of the combined use of improved dosing of cationics and improved flotation reagents. These results are the subject of another Paper at this conference.

Another, more significant, prediction was made (10) by claiming that, with appropriate generalisation, the mathematical methodology used in developing the sedimentation model could be used to determine in any field between those physically significant relationships parameters which have an underlying causal relationship. This approach has been applied to the problem of predicting how to vary flotation reagent dose rates in accordance with varying feed conditions.

Although the problem in flotation is more complex e.g. the number and type of important parameters, this approach has provided the basis for a total flotation control system which monitors and controls those parameters which have a crucial significance on flotation performance. This system is known as AUTOFLOTE and is currently being developed and marketed by Century Autoflote Pty. Ltd.

These findings will be the subject of a subsequent publication.

CONCLUSIONS

The quantitative semi-empiric model of sedimentation that was presented at the Second Australian Coal Preparation Conference (10) has been used as the basis of a simple, reliable system which provides complete on-line automatic control of thickener circuits. The system has been proven in practice in three Hunter Valley Coal Preparation Plants which use Hi-Rate thickeners.

The following process parameters may be controlled.

Flocculant dose rates: controlled on a feedforward basis achieve a desired settling velocity (or other operating objectiv with feedback adjustment based on bed-level measurement.

Underflow pumping: controlled on a feedforward basis so as to ensu that solids are removed at the rate at which they enter; feedba adjustment can be made on the basis of measured rake torque and/ bed level.

Rake torque, bed level: these parameters are normally controll within acceptable limits by ensuring both constant settling rates a thickener mass balance. However, when this is not the case, t underflow pumping rate can be adjusted on a feedback basis so as control rake torque and bed level.

Thickener overflow clarity: can be controlled automatically adjusting the dose rate of cationic polymers on a feedback basis.

The sedimentation model also provided the basis for the follow developments.

Significant reductions in the usage rates of cationics a: B.H Coal Washery have been achieved by means of appropriate alterati to the dosing system.

Significant reductions in chemical costs have been achieved Wambo Coal Preparation Plant via the combined effects of adjust process water chemistry and the AUTOFLOC flocculant control systen

Recovery from the flotation circuit at Coal Cliff Coal Preparat Plant was increased by 9% approximately by improving water qua: through the use of cationic polymers, in conjunction with impr flotation reagents.

The mathematical techniques used in developing the autom thickener/flocculant control system have been adapted to develop automatic flotation control system.

ACKNOWLEDGEMENTS

The author of this Paper would like to thank Catoleum Pty. for assistance given in developing the AUTOFLOC system and permission to publish this Paper and particularly the valu co-operation and assistance given by the staff of Warkworth, Hu Valley and Wambo Coal Preparation Plants who demonstrated that model did work under plant conditions.

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The following process parameters may be controlled.

ON-LINE CONTROL OF THICKENER CIRCUITS

REFERENCES

Coe H S and Clevenger G H, "Methods for Determining the Capacities of Slime-Settling Tanks", Trans. AIME 55 (1916) 356.

Robinson C S, "Some Factors Influencing Sedimentation", Ind. Eng. Chem. 18 (1926), 869.

Egolf C B and McCabe W B, "Rate of Sedimentation of Flocculant Particles", Trans, A. Inst. Chem. Eng. 33, (1937), 620.

Work L T and Kohler A S, "The Sedimentation of Suspensions", Trans. Am. Inst. Chem. Eng. 36 (1940) 701.

Steinour H H, "Rate of Sedimentation", Ind. Eng. Chem. 36 (1944), 618, 840, 901.

Kynch G J, "A Theory of Sedimentation", Trans. Faraday Soc. 48 (1952) 166.

Richardson J F and Zaki W M, "Sedimentation and Fluidisation, Part 1", Trans. Inst. Chem. Eng. 32 (1954), 35.

Talmage W P and Fitch E B, "Determining Thickener Unit Areas", Ind. Eng. Chem. 47 (1955) 38.

Dell C C and Brown D W, "Testing Polyelectrolyte Flocculants for Sedimentation", Filtration and Separation Sept/Oct 1973, 507.

Macdonald J R etal Proceedings of the 2nd Australian Coal Preparation Conference, Rockhampton, 1983 p. 397-420.